
APPENDIX E:

Draft Supplemental EIR Comment Letters

The following comment letters may have components that are not completely accessible for a screen-reader.

If you require assistance, contact:

Will Fourn
831.335.6318
Santa Cruz District, California Department of Parks and
Recreation
303 North Big Trees Park Road
Felton, CA 95018



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California Department of Transportation

CALTRANS DISTRICT 5
 50 HIGUERA STREET | SAN LUIS OBISPO, CA 93401-5415
 (805) 549-3101 | FAX (805) 549-3329 TTY 711
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December 1, 2025

SCH # 2001112104
 SCr-236-VAR

Will Fourt, Senior Planner
 California Department of Parks and Recreation
 Santa Cruz District
 303 North Big Trees Park Road
 Felton, CA 95018

Dear Mr. Fourt:

The California Department of Transportation (Caltrans) appreciates the opportunity to review the Draft Supplemental Environmental Impact Report (SEIR) for the Reimagining Big Basin Redwoods State Park Facilities Management Plan and General Plan Amendments dated October 2025. The proposed project is being prepared to guide the rebuilding, stewardship, management, and use of existing and future park facilities due to the 2020 CZU Lightning Complex Fire (CZU fire) which destroyed all park facilities. Caltrans offers the following comments:

AG1-01

General Comments

- Caltrans supports local development that is consistent with State planning priorities intended to promote equity, strengthen the economy, protect the environment, and promote public health and safety. We accomplish this by working with local jurisdictions to achieve a shared vision of how the transportation system should and can accommodate interregional and local travel and development.

AG1-02

Traffic Operations and Safety

- We request to review the detailed final site plans prior to the Caltrans Encroachment Permit Application submission.
- Please include the following in the site plans for review:
 - Parking lot sizes and locations.
 - Pedestrian crossing locations and enhancements across the State Highway System (SHS).
 - Vehicular turn-around locations if parking is full or if visitors do not want to pay the entry fee.

AG1-03

- Intersection improvements on the SHS.
- Proposed measures to prevent on-street parking at undesirable locations such as along the SHS.
- Contingency plan should parking lots and shuttles be full, such as signage providing motorist real time traffic conditions and guidance information.
- Pedestrian and bike path travel along or across the SHS connecting to staff housing, parking lot, shuttle stops, trailheads, and visitor center/concession.

**AG1-03
cont.**

Permits:

- Please be aware that if any work is completed in the State's right-of-way it will require an encroachment permit from Caltrans, and must be done to our engineering and environmental standards, and at no cost to the State. The conditions of approval and the requirements for the encroachment permit are issued at the sole discretion of the Permits Office, and nothing in this letter shall be implied as limiting those future conditions and requirements. For more information regarding the encroachment permit process, please visit our Encroachment Permit Website at: <https://dot.ca.gov/programs/traffic-operations/ep/applications>.

AG1-04

Thank you for the opportunity to review and comment on the proposed project. If you have any questions or need further clarification on the items discussed above, please contact me at (805) 835-6555 or email ingrid.mcroberts@dot.ca.gov.

AG1-05

Sincerely,

Ingrid McRoberts

Ingrid McRoberts
Caltrans District 5
Local Development Review Coordinator



State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Bay Delta Region
2825 Cordelia Road, Suite 100
Fairfield, CA 94534
(707) 428-2002
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GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director



December 3, 2025

Will Fourt, Senior Parks and Recreation Specialist
California Department of Parks and Recreation
303 North Big Trees Park Road
Felton, CA, 95018
Reimagining.BigBasin@parks.ca.gov

Subject: Reimagining Big Basin Redwoods State Park Facilities Management Plan and General Plan Amendments, Draft Supplemental Environmental Impact Report, SCH No. 2001112104, Santa Cruz County

Dear Will Fourt:

The California Department of Fish and Wildlife (CDFW) received a Notice of Availability of a Draft Supplemental Environmental Impact Report (EIR) from the California Department of Parks and Recreation (CDPR) for the Reimagining Big Basin Redwoods State Park Facilities Management Plan and General Plan Amendments Project (Project) pursuant to the California Environmental Quality Act (CEQA) and CEQA Guidelines.¹ CDFW previously submitted comments in response to the Notice of Preparation of the draft supplemental EIR.

Thank you for the opportunity to provide comments and recommendations regarding those activities involved in the Project that may affect California fish and wildlife. Likewise, we appreciate the opportunity to provide comments regarding those aspects of the Project that CDFW, by law, may be required to carry out or approve through the exercise of its own regulatory authority under the Fish and Game Code.

CDFW ROLE

CDFW is California's **Trustee Agency** for fish and wildlife resources and holds those resources in trust by statute for all the people of the State. (Fish & G. Code, §§ 711.7, subd. (a) & 1802; Pub. Resources Code, § 21070; CEQA Guidelines § 15386, subd. (a).) CDFW, in its trustee capacity, has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species. (*Id.*, § 1802.) Similarly, for purposes of CEQA, CDFW is charged by law to provide, as available, biological expertise during public agency environmental review efforts, focusing specifically on projects and related activities that have the potential to adversely affect fish and wildlife resources.

¹ CEQA is codified in the California Public Resources Code in section 21000 et seq. The "CEQA Guidelines" are found in Title 14 of the California Code of Regulations, commencing with section 15000.

AG2-01

Will Fourn
California Department of Parks and Recreation
December 3, 2025
Page 2

CDFW is also submitting comments as a **Responsible Agency** under CEQA. (Pub. Resources Code, § 21069; CEQA Guidelines, § 15381.) CDFW expects that it may need to exercise regulatory authority as provided by the Fish and Game Code. As proposed, for example, the Project may be subject to CDFW's Lake and Streambed Alteration (LSA) regulatory authority. (Fish & G. Code, § 1600 et seq.) Likewise, to the extent implementation of the Project as proposed may result in "take" as defined by State law of any species protected under the California Endangered Species Act (CESA) (Fish & G. Code, § 2050 et seq.), the project proponent may seek related take authorization as provided by the Fish and Game Code.

**AG2-01
cont.**

REGULATORY REQUIREMENTS

California Endangered Species Act

A CESA Incidental Take Permit (ITP) must be obtained from CDFW if the Project has the potential to result in "take" of plants or animals listed under CESA, either during construction or over the life of the Project. Under CESA, "take" means "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill." (Fish & G. Code, § 86). CDFW's issuance of an ITP is subject to CEQA and to facilitate permit issuance, any project modifications and mitigation measures must be incorporated into the CEQA document analysis, discussion, and mitigation monitoring and reporting program. If the Project will impact CESA listed species, early consultation is encouraged, as significant modification to the Project and mitigation measures may be required in order to obtain a CESA Permit.

CEQA requires a mandatory finding of significance if a project is likely to substantially impact threatened or endangered species. (Pub. Resources Code, §§ 21001, subd. (c) & 21083; CEQA Guidelines, §§ 15380, 15064 & 15065.) In addition, pursuant to CEQA, the Lead Agency cannot approve a project unless all impacts to the environment are avoided or mitigated to less-than-significant levels, or the Lead Agency makes and supports Findings of Overriding Consideration (FOC) for impacts that remain significant despite the implementation of all feasible mitigation. FOC under CEQA, however, do not eliminate the Project proponent's obligation to comply with the Fish and Game Code.

AG2-02

Lake and Streambed Alteration

CDFW requires an LSA Notification, pursuant to Fish and Game Code section 1600 et seq., for Project activities affecting rivers, lakes or streams and associated riparian habitat. Notification is required for any activity that may substantially divert or obstruct the natural flow; change or use material from the bed, channel, or bank (including associated riparian or wetland resources); or deposit or dispose of material where it may pass into a river, lake, or stream. Work within ephemeral streams, drainage ditches, washes, watercourses with a subsurface flow, and floodplains is generally

Will Fourt
California Department of Parks and Recreation
December 3, 2025
Page 3

subject to notification requirements. In addition, infrastructure installed beneath such aquatic features, such as through hydraulic directional drilling, is also generally subject to notification requirements. Therefore, any impact to the mainstems, tributaries, or floodplains or associated riparian habitat caused by the proposed Project will likely require an LSA Notification. CDFW may not execute a final LSA Agreement until it has considered the final supplemental EIR and complied with its responsibilities as a responsible agency under CEQA.

Migratory Birds and Raptors

CDFW has authority over actions that may result in the disturbance or destruction of active bird nest sites or the unauthorized take of birds. Fish and Game Code sections protecting birds, their eggs, and nests include section 3503 (regarding unlawful take, possession, or needless destruction of the nests or eggs of any bird), section 3503.5 (regarding the take, possession, or destruction of any birds-of-prey or their nests or eggs), and section 3513 (regarding unlawful take of any migratory nongame bird). Migratory birds are also protected under the federal Migratory Bird Treaty Act.

PROJECT DESCRIPTION SUMMARY

Proponent: California Department of Parks and Recreation

Objective: The proposed Project includes amendments to the Big Basin Redwoods State Park General Plan and the adoption of the Reimagining Big Basin Redwoods State Park Facilities Management Plan. The proposed General Plan amendments include text changes to provide clarity and consistency between the 2013 General Plan and the Facilities Management Plan. The General Plan amendments would also expand the park boundary to include new parcels. The proposed Facilities Management Plan guides the stewardship, management, and use of existing and future facilities, consistent with the 2013 General Plan and other relevant planning documents. Additionally, the proposed Project would guide the rebuilding of facilities lost in the 2020 CZU Lightning Complex fire and the construction of new facilities and infrastructure. This includes 19 identified sites in five proposed zones, including visitor-serving facilities; overnight facilities; tribal facilities; transportation-related facilities; utilities infrastructure; administrative facilities; and staff residences. The Project also includes road and circulation improvements, the introduction of a shuttle program, utility upgrades and replacement, habitat restoration, and an improved emergency response and evacuation plan. The objectives of the Big Basin Facilities Management Plans are as follows: prioritize forest health; provide equitable, diverse, and evocative visitor experiences; diversify transportation and access opportunities; practice land stewardship; include Indigenous perspectives; promote landscape connectivity; design with reverence and resilience; engage the park community and build partnerships

AG2-02
cont.

AG2-03

Will Fourt
California Department of Parks and Recreation
December 3, 2025
Page 4

supporting objectives. Primary Project activities include grading, demolition of existing structures, tree removal, soil compaction, and ground disturbing activities.

Location: Big Basin Redwoods State Park is in the western, coastal portion of the Santa Cruz Mountains between State Route (SR)-1 and SR-9, which both run north to south. The majority of the park is in the County of Santa Cruz and a small northern portion is in the County of San Mateo. The park is surrounded by other parks and open-space with communities along SR-9. Big Basin Redwoods State Park encompasses approximately 18,200 acres; however, the proposed Project focuses specifically on areas along SR-236 and Sky Meadow Road, encompassing approximately 5,500 acres in the eastern part of the park.

Timeframe: Activities will be implemented over five to fifteen years, or longer dependent on funding.

AG2-03
cont.

COMMENTS AND RECOMMENDATIONS

CDFW offers the comments and recommendations below to assist CDPR in adequately identifying and/or mitigating the Project's significant, or potentially significant, direct and indirect impacts on fish and wildlife (biological) resources. Editorial comments or other suggestions may also be included to improve the document.

I. Project Description and Related Impact Shortcoming

Would the Project have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by CDFW or U.S. Fish and Wildlife Service (USFWS)?

COMMENT 1: Marbled Murrelet

Section 3.1, Page 3-58

Issue: The supplemental EIR indicates CDPR will coordinate with CDFW and the USFWS prior to initiating construction activities that may affect marbled murrelet (MAMU) and/or their nesting habitat. However, formal coordination with CDFW and USFWS is not proposed to review survey results, habitat assessments, and/or proposed avoidance measures prior to initiating construction activities. Additional early coordination with CDFW is needed to ensure consistency with state regulatory requirements and to ensure significant impacts to MAMU will be avoided from project activities.

Evidence impact would be significant: The CZU Fire burned over 97 percent of Big Basin Redwoods State Park and 61.4 percent of known murrelet habitat in Zone

AG2-04

Will Fourt
California Department of Parks and Recreation
December 3, 2025
Page 5

6 (Singer and Rinkert 2025; SCMBC 2025). Almost half of the accessible potential nest trees have died and most will not likely provide optimal habitat for a year or two until foliage can grow (page 3-62). The Project proposes redevelopment in areas that were previously occupied by MAMU, which may delay and prevent habitat recovery. Habitat for MAMU may become suitable again and occupancy can vary annually. Brief or intermittent disturbance such as grading, heavy equipment operation, and vehicle traffic can disrupt MAMU breeding behavior and can result in nest abandonment and reduced feeding rates (USFWS 2020).

AG2-04
cont.

Recommendation and Mitigation Measure BIO-28: CDFW recommends the supplemental EIR update the beginning sentence of BIO-28 to require additional CDFW coordination prior to initiating construction activities as follows: *“Formal consultation with CDFW and the U.S. Fish and Wildlife Service (USFWS) shall be required to review and approve proposed MAMU survey methodologies, habitat assessments, and avoidance measures prior to initiating any project activity occurring during the marbled murrelet breeding season that may affect marbled murrelet and/or their nesting habitat.”*

ENVIRONMENTAL DATA

CEQA requires that information developed in environmental impact reports and negative declarations be incorporated into a database which may be used to make subsequent or supplemental environmental determinations. (Pub. Resources Code, § 21003, subd. (e).) Accordingly, please report any special-status species and natural communities detected during Project surveys to the California Natural Diversity Database (CNDDDB). The CNDDDB field survey form can be filled out and submitted online at the following link: <https://wildlife.ca.gov/Data/CNDDDB/Submitting-Data>. The types of information reported to CNDDDB can be found at the following link: <https://www.wildlife.ca.gov/Data/CNDDDB/Plants-and-Animals>.

AG2-05

ENVIRONMENTAL DOCUMENT FILING FEES

The Project, as proposed, would have an impact on fish and/or wildlife, and assessment of environmental document filing fees is necessary. Fees are payable upon filing of the Notice of Determination by the Lead Agency and serve to help defray the cost of environmental review by CDFW. Payment of the environmental document filing fee is required in order for the underlying project approval to be operative, vested, and final. (Cal. Code Regs, tit. 14, § 753.5; Fish & G. Code, § 711.4; Pub. Resources Code, § 21089.)

AG2-06

CONCLUSION

CDFW appreciates the opportunity to comment on the draft supplemental EIR to assist CDPR in identifying and mitigating Project impacts on biological resources.

AG2-07

Will Fourt
California Department of Parks and Recreation
December 3, 2025
Page 6

Questions regarding this letter or further coordination should be directed to Alexis Harrison, Environmental Scientist, at (707) 815-2778 or Alexis.Harrison@wildlife.ca.gov.

Sincerely,

DocuSigned by:

B77E9A6211EF486
Erin Chappell
Regional Manager
Bay Delta Region

cc: Office of Land Use and Climate Innovation (SCH No. 2001112104)]

REFERENCES

- CDFW (California Department of Fish and Wildlife). 2025a. California Natural Diversity Database. *California Natural Community List*.
- PSG (Pacific Seabird Group). 2024. A revised protocol for surveying Marbled Murrelets in Forests. *Pacific Seabird Group Technical Publication Number 6*. <https://pacificseabirdgroup.org/psg-publications/technical-publications/>.
- Santa Cruz (2025a). *The Santa Cruz Mountains Bioregional Council (SCMBC)*. The Santa Cruz Mountains Bioregional Council (SCMBC). <https://www.scmhc.org/>.
- Singer, S. W. and Rinkert, A. 2025. *Impact of the 2020 CZU Lightning Complex Fire on Marbled Murrelet Nesting Habitat at Big Basin Redwoods State Park*. Steven Singer Environmental & Ecological Services, Santa Cruz, CA.
- Smith, A. B., M. Kissling, A. M. Capuano, S. B. Lewis, and T. A. Mooney. 2023. Aerial hearing thresholds and ecoacoustics of a threatened pursuit-diving seabird, the marbled murrelet *Brachyramphus marmoratus*. *Endangered Species Research* 50:167–179.
- USFWS (United States Fish and Wildlife Service). 2020. *Revised transmittal of guidance: estimating the effects of auditory and visual disturbance to Northern Spotted Owls and Marbled Murrelets in northwestern California*. Arcata, California: U. S. Fish and Wildlife Service, Arcata Fish and Wildlife Office.

Rachel Goren

From: [REDACTED]
Sent: Saturday, November 15, 2025 11:33 AM
To: Reimagining Big Basin
Subject: Big Basin Redwoods State Park General Plan Supplemental EIR

You don't often get email from contact@audioguide.app. [Learn why this is important](#)

Dear Brilliant members of the Administration of Big Basin Redwoods State Park,

We, from Audioguide.app, congratulate you for the efforts of repairing and reimagining Big Basin. As part of the process of development of the State Park, we would like to introduce our technological solution to increase your visitors' experience, bring more tourists to the area, and incentivize them to return.

Audioguide.app is a solution that describes touristic spots and historical places with audio in more than 50 languages instantly. Visitors scan Smart Tags® with their phones and are directed to the page of the description. No need to download anything. All for free.

If you would like to know more about this initiative, please reply to this email or call me at [REDACTED]
[REDACTED]

ORG1-01

Best Regards,

Henrique Albiero
Director of Contact B2B
Audioguide.app



SANTA CRUZ COUNTY GROUP
of the Ventana Chapter
P.O. Box 604, Santa Cruz, CA 95061
EMAIL: sierraclubsantacruz@gmail.com
WEB: www.sierraclub.org/ventana/santa-cruz

November 30, 2025

Submitted via email to: Reimagining.BigBasin@parks.ca.gov

Santa Cruz District, California Department of Parks and Recreation
303 North Big Trees Park Road
Felton, CA 95018
Attn: Will Fourt

Re: Draft Supplemental Environmental Impact Report for the Reimagining Big Basin Redwoods State Park Facilities Management Plan and General Plan Amendments (State Clearinghouse No. 2001112104)

Dear Mr. Fourt,

These comments are submitted on behalf of the Sierra Club. The Sierra Club is a national, nonprofit conservation organization dedicated to the exploration, protection, and enjoyment of the wild places of the earth. With over 3.8 million members, online activists, and more than 400 local groups, the Sierra Club has a longstanding commitment to conserving the marbled murrelet and its old-growth habitat in California and throughout the West Coast through various Sierra Club chapter members.

The Sierra Club has the following comments on the Draft Supplemental Environmental Impact Report referenced above:

3. Biological Resource Environmental Analysis

The Sierra Club maintains that the Supplemental Environmental Impact Report (EIR) should pay particular attention to impacts to the endangered marbled murrelet. We encourage all measures to avoid, minimize, and mitigate impacts to this iconic old-growth-dependent species.

Marbled Murrelet Management and Conservation Guidelines (beginning at 3-11)

Murrelet 1: Consult with DFG and USFWS prior to initiating construction activities that may affect murrelets and/or their nesting habitat.

ORG2-01

ORG2-02

Comment Murrelet 1: Insufficient answer. The public is not aware of DFG and USFWS methods in protecting species during construction. There is not a description of the level of authority that DFG and USFWS will have here.

Questions: What are the best practices for protecting wildlife during construction in the State Parks? Will DFG and USFWS have decision and/or veto authority over State Parks construction practices? Is consulting with DFG and USFWS merely an advisory notification or will DFG and USFWS have authority?

**ORG2-02
cont.**

Murrelet 2: Control corvid populations and reduce the human influences that support unnaturally high corvid populations and concentrations in certain areas, especially in the Headquarters Area and Rancho del Oso; consider corvid management through direct removal when other control measures prove inadequate, and consult with experts on appropriate methods of corvid control and/or removal. Expand existing trash management measures noted above to include food storage lockers and animal-proof, user-friendly trash bins throughout Little Basin. Expand and emphasize the existing corvid management efforts by providing additional training to state park rangers and including corvid management as part of their regular duties.

Comment Murrelet 2: Insufficient information on how State Parks will identify what constitutes an overpopulation of corvids in Big Basin.

Questions: What is the “safe” number of corvid species in the Big Basin State Park? What impacts to marbled murrelet sites will need to be identified in order to trigger further control methods? What methods will you use to severely reduce these predators?

ORG2-03

Murrelet 3: Improve waste patrol and cleanup in visitor-use areas.

Comment Murrelet 3: Insufficient response to provide details on what that will include.

Question: How do the State Parks plan to maintain a consistent and much higher level of cleanliness in the visitor-use area?

ORG2-04

Murrelet 4: Educate visitors about the threatened status of the marbled murrelet and why they should not feed wildlife. Update the current trash education program to include “keep it crumb-free” signage and updated interpretive materials.

Comment Murrelet 4: The Sierra Club supports community environmental education, especially on ways to protect our heritage wildlife.

Questions: What measure does the State Parks intend to use for violations to the Crumb Clean guidelines? What monitoring will there be to see if the education of visitors is effective?

ORG2-05

Murrelet 5: Minimize disturbances, trail building, and maintenance activities in old-growth redwood habitat, including the use of loud motorized equipment, during the marbled murrelet breeding season (March–September). natural grade of the stream as much as possible to maximize fish passage.

Comment Murrelet 5: Inadequate response with regard to assessing whether minimized disturbances are sufficient.

Questions: How is the proper level of minimization determined? What assessment methods are proposed to determine if this minimization is sufficient?

ORG2-06

Murrelet 7: Where possible, consider relocating camping and/or picnic facilities or rotating use in areas with marbled murrelet habitat.

Comment Murrelet 7: Inadequate response. No assessment criteria or trigger level is stated. No definitive statement is made that camping would be relocated if sufficient impacts are seen.

Questions: Will the mentioned relocations occur if significant impacts are observed? What assessment methods are proposed to determine if significant impacts are occurring?

ORG2-07

It is clear from the Draft Supplemental EIR that significant impacts to marbled murrelet habitat are associated with human activity. Despite the proposed management guidelines, there is a lack of discussion of assessment of impacts and a possibility of triggering a substantial change to human visitation patterns.

The effectiveness of the mitigation measures remains uncertain due to incomplete scientific understanding of the factors influencing marbled murrelet populations and the impacts of the CZU fire on their habitat. Stakeholders have voiced concerns about the adequacy of current actions, recommending further refinements such as relocating the Sequoia Group Campground outside the Old Growth Area, creating larger buffer zones, enhancing corvid management programs, and strictly avoiding construction activities during the breeding season. The Draft Supplemental Environmental Impact Report ultimately concludes that the impact on the marbled murrelet is "significant and unavoidable," underscoring the need for ongoing research and monitoring to improve conservation strategies and ensure robust protection for the species.

ORG2-08

Thank you for your service and commitment to the quality of our State Parks.

Cynthia A. Denny
Chair, Public Lands Subcommittee

Michael A. Guth
Chair, Executive Committee

Sierra Club - Santa Cruz Group of the Ventana Chapter



December 1, 2025

Submitted via email to Reimagining.BigBasin@parks.ca.gov

Will Fourt
California Department of Parks and Recreation
PO Box 942896
Sacramento, CA 94296-0001

Re: Draft Supplemental Environmental Impact Report for the Reimagining Big Basin Redwoods State Park Facilities Management Plan and General Plan Amendments

Dear Mr. Fourt,

These comments on the Draft Supplemental Environmental Impact Report for the Reimagining Big Basin Redwoods State Park Facilities Management Plan and General Plan Amendments (“DSEIR”) are submitted on behalf of the Center for Biological Diversity (“Center”). The Center is a national, nonprofit conservation organization dedicated to the protection of endangered species and wild places with more than 1.8 million members and online activists. The Center has a long history of working to protect the marbled murrelet and its old-growth habitat in California and across the range, including our 2014 settlement agreement with State Parks requiring increased protections for marbled murrelets under the Big Basin Redwoods State Park General Plan.

Marbled murrelets in U.S. Fish and Wildlife Service Conservation Zone 6 (San Francisco Bay to Point Sur in central California) are highly endangered. This genetically distinct population was estimated at only 650 individuals as of 2017¹ and between 266-408 individuals during 2018-2023.² Primary threats to this population are predation by unnaturally high densities of corvid nest predators and continued destruction and degradation of old-growth nesting habitat.³ Big Basin Redwoods State Park (“Big Basin SP”) provides critically important habitat because it supports the largest remaining stand of old-growth redwoods left in the Santa Cruz Mountains and has a high concentration of known murrelet nest trees.⁴ While the CZU Fire

ORG3-01

¹ California Department of Parks and Recreation, Marbled Murrelet Landscape Management Plan for Zone 6 (May 2017), https://www.parks.ca.gov/?page_id=29911 at 2 (hereafter “MMLMP (2017)”).

² US Fish and Wildlife Service, Marbled Murrelet (*Brachyramphus marmoratus*) CA, OR, WA DPS, 5-Year Review: Summary and Evaluation (2024) at Table 2 (hereafter “USFWS (2024)”).

³ USFWS (2024) at 7-9; MMLMP (2017) at 68-112; Pacific Seabird Group, Terrestrial Habitat Recommendations for Marbled Murrelets, Pacific Seabird Group Technical Publication Number 7, 38 p. (2024), <https://pacificseabirdgroup.org/wp-content/uploads/2024/02/Terrestrial-Habitat-Management-Recommendations-for-MAMU-2024.pdf> at 1, 15.

⁴ MMLMP (2017) at 217.

killed most large Doug fir trees in Big Basin SP, almost all (~97%) redwood trees in the Park survived the fire. Given the rarity of old-growth habitat and precarious status of the Zone 6 murrelet population, the old-growth habitat in Big Basin SP requires full protection. Every last mature and old-growth tree is important and must be protected. Mitigation measures to avoid or reduce impacts to marbled murrelets from nest predators, habitat degradation, and other threats must be specific, comprehensive, and robust over time.

**ORG3-01
cont.**

The Big Basin Facilities Management Plan (“Facilities Plan”) will have significant adverse impacts on marbled murrelets that are not adequately avoided, minimized, or mitigated by the proposed plan or current set of avoidance and mitigation measures in the SDEIR. As State Parks is aware, it must comply with CEQA’s substantive mandate that requires effective avoidance and consideration of alternative, minimization and mitigation. “[P]ublic agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen the significant environmental effects of such projects.” (Pub. Res. Code § 21002.) While the SDEIR identifies many ways in which the Facilities Plan will significantly impact marbled murrelets, it has failed to consider all feasible alternatives that could avoid those impacts or to consider all feasible minimization and mitigation measures that could substantially lessen the Project’s significant impacts. (Pub. Res. Code §§ 21002.1(a), (b), 21100(b)(3), (4), 21081(a)(1); 14 C.C.R. §§ 15021(a)(2), 15091(a)(1).)⁵

ORG3-02

We strongly support the Facilities Plan proposal to not re-build the Blooms Creek, Sempervirens, and Jay Camp campgrounds in the “Old Growth Area” and instead provide camping facilities in the “Overnight Area” outside of redwood habitat. However, the SDEIR fails to consider alternatives that would avoid significant impacts to the marbled murrelet including relocating the Sequoia Group Campground and trail camp out of the Old Growth Area, and preventing construction of picnic areas in the Old Growth Area, despite comments requesting these alternatives be considered.

ORG3-03

ORG3-04

In addition, we are concerned that the SDEIR does not incorporate the recommendations in the Pacific Seabird Group’s 2024 *Terrestrial Habitat Management Recommendations for Marbled Murrelets* “(PSG Habitat Recommendations)”⁶ authored by marbled murrelet experts or adequately incorporate the avoidance and mitigation measures in the July 18, 2025, letter from California Department of Fish and Wildlife (“CDFW”).⁷

ORG3-05

⁵ Given the precarious status of the marbled murrelets and the importance of this area to its survival, State Parks must analyze and chose a feasible alternative to avoid significant impacts to the marbled murrelets and its old growth habitat. Simply put, State Parks cannot rationally find that alternatives which eliminate the proposed camping and picnicking in old growth areas are infeasible or rationally find that the benefits allowing camping and picnicking in old growth areas override the substantial evidence of significant environmental impacts to the marbled murrelets from the proposals to allow camping and picnicking in old growth areas. (Pub. Res. Code § 21081(b); 14 C.C.R. § 15093(b).)

⁶ Pacific Seabird Group, *Terrestrial Habitat Recommendations for Marbled Murrelets*, Pacific Seabird Group Technical Publication Number 7, 38 p. (2024), <https://pacificseabirdgroup.org/wp-content/uploads/2024/02/Terrestrial-Habitat-Management-Recommendations-for-MAMU-2024.pdf> (hereafter “PSG Habitat Recommendations (2024)”).

⁷ SDEIR at pdf pp. 388-392.

As detailed below, the SDEIR is inadequate in several ways and must be revised to ensure avoidance, minimization, and mitigation measures are fully considered, and proposed alternatives and mitigation measures are strengthened to adequately avoid significant impacts and mitigate key threats to marbled murrelets.

1. State Parks should avoid impacts to marbled murrelets by not constructing the Sequoia Group Campground and trail camp in the Old Growth Area.

The Center’s NOP comments highlighted the impacts to marbled murrelets that would result from the proposal to re-construct the Sequoia Group Campground with the capacity for 100 campers in the Old Growth Area. The Center recommended that State Parks re-locate the group camping capacity from the Sequoia Campground to the “Overnight Area” or another area outside of the Old Growth Area as part of the proposed project or, at minimum, include an alternative that is fully analyzed in the SDEIR to avoid impacts to marbled murrelets in this area. These avoidance measures were not even considered in the SDEIR and, therefore, the environmental review is inadequate. Instead, the Facilities Plan retained the proposal to re-construct the Sequoia Group Campground in the heart of the Old Growth Area: “Sequoia Campground would be reconstructed similar to its pre-fire design. This includes two group campsites, each with capacity to hold 50 people.”⁸ The SDEIR failed to analyze any alternative that could avoid the inevitable negative impacts to marbled murrelets of re-constructing this campground in old-growth murrelet habitat, and also failed to provide proposed measures that could adequately minimize or mitigate these impacts.

Abundant scientific studies – including State Parks’ 2017 *Marbled Murrelet Landscape Management Plan for Zone 6* (“MMLMP”) – establish that campgrounds in Big Basin SP pose a threat to marbled murrelets by supporting unnaturally high densities of murrelet nest predators, primarily Common Ravens and Steller’s Jays, due to the availability of anthropogenic food sources.⁹ State Parks’ MMLMP states that evidence “suggest that campgrounds in Big Basin Redwoods State Park serve as ‘source’ habitats for Steller’s jays on the landscape, which ultimately impact murrelets....”¹⁰ Further, “moving campgrounds and associated anthropogenic food resources out of marbled murrelet nesting habitat during the breeding season may be an effective long-term management strategy for reducing subsidies to jays in these areas.”¹¹ Importantly, a study by Brunk et al. (2021) in Big Basin SP found that “Steller’s jay density is

⁸ SDEIR at 2-19.

⁹ MMLMP (2017) at 14, 68-112; USFWS (2024) at 8-9; West, E.H. et al., Influence of food subsidies on the foraging ecology of a synanthropic species in protected areas, 7 *Ecosphere* e01532 (2016), <https://doi.org/10.1002/ecs2.1532>; West, E.H. and M.Z. Peery, Behavioral mechanisms leading to improved fitness in a subsidized predator, 184 *Oecologia* 787 (2017), <https://doi.org/10.1007/s00442-017-3898-0>; West, E.H. et al., When protected areas produce source populations of overabundant species, 238 *Biological Conservation* 108220 (2019), <https://doi.org/10.1016/j.biocon.2019.108220>.

¹⁰ MMLMP (2017) at 220.

¹¹ MMLMP (2017) at 97.

high in subsidized campground areas” and “limiting anthropogenic subsidies can successfully reduce generalist predator populations” (i.e., Steller’s jay populations).¹²

Not only is the proposed Sequoia Group Campground within the heart of old-growth habitat, but it is also within a half-mile of three of the four stands of unburned old-growth in Big Basin SP.¹³ The importance of fully protecting these remaining unburned old-growth habitat “refugia” cannot be over-stated. Yet the proposed re-opening of the Sequoia Group Campground will almost certainly increase food subsidies and nest predator densities in the Old Growth Area, including these unburned habitat refugia. As stated in the MMLMP, Steller’s jays in the Santa Cruz Mountains “move up to 2 km (1.24 miles) to visit campgrounds and picnic areas.”¹⁴ This campground will also increase harmful noise impacts to marbled murrelets.¹⁵

ORG3-07
cont.

The SDEIR also states that a trail camp will be re-constructed in the Old Growth Area: “A small trail camp with water, vault restroom, and dishwash station would be located approximately 0.75 miles beyond the road’s southern access gate.”¹⁶ The SDEIR impermissibly provides no further information about the trail camp, including the number of sites, and provides no alternatives, making it impossible to fully assess the impacts of the trail camp or how these impacts can be avoided.

ORG3-08

Importantly, the PSG Habitat Recommendations recommend avoiding placing campgrounds within a half-mile of murrelet habitat to reduce impacts from nest predators and recreation: “Reduce, and where possible avoid, the placement of recreational features within and near (e.g., within 0.8 km [0.5 mi] of) habitat, including but not limited to construction of new *campgrounds*, picnic areas, off-highway vehicle staging areas, trailheads, and trails.”¹⁷ Re-constructing the Sequoia Group Campground and trail camp in the heart of the Old Growth Area and within a half-mile of unburned habitat refugia is counter to these PSG recommendations and would negatively impact marbled murrelets. The proposal to institute Crumb Clean measures at these campgrounds as minimization and mitigation measures, does not relieve State Parks of the need to first examine alternatives that would *avoid* the significant impacts to the marbled murrelets, by relocating the campground and trail camp at least one half-mile from marbled murrelet old-growth habitat. The efficacy of the Crumb Clean campaign in reducing predation of marbled murrelet eggs and chicks is still undetermined and cannot be relied on to reduce significant impacts of siting campgrounds within the Old Growth Area.

ORG3-09

¹² Brunk, Kristin M. et al., Reducing anthropogenic subsidies can curb density of overabundant predators in protected areas, 256 Biological Conservation 109081 (2021), <https://doi.org/10.1016/j.biocon.2021.109081>.

¹³ SDEIR at pdf p. 376; See also map titled “Location of Refugia Relative to Proposed Park Zone and Sites” at SDEIR pdf p. 380.

¹⁴ MMLMP (2017) at 126.

¹⁵ MMLMP (2017) at 129.

¹⁶ SDEIR at 2-18 and 3-61.

¹⁷ PSG Habitat Recommendations (2024) at 21.

The SDEIR is flawed in failing to assess the impacts to marbled murrelets of placing campgrounds in Old Growth Area and failing to consider an alternative that prevents the construction of any campgrounds in the Old Growth Area.

2. State Parks should avoid impacts to marbled murrelets by not building picnic areas in the Old Growth Area.

State Parks in the Facilities Management Plan proposes to build multiple picnic areas in the Old Growth Area.¹⁸ The SDEIR states that “two group picnic areas would be reconstructed with vault toilets, potable water, dishwash stations, and wildlife-proof trash and recycling containers along North Escape Road and at Gazos Road near the intersection with North Escape Road, with visitor parking included at each location.”¹⁹ In addition, “the former Blooms Creek Campground would also have a “dry walk-in picnic areas with wildlife-proof trash and recycling containers.”²⁰ No alternatives are provided in the SDEIR that would avoid the significant impacts of these proposals on marbled murrelets.

Scientific research shows that picnic areas provide food subsidies for murrelet nest predators, lead to increased corvid densities, and negatively impact murrelets. For example, State Parks’ MMLMP states that “[a] key to reducing corvid impacts will likely require reducing predation rates in state and county parks that contain unnaturally high raven and jay densities due to the availability of anthropogenic food sources in campgrounds, *picnic areas*, and day use areas.”²¹ The PSG Habitat Recommendations state that “[w]hile campgrounds are a known problem, other developments such as trailheads, off-highway vehicle staging areas, target shooting lanes, and *picnic areas* are also of concern.”²²

The PSG Habitat Recommendations recommend *avoiding* placing picnic areas within a half-mile of murrelet habitat: “Reduce, and where possible avoid, the placement of recreational features within and near (e.g., within 0.8 km [0.5 mi] of) habitat, including but not limited to construction of new campgrounds, *picnic areas*, off-highway vehicle staging areas, trailheads, and trails”²³ State Parks’ proposal to build multiple picnic areas in the Old Growth Area is directly counter to this recommendation. In addition, many of these picnic areas would be within a half-mile of three of the four unburned old-growth habitat refugia for murrelets. Similar to campgrounds discussed above, any proposal to implement Crumb Clean measures at picnic sites as minimization and mitigation measures, does not relieve State Parks of the need to first examine alternatives that would *avoid* the significant impacts to the marbled murrelets, by not building the picnic sites, or by locating the picnic sites at least one half-mile outside of marbled murrelet habitat old-growth habitat. The efficacy of the Crumb Clean campaign in reducing

¹⁸ SDEIR at 2-18.

¹⁹ SDEIR at 2-18.

²⁰ SDEIR at 2-19.

²¹ MMLMP (2017) at 2.

²² PSG Habitat Recommendations (2024) at 19.

²³ PSG Habitat Recommendations (2024) at 21.

predation of marbled murrelet eggs and chicks is still undetermined and cannot be relied on to reduce significant impacts of siting picnic areas within the Old Growth Area.

ORG3-10
cont.

The SDEIR is flawed in failing to assess the impacts to marbled murrelets of placing picnic sites in Old Growth Area and failing to consider an alternative that prevents the construction of any picnic sites in the Old Growth Area.

3. Bio-23 must be more specific to provide effective mitigation.

Mitigation Measure Bio-23 states “To improve habitat conditions for marbled murrelet, appropriate management activities such as the Crumb Clean Campaign and improved waste patrol and cleanup in visitor-use areas will continue to be implemented by DPR to control corvid food sources and the risks these species pose to marbled murrelet breeding success.”²⁴

This mitigation measure is too vague. Reducing food and trash food subsidies for corvid predators is a priority conservation action for marbled murrelets, and the mitigation measures must be specific. Mitigation measures should include the Best Management Practices in the MMLMP regarding Food and Trash Subsidies and Enforcement, which include the following:

Reduce/Eliminate Food and Trash Subsidies

- All trash receptacles should be animal proof
- Trash receptacles should not be allowed to overflow (emptied regularly)
- Garbage trucks will housed where animals cannot gain access
- Animal proof food storage lockers will be installed in all campsites
- Dishwashing stations will be installed in all campgrounds
- Water spigots will have grates installed which allow food to fall out of reach of predators
- Water spigots will have a no dishwashing sign on them
- The Camp-dishes 101 sign will be placed throughout the campground²⁵

ORG3-11

Enforcement

- Campgrounds will be patrolled by park rangers first thing in the morning for enforcement
- Campgrounds will be patrolled by interpretive rangers in the evening cooking hour for interpretive education²⁶

4. Bio-24 must be more specific to provide effective mitigation.

Mitigation Measure BIO-24 states “Interpretive programs to educate visitors about the threatened status of marbled murrelet and why they should not feed wildlife will continue.”²⁷

ORG3-12

²⁴ SDEIR at 3-24.

²⁵ MMLMP (2017) at 142.

²⁶ MMLMP (2017) at 142.

This mitigation measure is too vague and should include the Best Management Practices in the MMLMP regarding Interpretive Messaging, which include the following:

Interpretive Messaging

- Begins during campsite check-in, campers will sign the Crumb Clean Commitment
- All food lockers will have the Keep it Crumb Clean sign on them
- All trail heads will have the Keep it Crumb Clean at their entrance
- All Kiosks will have the Keep it Crumb Clean sign on them
- The Crumb Clean Campaign will be used at all park facilities
- All campers will watch the marbled murrelet video prior to securing a reservation
- Each picnic table will have the Keep it Crumb Clean sign
- The murrelet will be a feature during every campfire talk
- The murrelet will be mentioned during all junior ranger programs, interpretive walks/talks and interactions
- Murrelet materials like stickers and magnets will be given out to help raise awareness and support for the murrelet.²⁸

**ORG3-12
cont.**

5. BIO-25 does not provide adequate protection for marbled murrelet nesting habitat.

Mitigation Measure BIO-25 states: “Trees determined to have suitable elements for nesting by marbled murrelet and screen trees important for nest protection will be retained.”²⁹ This vague mitigation measure does not provide adequate protection for marbled murrelet habitat and does not sufficiently incorporate the mitigation measures for marbled murrelet habitat avoidance specified in the July 18, 2025, letter from CDFW.³⁰

All old-growth habitat in Big Basin SP is rare and should be protected as potential current and future suitable murrelet nesting habitat. Second-growth redwood habitat should also be protected based on its potential to develop into future suitable nesting habitat. Although the CZU Fire significantly altered forests throughout the Park, the old-growth habitat areas retain currently suitable nest trees and screen trees for murrelets, and trees that will become suitable nest and screen trees over time, all of which should be protected. Suitable nest trees in the old-growth habitat include unburned trees and burned mature and old-growth trees that lost their large limbs in the fire but that currently provide suitable nesting platforms through broken tops or large branch stubs.³¹ In addition, all remaining mature and old-growth trees are critical for

ORG3-13

²⁷ SDEIR at 3-24.

²⁸ MMLMP (2017) at 142.

²⁹ SDEIR at 3-24.

³⁰ SDEIR at pdf pp. 388-392.

³¹ SDEIR at 3-24, 3-42, pdf p. 376 (“Also, if there are groups of trees with broken-off tops or with large bare branches or dead stubs coincident with epicormic sprouting, those areas should be mapped out and protected since they have the potential to develop into future murrelet nesting platforms (Baker et al, 2006).” *See also* Baker, L.M.

providing screening for nest trees, particularly through the vigorous post-fire epicormic branching of redwoods occurring in the Park³²; for increasing forest stand integrity; for avoiding edge effects; and because redwood and Doug Fir trees that do not currently have “suitable nesting elements” will develop large branches and broken tops suitable for nesting over time. Researchers do not yet know how long it will take mature and old-growth trees to re-grow branches large enough for nesting, and how marbled murrelets will use the post-fire habitat in the Park. There may be surprises such as the successful fledging of a murrelet chick from a burned tree that “lacked both vertical and horizontal branches that provide screening cover, and was much more visible than is typical” in the Old Growth Area post-fire in 2021.³³

The SDEIR mitigation measure should specify that all mature and old-growth trees throughout Big Basin SP should be protected and retained, not just trees determined to *currently* have suitable elements for nesting or *currently* be screen trees. This is consistent with the recommendations of the CDFW. The CDFW provided a broad definition of “suitable habitat characteristics” for marbled murrelets that include all mature and old-growth coniferous forest stands: “[s]uitable habitat characteristics [for marbled murrelets] shall be defined as mature and old-growth coniferous forest stands, and younger coniferous forest stands having platforms with a relatively flat surface at least 10 centimeters in diameter and 10 meters high in the live crown of a coniferous tree. Platforms can be created by a wide bare branch, moss or lichen covering a branch, mistletoe, witches’ brooms, and other deformities, or structures such as squirrel nests (Pacific Seabird Group 2024).”³⁴ The CDFW then specified a series of mitigation measures for marbled murrelet nesting habitat avoidance (Mitigation Measure 3) that include restrictions on tree removal that are not incorporated into the SDEIR.³⁵ The SDEIR must fully incorporate these CDFW recommended mitigation measures.

ORG3-13
cont.

6. The SDEIR must add mitigation measures related to hazard tree management to prevent harm to murrelets.

The PSG Habitat Recommendations include an extensive set of recommendations for hazard tree management that should be included in the SDEIR mitigation measures to prevent the unintended and unnecessary removal of trees that may serve as murrelet nest trees now or in the future. As stated in the PSG Recommendations:

ORG3-14

et al., Nesting habitat characteristics of the marbled murrelet in Central California Redwood Forests, 70 Journal of Wildlife Management 939 (2006) at 944-945.

³² Mahdizadeh, M. and W. Russell, Initial floristic response to high severity wildfire in an Old-Growth Coast Redwood (*Sequoia sempervirens* (D. Don) Endl.) Forest, 12 Forests 1135 (2021), <https://doi.org/10.3390/f12081135>.

³³ Rinkert, Alex et al., A marbled murrelet chick fledges at Big Basin, 66 Santa Cruz Bird Club Newsletter 2 (2021), https://static1.squarespace.com/static/5391fcafe4b0df683d9c51dd/t/61de1241dae755313ec62aa0/1641943618846/MAMU_NEST_BirdClubNL_66-2_NOV-DEC_2021_art_dft.pdf.

³⁴ SDEIR at pdf p. 389.

³⁵ SDEIR at pdf p. 389-392.

Periodically, mature and old-growth trees, that may serve as murrelet nest trees, are designated by land managers as **Hazard Trees** when they might be in danger of falling on structures.... In such circumstances, they are often removed or their large branches are pruned off. We are concerned about their removal as these hazard trees may contain or contribute to suitable murrelet nest sites. We recommend an approach whereby the risks of potential hazard trees are duly evaluated, including whether the resources at risk can be relocated or removed, whether potential hazard trees can be left untouched, or large branches pruned off rather than felling the tree. Mitigation measures within and near habitat to reduce the risk of negative impacts to murrelets and their habitat due to hazard tree management-related activities.³⁶

The PSG Recommendations provide a set of 11 recommendations for mitigating harms to murrelets from hazard tree management which should be incorporated into the SDEIR. These mitigation measures include but are not limited to:

- ensure that a wildlife biologist participates in the design, implementation, and monitoring of proposed hazard tree activities in murrelet habitat
- require that all trees proposed to be removed or pruned in or adjacent to murrelet habitat be inspected by a qualified forest health protection pathologist or certified arborist to determine whether they are truly hazard trees
- avoid the removal of active or historical murrelet nest trees
- avoid and/or minimize the removal of large trees or large branches that may later support nests or nest sites, or contribute to habitat characteristics.³⁷

7. The SDEIR must protect and buffer the unburned and lightly burned stands of old-growth habitat.

There are at least four areas of unburned old-growth habitat in Big Basin SP, as identified in the comments submitted by the Pacific Seabird Group.³⁸ These critical areas of unburned and lightly burned nesting habitat should be identified, mapped, and fully protected from any tree removal or development. In addition, following the guidance in the PSG Habitat Recommendations, a buffer zone of no tree removal of at least 100 meters,³⁹ and a buffer zone of no development including Park infrastructure of at least a half-mile (800 meters),⁴⁰ should be implemented around all unburned and lightly burned habitat areas. These buffer zones are important for protecting high-integrity nesting habitat, minimizing the impacts of forest edges on

**ORG3-14
cont.**

ORG3-15

³⁶ PSG Habitat Recommendations (2024) at 21.

³⁷ PSG Habitat Recommendations (2024) at 21-22.

³⁸ SDEIR at pdf p. 376; *See also* map titled “Location of Refugia Relative to Proposed Park Zone and Sites” at SDEIR pdf p. 380.

³⁹ PSG Habitat Recommendations (2024) at 6.

⁴⁰ PSG Habitat Recommendations (2024) at 20.

murrelets, decreasing human disturbance, and reducing attraction of predators to murrelet nests.⁴¹

The SDEIR is flawed in failing to address the impacts to marbled murrelets of placing recreational facilities and development within or near the unburned and lightly burned habitat areas; and failing to analyze an alternative that could avoid the inevitable negative impacts to marbled murrelets by fully protecting the unburned and lightly burned stands of old-growth habitat from any tree removal or development and establishing a buffer zone of no tree removal of at least 100 meters, and a buffer zone of no development of at least a half-mile, around all unburned or lightly burned habitat areas.

**ORG3-15
cont.**

8. The SDEIR should add a mitigation measure to create a murrelet management team by a near-term set date.

The SDEIR should add a mitigation measure to create and implement a marbled murrelet management team by a near-term set date to inform construction activities, long-term monitoring, and adaptive management. The mitigation measure should specify that the team should include participation from relevant state and federal agencies and experts on murrelet ecology and conservation. The team should develop and implement a marbled murrelet adaptive management plan that includes regular monitoring of murrelet activity levels and uses visual and acoustic surveys to maximize detection of murrelets.

ORG3-16

9. The SDEIR should consider the need for stronger protections for murrelet habitat in Butano and Portola State Parks.

Marbled murrelet habitat in Big Basin SP was heavily impacted by the CZU Fire. Given that the Big Basin Facilities Plan will have adverse harms to marbled murrelets, State Parks should consider the need to strengthen protections in the remaining marbled murrelet habitat in Zone 6, particularly in Butano and Portola State Parks. Effective protections may need to include relocating the campgrounds and picnic areas out of old-growth habitat in these parks.

ORG3-17

Conclusion

The Center appreciates the opportunity to comment on the SDEIR. We strongly support the proposal to not re-build the Blooms Creek, Sempervirens, and Jay Camp campgrounds in the Old Growth Area and instead provide camping facilities outside of old-growth redwood habitat. However, because substantial evidence shows that the Big Basin Facilities Management Plan will have significant adverse impacts on marbled murrelets that are not adequately considered, avoided, minimized, or mitigated by the proposed plan or current set of alternatives and mitigation measures in the SDEIR, we urge State Parks to revise and recirculate the SDEIR. We look forward to reviewing a revised document that includes additional feasible alternatives and

ORG3-18

⁴¹ SDEIR at pdf p. 376.

mitigation measures to avoid, minimize and mitigate the impacts to marbled murrelets in Old Growth Areas and throughout the park.

We are submitting pdfs of the cited references with these comments.

Sincerely,



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**ORG3-18
cont.**



Nesting Habitat Characteristics of the Marbled Murrelet in Central California Redwood Forests

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Nesting Habitat Characteristics of the Marbled Murrelet in Central California Redwood Forests

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Abstract

The marbled murrelet (*Brachyramphus marmoratus*) is a threatened seabird that nests in old-growth forests in the Pacific Northwest. Despite concern for this species, little has been published on murrelet nesting habitat in the coast redwood (*Sequoia sempervirens*) region. Here we present the first comprehensive study of marbled murrelet nesting characteristics in redwood forests based on confirmed nest sites. In this study, we 1) described habitat characteristics at 17 murrelet nest sites in the Santa Cruz Mountains, California, USA, located using radiotelemetry and visual searches, and 2) compared nest sites with random sites located in nearby stands and centered on trees ≥ 120 cm diameter at breast height (dbh [potential nest trees or PNTs]). All 17 nests were located in stands of old-growth redwood forest and the mean dbh of nest trees was 210 cm (SD = 91 cm). Eighty-two percent of nests (90% of telemetry-found nests) were in unharvested stands and 18%, all on private property, had been lightly harvested but did not contain significantly fewer trees ≥ 120 cm dbh than unharvested nest sites. Twelve of 15 (80%) nests for which we were able to locate the nesting platform were on limbs and the remaining 3 (20%), all in redwood trees, were located on broken tops. Nest trees were significantly larger than PNTs and tended to be Douglas-fir (*Pseudotsuga menziesii*) despite the fact that nest stands were dominated by redwoods, perhaps because of greater nest platform availability in Douglas-fir trees. Nest sites were located closer to streams, had a greater basal area of trees ≥ 120 cm dbh, and were located lower on slopes than random sites based on analysis of variance models. We classified 71% of nest sites correctly with a simple logistic regression model that included only nest tree dbh and distance to stream—a model that could be used by managers in the region to identify potentially suitable nesting habitat. Our findings indicated that murrelets in central California, USA, primarily use old-growth redwood stands for nesting but will use partially harvested stands if a significant residual component remains; stands that have experienced some harvest but retain old-growth characteristics should be considered potential murrelet habitat in redwood forests. (JOURNAL OF WILDLIFE MANAGEMENT 70(4):939–946; 2006)

Key words

Brachyramphus marmoratus, endangered species, habitat use, marbled murrelet, nesting habitat, old-growth redwood forest, Santa Cruz Mountains.

Intensive timber harvesting has occurred in the coastal old-growth forests of the Pacific Northwest since the middle of the 19th century. Only 4% of the original old-growth coast redwood (*Sequoia sempervirens*) forest remains in California, USA (Fox 1989). As a result, some species of wildlife dependent on old-growth redwood forests have experienced large population declines (Noss 2000). One such species is the marbled murrelet (*Brachyramphus marmoratus*), a small seabird in the family Alcidae that forages at sea but nests on large tree limbs in coastal forests (Nelson 1997). Scientists generally believe that the logging of nesting habitat greatly reduced murrelet populations in California (Carter and Erickson 1992), and loss of nesting habitat was the primary reason the murrelet was placed on the federal threatened and state endangered species lists in California (Larsen 1991, U.S. Fish and Wildlife Service 1992). Two primary murrelet populations remain in the state; the larger population nests in remnant old-growth redwood forests in northern California and

the smaller population nests in remnant old-growth redwood forests in central California.

Finding nests and characterizing nesting habitat is extremely challenging because the marbled murrelet prefers to nest high in large trees and exhibits secretive nesting behavior. Published literature has described only 4 murrelet-nest trees from California (Binford et al. 1975, Singer et al. 1991, 1995), although an additional 5 nest trees were pooled with data from other regions in a range-wide analysis of murrelet nesting habitat (Hamer and Nelson 1995). The more detailed studies of murrelet nesting habitat in the redwood region have used observations of birds flying beneath the canopy (Miller and Ralph 1995, Meyer and Miller 2002, Meyer et al. 2004), but inferences from such studies are limited because stands where murrelets are detected are not necessarily used for nesting. The recent development of capture and radiotelemetry techniques for seabirds (Whitworth et al. 1997, Newman et al. 1999) has greatly increased researchers' ability to locate and describe murrelet nest sites (e.g., Zharikov et al. 2006), but detailed analyses of murrelet nesting habitat in the redwood region based on known nests have not been conducted.

We present the first study of marbled murrelet nesting habitat characteristics in redwood forests based on confirmed nest sites that compares habitat use versus habitat availability, involves a

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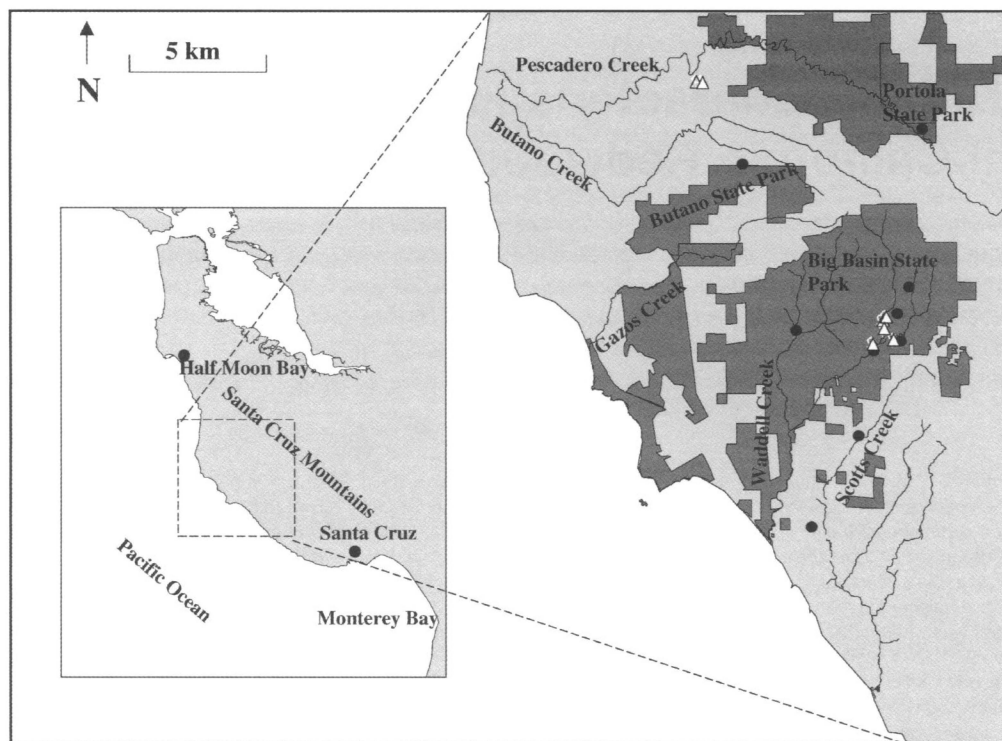


Figure 1. Study area and marbled murrelet nest locations in the Santa Cruz Mountains, central California, USA, 1989–2001. Dark circles represent nests found with radiotelemetry, and white triangles represent nests found visually.

detailed quantification of forest structure at the stand scale, and uses a relatively large number of nest sites. Using radiotelemetry and ground-based visual searches for nest sites in central California, we sought to 1) determine the frequency of murrelet nests in unharvested versus harvested redwood stands; 2) characterize murrelet nest sites at the stand, tree, and platform scales; and 3) identify important habitat characteristics by comparing habitat use to habitat availability at the tree and stand scales (Johnson 1980).

Study Area

We conducted the study in coast redwood forest in the Santa Cruz Mountains of central California, USA (Fig. 1). The Santa Cruz Mountains run from San Francisco to the Pajaro River (a distance of 119 km) and are part of the California Outer Coastal Range. Elevation ranges from sea level to 1,154 m. The redwood forest in this region is dominated by coast redwood in the overstory, but Douglas-fir (*Pseudotsuga menziesii*) is also present to a lesser degree. Hardwoods in the understory include tanoak (*Lithocarpus densiflorus*), coast live oak (*Quercus agrifolia*), and California bay (*Umbellularia californica* [Zinke 1977, Sawyer and Keeler-Wolf 1995]). Logging of most original old-growth in the range occurred around 1900 (Singer et al. 1991, Noss 2000). Harvesting in the region from the late 1800s through the 1960s generally involved clear-cutting, including true clear-cutting, seed tree retention, and leaving small pockets of inaccessible timber (J. B. Bulger, personal communication; Evarts and Popper 2001). Most of the harvesting since the 1970s has been selective, which generally entails removing 25–30% of the total stems in the stand

at 12- to 15-year intervals (J. B. Bulger, personal communication). There are currently less than 4,100 ha of old-growth redwood forest remaining in the Santa Cruz Mountains (J. B. Bulger, unpublished data), and many of the remaining old-growth stands are in state and county parks (Fig. 1). Smaller, isolated stands of old-growth redwood forest are located on smaller parks and on private property. Climatic conditions in the Santa Cruz Mountains vary from west to east because of high ridges that limit the penetration of maritime air masses and orographic effects. Our study sites were in the west half of the range where summer conditions are typically moderately cool with frequent low overcast or fog, and winter conditions are cool and wet. Average annual precipitation on the west side ranges from 70 cm on the coast (Davenport) to 147 cm at the summit (Ben Lomond Mountain; California Department of Water Resources 1982). Precipitation on the west side is mostly rain falling between October and May.

Methods

Locating Nests

We used a combination of radiotelemetry and ground-based visual searches to locate 17 marbled murrelet nests in the Santa Cruz Mountains (10 with radiotelemetry and 7 with visual searches). These nests constitute 17 of the 18 known nests in the region and include the nest trees described by Singer et al. (1991, 1995), but not the nest described by Binford et al. (1975). To locate murrelet nests with radiotelemetry, we captured and radiotagged murrelets in Año Nuevo Bay, California, USA, in April–June from 1997 to 2001 with a dip-net from a 4.5-m inflatable boat (Peery et al.

2004a,b). Radiotransmitters were attached using the subcutaneous anchor technique (Newman et al. 1999), were made by Holohil Systems Ltd. (model BD-2G, Carp, Ontario, Canada), and weighed 2.2 g with an expected life of 12–16 weeks. We tracked murrelets using aerial telemetry from a fixed-wing aircraft and ground-based telemetry from 4-wheel-drive vehicles outfitted with a null-peak antenna arrangement (Kenward 1987). We attempted to obtain at least one location at sea every 24 hours for each murrelet. If a radiomarked murrelet was not located at sea, we flew over all forested habitat in the Santa Cruz Mountains between Santa Cruz and Half Moon Bay to determine if the individual went inland to initiate incubation. When we detected a bird inland, we visited the forested area where the signal originated to locate the nest tree as soon as possible (usually the same day). We returned as soon as possible (usually early the following morning) to observe the nesting pair exchanging incubation duties in order to locate the exact nest site (Peery et al. 2004a,b). We detected radiomarked murrelets, or they had moved to at-sea areas far from nesting habitat (>250 km), on >95% of the days they carried a functioning radiotransmitter. Therefore, it is unlikely that we failed to detect many nests or that we biased nest locations towards forested areas with easy access.

We found 4 of the visually located nests during targeted nest searches and 3 of the visually located nests fortuitously. We conducted targeted searches during the breeding seasons in old-growth portions of Big Basin Redwoods State Park in 1989 and from 1991 to 1996 by placing observers around possible nest trees to watch for incoming murrelets from 1 hour before sunrise to 1 hour after sunrise (Singer et al. 1991, 1995; E. E. Burkett, California Department of Fish and Game, unpublished data). We selected possible nest trees based on tree size and the presence of suitable nest platforms, which we defined as any area within the live crown that was at least 18 cm in diameter, had some cover present, and was above the lower one-quarter of the live crown. We spent an average of 253 hours per year for the 7 years that we carried out targeted nest searches (SD = 316 hr), with a range of 51 to 831 hours per year. An observer conducting inland audiovisual surveys (Evans Mack et al. 2003) found 2 of the 3 fortuitously located nests because he witnessed predation events at the nest sites by common ravens (*Corvus corax*). Audiovisual surveys are a required component of timber harvest planning in any stand that has trees with suitable nest platforms. Surveyors have carried out audiovisual surveys in a large number of locations and range of habitats in the Santa Cruz Mountains. A third nest site was located by observing marbled murrelet eggshell fragments at the base of an old-growth tree below a suitable nest limb. We assumed that nests found with radiotelemetry constituted a random representation of murrelet nesting habitat, but the same may not be true for visually located nests because some searches were concentrated in old-growth habitat. We statistically compared habitat variables at nest sites located with radiotelemetry and visual techniques to determine if visually located nests were biased representations of nesting habitat.

Assessing Important Habitat Attributes

We employed a use-versus-availability study design to determine which habitat attributes murrelets used more than would be expected based on their availability (Johnson 1980). Nest sites

constituted *used habitat* while randomly selected sites in the Santa Cruz Mountains were treated as *available habitat*. Each random site was paired with a nearby nest site and was placed in stands that contained at least a residual component of old growth. We defined *stands* as the 25-m-radius area surrounding a nest tree and *old growth* to be forest in a late seral stage in which the canopy is dominated by trees originating prior to about 1850 when significant logging began. By pairing nest and random sites and by excluding heavily harvested and pure second-growth stands, we attempted to determine which attributes within old-growth forests constitute important elements of murrelet nesting habitat. In doing so, we assumed that murrelets require at least a residual component of old growth for nesting.

Each random site was located within a 1-km radius of a nest site. To locate random sites, we randomly generated a series of Universal Transverse Mercator (UTM) coordinates and designated the closest tree to the first UTM coordinate with a diameter at breast height (dbh) of ≥ 120 cm as the center of the random site and the “potential nest tree” (PNT). We used a minimum of 120 cm dbh for PNTs because this measurement was approximately equal to the dbh of the smallest-sized tree expected to contain a suitable nesting platform in the Santa Cruz Mountains and was very similar to the minimum nest tree dbh (134 cm). If we did not locate a tree with a dbh of ≥ 120 cm in the area indicated by the randomly generated UTM coordinates, we searched for a PNT along a 150-m transect in a random direction. We used the first tree ≥ 120 cm dbh within 25 m of the transect line as the center of the random site. We excluded randomly generated locations that did not contain a residual component of old-growth and instead searched the next randomly located site until we located a suitable site.

Measuring Habitat Characteristics

We measured habitat variables at the nest-platform, nest-tree, and nest-stand scales. To measure stand-level characteristics, we centered a 25-m-radius plot (0.2 ha) on the nest tree or PNT. We measured dbh (cm) and determined the species of each tree >10 cm dbh within the plot. We also measured the dbh, height (m), canopy lift (distance to the bottom of the live crown; m), and crown diameter (m) of 5 randomly selected dominant and midstory trees within each plot. For analysis purposes, we grouped all trees within the 25-m-radius plots into 1 of 4 size classes based on their dbh: 10–60 cm (“small trees”), 60–90 cm (“medium trees” that consisted of large midstory to small dominant trees), 90–120 cm (“large trees” that consisted of old-growth trees; as defined by Miller and Ralph 1995), and >120 cm (“very large trees” consisting of old-growth trees that would qualify as PNTs in this study). Although not used for nesting by murrelets, we compared the basal area of small, medium, and large trees between nest and random sites because tree size may provide important habitat elements such as concealing nests from predators. We then calculated the basal area (m^2/ha) in each size class in each plot. We also measured the slope (%), aspect ($^\circ$), position on slope (lower third, middle third, and upper third), number of canopy layers (for trees >10 m in height), and canopy cover (midstory, dominant, and total; %) at the center of the plot. Finally, we estimated the distance to nearest permanent stream (m), distance inland (km), and elevation (m) using range finders and topographic maps.

Some sites did not have measurements for the number of canopy layers, canopy cover, or for random midstory and dominant tree variables because we collected data prior to the establishment of habitat-characterization protocols.

At the nest tree scale, we measured the dbh (cm), height (m), canopy lift (m), crown area (calculated in m^2 from crown diameter along the cardinal directions), and number of platforms (limbs >10 cm in diameter) for all nest trees and PNTs. The limited data sites did not have measurements for the number of platforms, canopy lift, or crown area of the nest tree.

When feasible, we climbed nest trees and measured habitat characteristics at nest limbs and platforms including tree diameter at nest (cm), branch diameter at nest (cm), nest limb aspect ($^\circ$), limb height (m), moss cover on all limbs (%), moss cover on the nest platform (%), lichen cover on all limbs (%), and lichen cover on the nest platform (%). We did not collect nest platform data for PNTs due to logistical constraints.

Data Analysis

Univariate analyses.—We used a chi-square analysis to compare categorical habitat variables such as harvest history, position on slope, and number of canopy layers between nest and random sites. We used a mixed-model analysis of variance (Littell et al. 1996) to compare continuous habitat variables between nest and random sites. Site classification (nest or random), method of locating the nest (visual or telemetry), and the interaction between site classification and method of location were treated as fixed effects, while site was treated as a random blocking effect. Method of location was included in the model to test for potential biases in visual searches, such as biases towards large trees and old-growth stands. We treated site as a random blocking effect to pair nest and random sites. Initially we included all factors in the model, then we systematically removed factors that were not significant in the following order: 1) the interaction between site classification and location method, 2) site classification, and 3) location method. We employed a 2-sample Watson–Williams test for circular data (Zar 1999) to compare aspect between nest and random sites. We assessed the normality of all continuous habitat variables using Shapiro–Wilk tests and transformed nonnormal variables using square root and $\log_{10}+1$ transformations. We considered P values of 0.05 to be significant for all statistical tests. We did not adjust critical values to account for multiple tests because 1) doing so would have resulted in low power to detect differences given our small sample size, and 2) our univariate analyses were exploratory and our intention was to identify habitat characteristics that were potentially important for murrelet nesting.

Logistic regression analyses.—We used logistic regression analysis (Hosmer and Lemeshow 2000) to develop a predictive model that could identify suitable nesting habitat for marbled murrelets. The basal area of large trees, the basal area of very large trees, total canopy cover, dbh of the nest tree, distance to stream, and slope were treated as independent variables and used to predict whether a site was a random or a nest site. We only used 2 basal area variables, the basal area of large trees and basal area of very large trees because 1) small and medium trees were not important in the univariate analysis, and 2) the basal area of large and very large trees was highly correlated with the basal area of individual species in these size classes. Variables not measured at

all sites (random midstory and dominant tree variables, number of platforms, canopy lift and crown of the nest tree, and mid- and overstory canopy cover), that were circular (aspect), or exhibited little variation (elevation) were excluded. To restrict the number of candidate models, we first modeled all combinations of the basal area of large trees, the basal area of very large trees, and nest tree dbh separately from all combinations of slope, total canopy cover, and distance to nearest stream. We then explored a model that combined the most important variables from each of the 2 preliminary sets of models. We ranked competing models using Akaike's Information Criterion scores corrected for small sample size (AIC_c; Burnham and Anderson 2002).

We used a jackknifing procedure to determine the ability of the best logistic regression model to predict whether a site was a nest or random site. We conducted 34 sets of logistic regression analyses using the original data set with a unique observation removed. If the probability of the site being a nest was >0.50 , we classified it as a nest site; otherwise we classified it as a random site.

Results

Distribution of Nest Sites with Respect to Landownership and Harvest History

We located 17 nest sites in the Santa Cruz Mountains (Fig. 1): 13 (76%) in California state parks and 4 (24%) on private property. Eight of 10 (80%) nests located with radiotelemetry and 5 of 7 (71%) nests located visually were in state parks. All nests were located in either unharvested (82%) or lightly harvested (18%), old-growth, coast redwood–Douglas-fir stands. Ninety percent of nests located with radiotelemetry and 71% of visually located nests were in unharvested forest stands, suggesting that we did not bias visually located nests towards or against unharvested stands. All 13 nest sites on state park lands were unharvested, but 3 out of 4 sites on private property had been harvested. Two harvested sites were logged over 50 years ago (J. B. Bulger, unpublished data) and one site was logged as recently as 10 years ago (M. Z. Peery, University of California Berkeley, unpublished data), all using individual tree selection harvesting techniques. Logging within all harvested stands had left a significant number of live trees and a significant component of residual old-growth trees (4–6 trees ≥ 120 cm dbh per plot). The number of very large trees in harvested nest plots ($\bar{x}=5.3$, $SD=1.2$) did not differ ($t_{16}=-0.48$, $P=0.64$) from the number of very large trees in unharvested nest plots ($\bar{x}=6.0$, $SD=2.3$). Moreover, the dbh of very large trees did not differ ($t_{16}=0.12$, $P=0.91$) between partially harvested ($\bar{x}=179$ cm, $SD=50$) and unharvested sites ($\bar{x}=183$ cm, $SD=31$). No difference in harvest history existed between nest and random sites ($\chi^2_1=0.66$, $P=0.42$).

Habitat Characteristics and Selection at the Stand Scale

Nest sites were located an average of 9.0 km ($SD=2.9$) from the coast, with a range of 1.7 to 16.2 km inland. All nest sites were on the bottom two-thirds of the slope, with 11 (65%) on the bottom third and 6 (35%) on the middle third of the slope. To ensure that expected values were ≥ 5 for the chi-square analysis comparing slope position between nest and random sites, we pooled sites on the middle and upper third of the slope. The distribution of nest sites with respect to slope position differed significantly from the

Table 1. Nest tree and site characteristics for 17 marbled murrelet nest sites and 17 random sites in the Santa Cruz Mountains, California, USA, 1989–2001.

Habitat variable	Nest sites			Random sites			F	P	df
	$\bar{x}$	SD	n	$\bar{x}$	SD	n			
Site characteristic ^a									
Elevation (m) ^b	280.4	86.7	17	314.7	109.3	17	1.03	0.32	1,32
Slope (%) ^c	48.9	25.7	17	47.5	24.1	17	0.03	0.87	1,32
Aspect (°) ^d	278.0	87.4	16	78.0	100.1	17	14.44	<0.01	1,31
Nearest stream (m) ^e	103.1	75.7	17	270.0	237.1	17	7.32	0.01	1,32
Dominant canopy cover (%)	29.6	11.9	14	30.1	11.0	17	0.31	0.58	1,26
Midstory canopy cover (%)	52.9	13.8	14	48.6	13.0	17	0.09	0.76	1,26
Total canopy cover (%)	65.0	16.5	17	69.8	8.8	17	1.12	0.30	1,32
Nest tree or potential nest tree characteristic									
Diameter at breast height (cm) ^f	209.5	90.6	17	165.7	47.1	17	4.63	0.04	1,32
Height (m)	56.6	11.9	17	51.4	14.2	17	1.33	0.26	1,32
Crown area (m ²)	125.6	59.2	13	105.1	58.9	17	0.82	0.37	1,24
Canopy lift (m)	21.7	6.8	14	18.8	7.2	17	1.08	0.31	1,26
No. of platforms	7.4	4.9	13	5.1	3.5	17	2.17	0.15	1,24

^a Observations only included if a matching nest and random site were available.

^b Random site effect significant at $P \leq 0.05$.

^c Method of location significant at $P \leq 0.05$; visually detected nests had lower values than nests found with radiotelemetry.

^d Watson–Williams circular distribution test used to compare aspect between nest and random sites (Zar 1984).

^e Analysis conducted using square root transformation.

^f Analysis conducted using log transformation.

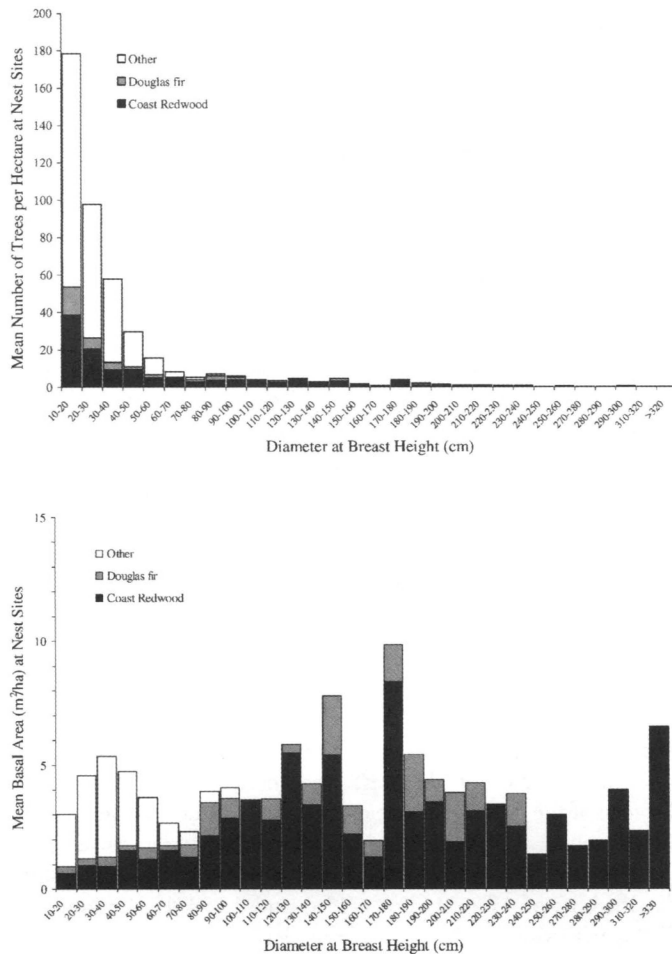


Figure 2. Trees at marbled murrelet nest sites in central California, USA, measured in 25-m-radius plots centered on the nest tree, 1989–2001. (a) Mean number of trees by size class and species, (b) mean basal area by tree species and size class. Species listed are coast redwood, Douglas-fir, and other.

random sites ($\chi^2_1 = 9.9$, $P < 0.01$), with 35% of random sites on the bottom third and 65% on the upper two-thirds of the slope. Nest sites were located significantly closer to streams than random sites ($P = 0.01$; Table 1). Nest and random sites were not different in percent slope, but differed significantly in aspect ($P < 0.01$), as nest sites generally faced west (Table 1). There was no significant difference in canopy cover between nest and random plots (Table 1). Nest and random sites had a minimum of 2 canopy layers and nest sites tended to have more canopy layers than random sites, but this difference was not significant ($\chi^2_1 = 2.5$, $P = 0.11$). Two of 4 cells in this chi-square analysis had expected values < 5 , and it is possible that we would have detected a difference with a greater sample size of nests.

Marbled murrelets generally nested in stands where coast redwoods dominated the total basal area, but most trees within nest stands were small tanoaks (Fig. 2). Although there were relatively few large trees in nest plots, 66% of the basal area at nest sites was in trees ≥ 120 cm dbh (Fig. 2). The basal area of very large trees in nest plots ($\bar{x} = 79.2$ m²/ha, SD = 43.6) was significantly greater than in random plots ($\bar{x} = 58.0$ m²/ha, SD = 47.4; $F_{1,32} = 4.42$, $P = 0.04$). The basal area of very large redwood trees tended to be greater at nest sites than at random sites (nest: $\bar{x} = 64.8$ m²/ha, SD = 47.1; random: $\bar{x} = 42.1$ m²/ha, SD = 37.8; $F_{1,32} = 3.70$, $P = 0.06$), but Douglas-fir trees did not follow this pattern (nest: $\bar{x} = 14.4$ m²/ha, SD = 12.0; random: $\bar{x} = 15.9$ m²/ha, SD = 22.5; $F_{1,32} = 0.33$, $P = 0.57$). No difference existed between nest and random sites in the basal area of any other size class or size class by species combination (all P values > 0.05). Nest sites did not have significantly more very large trees per hectare ($\bar{x} = 29.4$, SD = 10.6) than random sites ($\bar{x} = 25.3$, SD = 16.6; $F_{1,32} = 0.74$, $P = 0.40$), but the dbh of very large trees tended to be greater in nest sites ($\bar{x} = 180$ cm, SD = 46) than in random sites ($\bar{x} = 157$ cm, SD = 25; $F_{1,32} = 3.2$, $P = 0.08$). There were no significant differences between the height, lift, crown area, or dbh



Figure 3. Marbled murrelet nest platform on the broken top of an old-growth coast redwood tree. Note the egg, marked by the white arrow, in the middle of the picture beneath the epiphytic redwood sapling. (Photo by J. Spickler.)

of the 5 random dominant and subdominant trees measured for 13 nest and random sites (all P values > 0.05).

Habitat Characteristics and Selection at the Tree Scale

All 17 nests were found in very large conifers (mean dbh = 210 cm, SD = 91); 7 nests (41%) were in redwood trees and 10 (59%) were in Douglas-fir trees. Redwood ($\bar{x}$ = 244 cm, SD = 135) and Douglas-fir ($\bar{x}$ = 186 cm, SD = 30) nest trees did not differ significantly in dbh ($t_{16} = 1.33$, $P = 0.20$). However, Douglas-fir nest trees had a significantly greater number of platforms ($\bar{x}$ = 10.5, SD = 3.4, $n = 8$) than redwood nests ($\bar{x}$ = 2.4, SD = 1.1, $n = 5$; $t_{16} = 5.05$, $P < 0.01$). Of the 17 PNTs, 9 were in redwood trees (53%) and 8 were in Douglas-fir trees (47%). There was no significant difference in the proportions of the 2 species between nest trees and PNTs ($\chi^2_1 = 0.47$, $P = 0.49$). The mean diameter of nest trees was significantly greater than PNTs, which we randomly selected within old-growth forests and were at least 120-cm dbh (Table 1). The mean height, crown area, canopy lift, and number of platforms in nest trees and PNTs did not differ (Table 1).

Habitat Characteristics at the Platform Scale

We measured characteristics of 15 nest platforms from 14 nest trees (platforms for 3 of the 17 nest trees were not located and 1 tree was used twice for nesting). Twelve of the 15 (80%) platforms were located on limbs and 3 of the 15 (20%) platforms were created by broken tops (Fig. 3). All 3 broken-top nests were in redwood trees. The remaining 5 of 8 (63%) redwood nests and all Douglas-fir nests ($n = 7$) were on limbs. Mean diameter of the nest limb, including epiphyte cover, was 46.5 cm (SD = 12.1, $n = 12$) at the nest cup, with a range of 29–70 cm, and the mean diameter of the tree at the nest limb was 99.7 cm (SD = 28.6, $n = 11$). Mean limb height was 41 m (SD = 7.7, $n = 6$), mean limb aspect was 95° (SD = 100, $n = 13$), and mean nest limb length was 6.9 m (SD = 3.8, $n = 8$). Mean moss cover on nest limbs was 32.3% (SD = 35, $n = 10$) and mean moss cover on nest platforms

Table 2. Akaike's Information Criterion scores (AIC) for 16 logistic regression models predicting whether a site was a marbled murrelet nest site or a randomly measured site in the Santa Cruz Mountains, California, USA, 1989–2001.

Model	K^a	AIC_c^b	ΔAIC_c^c
Nest Tree dbh ^d + Distance to Stream	3	42.43	0.00
Distance to Stream	2	44.31	1.88
Total Canopy Cover + Distance to Stream	3	46.19	3.76
Nest Tree dbh	2	46.41	3.98
Distance to Stream + Slope	3	46.66	4.23
BA ^e Very Large Trees	2	47.06	4.63
BA Large Trees + Nest Tree dbh	3	47.24	4.81
BA Very Large Trees + Nest Tree dbh	3	47.91	5.48
Slope + Total Canopy Cover + Distance to Stream	4	48.61	6.18
BA Very Large Trees + BA Large Trees	3	48.83	6.40
BA Very Large Trees + BA Large Trees + Nest Tree dbh	4	49.21	6.78
Intercept	1	49.26	6.83
Total Canopy Cover	2	50.26	7.83
BA Large Trees	2	50.44	8.01
Slope	2	51.50	9.07
Slope + Total Canopy Cover	3	52.47	10.05

^a Number of parameters.

^b AIC score corrected for small sample size.

^c The difference in AIC_c scores between the best model and the model in question.

^d Diameter at breast height.

^e Basal area.

was 27.2% (SD = 32.5, $n = 10$). Douglas-fir trees had significantly more moss cover ($\bar{x}$ = 59.0%, SD = 30.9, $n = 5$) than redwood trees ($\bar{x}$ = 5.6%, SD = 4.3, $n = 5$; $t_9 = 3.8$, $P < 0.01$). Mean lichen cover on all limbs was 16.1% (SD = 16.2, $n = 10$) and mean lichen cover on the nest platform was 5.8% (SD = 6.1, $n = 9$).

Multivariate Analyses

Multicollinearity was generally not an issue because the 6 independent variables used in the logistic regression analysis were uncorrelated (all $r < 0.35$) except for nest tree dbh and the basal area of very large trees ($r = 0.60$, $P < 0.01$). The logistic model that provided the best discrimination between nest and random sites contained nest tree dbh and distance to stream; it ranked 1.88 AIC_c units higher than the next best model, which only contained distance to stream (Table 2). The following equation describes the best model:

$$P = \frac{e^{7.85 \times \log(\text{NSTDBH}) - 0.18 \times \text{STMDST}^{1/2} - 15.50}}{1 + e^{7.85 \times \log(\text{NSTDBH}) - 0.18 \times \text{STMDST}^{1/2} - 15.50}},$$

where P was the probability that a site was a nest site, NSTDBH was the diameter of the nest tree (cm), and STMDST was distance of the nest to the stream (m). This model was the highest ranked model regardless of which observation we removed from the data set. Using the jackknifing procedure, we successfully classified 12 of 17 nest sites (71%) and 12 of 17 random sites (71%) with this relatively simple model.

Discussion

We found that unharvested and lightly harvested old-growth forest stands are the primary sources of nesting habitat for marbled

murrelets in central California, and second-growth and heavily harvested (e.g., previously clear-cut) stands do not provide essential habitat features. This strong preference for old-growth forests at the nest tree and stand scales is consistent with the range-wide analysis conducted by Hamer and Nelson (1995) and corroborates results from counts of murrelets in inland habitats in California and other regions (Grenier and Nelson 1995, Hamer 1995, Miller and Ralph 1995, Meyer and Miller 2002, Meyer et al. 2004).

Inferences from our use-versus-availability analyses were limited by the sample size of nests ($n = 17$). Also, we compared nest sites to random sites instead of to unused sites, which could have compromised the power to detect important habitat characteristics (Garshelis 2000). Nevertheless, our nest-site characterization was based on 17 of the 18 known nests in central California, USA, and our use-versus-availability analyses allowed for some inferences to be made about murrelet habitat attributes. We found that nest sites were much closer to streams than would be expected based on randomly available sites within old-growth forests. Nest sites may have been located near streams because these sites afforded murrelets better access from at-sea flyways. Studies have found proximity to streams or other openings to be important for murrelet nesting in other regions as well (Hamer and Nelson 1995, Meyer et al. 2004, Zharikov et al. 2006). Murrelets also used very large trees ($\bar{x}$ dbh = 210 cm) for nesting that were significantly larger than the dbh of PNTs ($\bar{x}$ dbh = 166 cm). The large dbh of nest trees may also be an indicator for other important factors for murrelets at the nest limb, platform, and cup scales, such as increased nest concealment through increased vertical cover over limbs or a more favorable microclimate. Perhaps more importantly, large trees may harbor larger platforms or be older and have a higher incidence of limb and tree deformities, which we found to be important for murrelets. Finally, marbled murrelets selected stands characterized by greater basal area of very large trees, greater basal area of very large redwood trees, and a low position on the slope. The tendency for murrelets to nest in sites with greater basal area of very large trees suggests that, even within old-growth forests, murrelets select nest stands dominated by the largest trees.

Despite the importance of very large redwoods at the stand scale, more nests were located in Douglas-fir (59%) than in redwood trees (41%), possibly because Douglas-fir trees are more likely to contain suitable nesting platforms. Redwoods, even very large ones, had almost 4 times fewer limbs >10 cm than Douglas-fir nest trees and mean nest limb diameter was much greater for Douglas-fir than for redwood nests. When murrelets did nest in redwood trees, they often used broken tops (3 of 8 nests) instead of nest limbs. No literature has previously reported the use of broken tops, which may compose an important component of murrelet nesting habitat in redwood forests.

We did not find a difference in the number of potential nesting platforms between nest trees and PNTs. However, the presence of multiple suitable platforms does not necessarily indicate that a tree is suitable for nesting. Mean limb diameter was 59.8 cm, considerably larger than the 10-cm criteria used to identify suitable platforms during platform counts. Counts of limbs >10

cm, which are often used by managers to determine if a site is suitable for murrelet nesting, is probably not a useful index of nest-site availability in central California, USA, as the smallest nest limb we found was 29 cm in diameter.

Nesting habitat use by murrelets varies geographically because of regional differences in forest composition and structure, as well as murrelet behavior. For example, the majority of murrelet nests in British Columbia have been near natural and man-made forest edges (Burger 2002, Zharikov et al. 2006), whereas our nest sites were generally located in contiguous forests. Nevertheless, marbled murrelets appear to consistently select certain habitat features throughout much of their range, including locations low on the slope, close to streams, and a high basal area of very large trees (Hamer and Nelson 1995, Meyer et al. 2004, Zharikov et al. 2006).

Management Implications

Management for marbled murrelet nesting habitat in the Santa Cruz Mountains should protect unharvested and partially harvested stands of old-growth redwood forests, particularly those low on the slope and near streams. Our logistic regression model, which contained nest tree dbh and distance to stream, could be used by land managers to identify potential murrelet nesting for timber harvest and conservation planning. However, caution should be used when applying this model because 29% of nesting habitat would be incorrectly classified as nonhabitat and because of the small sample size of nests ($n = 17$) used to develop the model. Land managers could reduce the probability of a false negative (treating nesting habitat as nonhabitat) by conducting audiovisual surveys to determine occupancy status in areas not predicted to be nesting habitat.

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Literature Cited

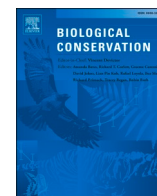
- Binford, L. C., B. G. Elliott, and S. W. Singer. 1975. Discovery of a nest and downy young of marbled murrelet. *Wilson Bulletin* 87:303–319.
- Burger, A. E. 2002. Conservation assessment of marbled murrelets in British Columbia: a review of the biology, populations, habitat associations, and conservation. Technical Report Series 387, Canadian Wildlife Service, Pacific and Yukon Region, British Columbia, Canada.
- Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.
- California Department of Water Resources. 1982. Rainfall depth–duration–frequency for California. California Resources Agency, Sacramento, USA.
- Carter, H. R., and R. A. Erickson. 1992. Status and conservation of the marbled murrelet in California. *Proceedings of the Western Foundation of Vertebrate Zoology* 5:92–116.
- Evans Mack, D., W. P. Ritchie, S. K. Nelson, E. Kuo-Harrison, P. Harrison, and T. E. Hamer. 2003. Methods for surveying marbled murrelets in forests: a revised protocol for land management and research. Pacific Seabird Group, Arcata, California, USA.
- Evarts, J., and M. Popper, editors. 2001. Coast redwood: a natural and cultural history. Cachuma, Los Olivos, California, USA.
- Fox, L. J. 1989. A classification, map, and volume estimate for the coast redwood forest in California. Forest and Rangeland Resources Assessment Program, California Department of Forestry and Fire Protection, Sacramento, USA.
- Garshelis, D. L. 2000. Delusions in habitat evaluation: measuring use, selection, and importance. Pages 111–164 in L. Boitani and T. K. Fuller, editors. *Research techniques in animal ecology: controversies and consequences*. Columbia University, New York, New York, USA.
- Grenier, J. J., and S. K. Nelson. 1995. Marbled murrelet habitat associations in Oregon. Pages 191–204 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, editors. *Ecology and conservation of the marbled murrelet*. U.S. Department of Agriculture Forest Service General Technical Report PSW-152, Albany, California, USA.
- Hamer, T. E. 1995. Inland habitat associations of marbled murrelets in western Washington. Pages 163–176 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, editors. *Ecology and conservation of the marbled murrelet*. U.S. Department of Agriculture Forest Service General Technical Report PSW-152, Albany, California, USA.
- Hamer, T. E., and S. K. Nelson. 1995. Characteristics of marbled murrelet nest trees and nesting stands. Pages 69–82 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, editors. *Ecology and conservation of the marbled murrelet*. U.S. Department of Agriculture Forest Service General Technical Report PSW-152, Albany, California, USA.
- Hosmer, D. W., and S. Lemeshow. 2000. *Applied logistic regression*. John Wiley and Sons, New York, New York, USA.
- Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65–71.
- Kenward, R. 1987. *Wildlife radio tagging: equipment, field techniques and data analysis*. Academic, London, United Kingdom.
- Larsen, C. J. 1991. Report to the Fish and Game Commission: a status review of the marbled murrelet (*Brachyramphus marmoratus*) in California. California Department of Fish and Game, Wildlife Management Division, Candidate Species Status Report 91–1, Sacramento, USA.
- Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system for mixed models. SAS Institute, Cary, North Carolina, USA.
- Meyer, C. B., and S. L. Miller. 2002. Use of fragmented landscapes by marbled murrelets for nesting in southern Oregon. *Conservation Biology* 16:755–766.
- Meyer, C. B., S. L. Miller, and C. J. Ralph. 2004. Stand-scale habitat associations across a large geographic region of an old-growth specialist, the marbled murrelet. *Wilson Bulletin* 116:197–210.
- Miller, S. L., and C. J. Ralph. 1995. Relationship of marbled murrelets with habitat characteristics at inland sites in California. Pages 205–218 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, editors. *Ecology and conservation of the marbled murrelet*. U.S. Department of Agriculture Forest Service General Technical Report PSW-152, Albany, California, USA.
- Nelson, S. K. 1997. Marbled murrelet (*Brachyramphus marmoratus*). Pages 1–25 in A. Poole and F. Gill, editors. *The birds of North America*, number 276. The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA, and the American Ornithologists' Union, Washington, D.C., USA.
- Newman, S. H., J. Y. Takekawa, D. L. Whitworth, and E. Burkett. 1999. Subcutaneous anchor attachment increases retention of radio-transmitters on Xantus' and marbled murrelets. *Journal of Field Ornithology* 70:520–534.
- Noss, R. F. 2000. *The redwood forest: history, ecology, and conservation of the coast redwoods*. Island, Washington, D.C., USA.
- Peery, M. Z., S. R. Beissinger, S. H. Newman, B. H. Becker, E. B. Burkett, and T. D. Williams. 2004a. Individual and temporal variation in inland flight behavior of marbled murrelets: implications for population monitoring. *Condor* 106:344–353.
- Peery, M. Z., S. R. Beissinger, S. H. Newman, E. B. Burkett, and T. D. Williams. 2004b. Applying the declining population paradigm: diagnosing causes of poor reproduction in the marbled murrelet. *Conservation Biology* 18:1088–1098.
- Sawyer, J. O., and T. Keeler-Wolf. 1995. *A manual of California vegetation*. California Native Plant Society, Sacramento, USA.
- Singer, S. W., N. L. Naslund, S. A. Singer, and C. J. Ralph. 1991. Discovery and observations of two tree nests of the marbled murrelet. *Condor* 93:330–339.
- Singer, S. W., D. L. Suddjian, and S. A. Singer. 1995. Fledging behavior, flight patterns and forest characteristics at marbled murrelet tree nests in California. *Northwestern Naturalist* 76:54–62.
- U.S. Fish and Wildlife Service. 1992. Determination of the threatened status for the Washington, Oregon, and California population of the marbled murrelet. U.S. Fish and Wildlife Service, Portland, Oregon, USA.
- Whitworth, D. L., J. Y. Takekawa, H. R. Carter, and W. R. McIver. 1997. A night-lighting technique for at-sea capture of Xantus' murrelets. *Colonial Waterbirds* 20:525–531.
- Zar, J. H. 1999. *Biostatistical analysis*. Prentice Hall, Upper Saddle River, New Jersey, USA.
- Zharikov, Y., D. B. Lank, F. Huettmann, R. W. Bradley, N. Parker, P. P.-W. Yen, L. A. McFarlane Tranquilla, and F. C. Cooke. 2006. Habitat selection and breeding success in a forest-nesting alcid, the marbled murrelet, in two landscapes with differing degrees of forest fragmentation. *Landscape Ecology* 21:107–120.
- Zinke, P. J. 1977. The redwood forest and associated north coast forests. Pages 679–698 in M. G. Barbour and J. Major, editors. *Terrestrial vegetation of California*. 1988, Reprint. California Native Plant Society, Sacramento, USA.

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Policy analysis

Reducing anthropogenic subsidies can curb density of overabundant predators in protected areas

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ABSTRACT

Protected areas safeguard biodiversity and provide opportunities for human recreation. However, abundant anthropogenic food subsidies associated with human activities in protected areas can lead to high densities of generalist predators, posing a threat to rare species at broad spatial scales. Reducing anthropogenic subsidies could curb populations of overabundant predators, yet the effectiveness of this strategy is unclear. We characterized changes in the foraging ecology, body condition, and demography of a generalist predator, the Steller's jay, three years after implementation of a multi-faceted management program to reduce anthropogenic subsidies in a protected area in California. Stable isotope analysis revealed that the proportional contribution of anthropogenic foods to jay diets declined from 88% to 47% in response to management. Overlap between jay home ranges decreased after management began, while home range size, body condition, and individual fecundity remained stable. Adult density in subsidized areas decreased markedly from 4.33 (SE: ± 0.91) to 0.65 (± 0.20) jays/ha after the initiation of management, whereas density in unsubsidized areas that were not expected to be affected by management remained stable (0.70 ± 0.22 pre-management, 0.58 ± 0.38 post-management). Thus, the response of jays to management was density-dependent such that reduced densities facilitated the maintenance of individual body condition and fecundity. Importantly, though, jay population size and collective reproductive output declined substantially. Our study provides evidence that limiting anthropogenic subsidies can successfully reduce generalist predator populations and be part of a strategy to increase compatibility of species protection and human recreation within protected areas.

1. Introduction

Protected areas are a foundation for global biodiversity conservation (Bruner et al., 2001; Naughton-Treves et al., 2005; Watson et al., 2014), yet they are also increasingly relied upon to provide recreation and ecotourism opportunities (Balmford et al., 2009; Watson et al., 2014). Human use of protected areas often results in abundant anthropogenic food subsidies for wildlife, which have ecological and evolutionary implications for biodiversity globally (Oro et al., 2013). Spatially and temporally predictable food subsidies can alter many aspects of species ecology (Oro et al., 2013) and threaten species of conservation concern (Kristan and Boarman, 2003). In some cases, access to subsidies improves fitness by boosting fecundity (Prange et al., 2003; Beckmann et al., 2008) or increasing survival (Prange et al., 2003). Indeed, areas with abundant subsidies are typically characterized by higher densities of subsidized species than unsubsidized areas (Beckmann and Berger,

2003; Prange et al., 2003; Shochat, 2004; Rodewald and Shustack, 2008). Elevated densities of subsidized species can modify interspecies interactions like competition and predation (Rodewald et al., 2011; Newsome et al., 2015b; Ciucci et al., 2020), which can lead to increased human-wildlife conflict (Hopkins et al., 2014) and spillover predation (Kristan and Boarman, 2003). Spillover predation occurs when plentiful food resources in one habitat allow predators to achieve high densities and spread into other habitats where they may prey upon rare species (Holt, 1984; West et al., 2019). Spillover predation can exacerbate declines and, in some cases, present an existential threat to rare species (Kristan and Boarman, 2003). Generalist predators, in particular, are adept at taking advantage of anthropogenic food subsidies (Marzluff et al., 2001; Newsome et al., 2010), and those capitalizing on anthropogenic food available in heavily-visited sections of protected areas have the potential to spill over into undeveloped areas that provide important habitat for species of conservation concern.

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Several management strategies have been recommended to reduce subsidized predator populations in protected areas, including lethal control of populations and selective removal of problematic individuals (Boorman, 2003; Peery and Henry, 2010). However, these strategies can be challenged by high cost, recolonization by new recruiting individuals, potential for community changes such as mesopredator release when predators are removed, and public opposition to lethal tactics (Goodrich and Buskirk, 1995). An alternative strategy that has been proposed as a potential long-term solution is reducing the availability of anthropogenic food subsidies on the landscape (Peery and Henry, 2010; Hopkins et al., 2014; Walker and Marzluff, 2015). This approach has been used successfully to reduce black bear consumption of anthropogenic foods in Yosemite National Park (Hopkins et al., 2014), but the effectiveness of this management strategy for broader application remains unclear. Furthermore, an understanding of how anthropogenic subsidy reduction affects species ecology, social systems, and density-dependent processes could elucidate the general effectiveness of this strategy.

The Steller's jay (*Cyanocitta stelleri*) is a generalist predator that readily takes advantage of anthropogenic food subsidies (Marzluff and Neatherlin, 2006) and is an important nest predator of the marbled murrelet, a federally threatened seabird (USFWS, 1997; Peery et al., 2004), as well as several songbirds in the Pacific Northwest (Vigallon and Marzluff, 2005). Indeed, one of the most serious threats to the murrelet is low reproductive success, which is largely attributed to high predation rates by corvids such as Steller's jays (Peery et al., 2004; Marzluff and Neatherlin, 2006; Peery and Henry, 2010). Population viability analyses have shown that reducing corvid predation may be the most effective way to recover the marbled murrelet (Peery and Henry, 2010).

Protected areas harbor the majority of remaining nesting habitat for the genetically distinct population of marbled murrelets in central California (Peery et al., 2004; Hall et al., 2009; Halbert and Singer, 2017), and frequent and abundant human visitors and subsequent food subsidies in these areas have been implicated in producing overabundant populations of Steller's jays (Walker and Marzluff, 2015; West et al., 2019). Steller's jay density is high in subsidized campground areas, and jay body condition and fecundity are improved by food subsidies provided by park visitors (West and Peery, 2017), which could result in spillover predation on marbled murrelets (West et al., 2019). In an effort to reduce the effects of jay predation on murrelet populations, California State Parks initiated an intensive visitor education and food management program to reduce food subsidies to Steller's jays. The "Keep it Crumb Clean" campaign (hereafter referred to as "management efforts") began in 2013, and it combines visitor education, improved food management strategies (such as the installation of wildlife-proof food lockers and trash cans and limiting food waste at dishwashing stations in campgrounds), and enforcement of food policies by rangers and other park staff. This initiative provides a unique opportunity to gauge the effectiveness of visitor education and food management as a general strategy to reduce anthropogenic food subsidies within natural areas and to understand the fitness and demographic consequences of reducing food subsidies to generalist predator species.

Here, we aimed to evaluate (1) the effectiveness of management efforts in reducing anthropogenic food subsidies to jays, and (2) the response of jays in subsidized areas to the reduction of previously abundant subsidies at multiple scales including individual behavior, body condition and fecundity, and emergent population effects. We predicted that management efforts would reduce the amount of anthropogenic food in the diets of jays in subsidized areas. We also used a before-after-control-impact design (Green, 1979) to examine population-level consequences of management efforts on jay density and fecundity using surveys in subsidized and unsubsidized areas. We posed two alternative hypotheses about how jay populations would respond to a reduction in food subsidies: fewer subsidies could result in 1) reduced body condition and fecundity of jays that maintained similar density or 2) reduced density of jays that maintained similar body condition and

fecundity. Under the first hypothesis, in addition to reduced body condition and fecundity, we also predicted that management efforts would result in larger home ranges, as jays would need to travel greater distances to find food when fewer subsidies were available (Marzluff and Neatherlin, 2006; Bautista et al., 2017). Under this hypothesis we also predicted stable or increasing overlap of jay home ranges because territoriality may break down if jays relied upon more dispersed, less defensible food resources after management efforts began (Wilson, 2001; Robb et al., 2008). Additionally under this hypothesis, we predicted that jay density in both subsidized and unsubsidized areas would remain stable. Alternatively, under the second hypothesis, in addition to stable body condition and fecundity, we expected home range size to remain stable and the amount of overlap between home ranges to decrease as food resources may be more easily defensible for remaining territorial jays (Robb et al., 2008). We also predicted that jay density in subsidized areas would decrease in response to management while density in unsubsidized areas would remain comparatively stable. Given the limited number of existing assessments and the broad potential applicability of these types of management efforts, this study will help guide conservation initiatives in protected areas that offer opportunities for outdoor recreation and also provide important habitat for species of conservation concern.

2. Materials and methods

2.1. Study area and time periods

We studied a population of Steller's jays in Big Basin Redwoods State Park (Santa Cruz County, California; hereafter Big Basin) to understand the effects of management efforts on their diet, behavior and fitness, and demography. Big Basin includes approximately 4300 acres of old-growth forest, with an overstory largely composed of Coast Redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*). Big Basin includes the largest tract of remaining old-growth forest nesting habitat for marbled murrelets in central California (Peery et al., 2004; Halbert and Singer, 2017) and also receives over 100,000 campers per year to its almost 200 campsites (California State Parks, 2017). We collected data related to jay diet and fitness during the breeding season in two distinct time periods: "pre-management" from 2010 to 2013, before management began (West and Peery, 2017), and "post-management" from 2017 to 2019, after management had been implemented for three years. We were primarily interested in changes in jay populations in areas where human food subsidies were abundant in the pre-management period (West and Peery, 2017), so we intensively studied jays in seven heavily-used campgrounds in Big Basin (hereafter referred to as "subsidized areas;" Fig. 1). However, we also collected density and fecundity data (see "density and fecundity" below) in unsubsidized forest areas with less human use that were at least 2 km from campgrounds (hereafter referred to as "unsubsidized areas").

2.2. Capture and sampling

We captured Steller's jays to collect data related to diet, home range, and body condition (see next sections), using a combination of mist nets (Avinet Research Supplies) and live traps (Havahart or homemade) during the breeding season (May – August) in both pre- and post-management periods. All jay capture and sampling took place within subsidized areas. We banded jays with a steel USGS band and a unique combination of colored plastic bands (Avinet Research Supplies) to enable individual recognition. We determined the sexes of jays in the field when possible by noting sex-specific vocalizations (Hope, 1980), and we confirmed all sexes later using extracted DNA from blood samples collected from the brachial vein (Griffiths et al., 1998). We distinguished adult jays from juveniles using a combination of vocal characteristics (e.g., use of begging calls; Hope, 1980) and differences in gape coloration and plumage pattern (Pyle, 1997). We weighed jays,

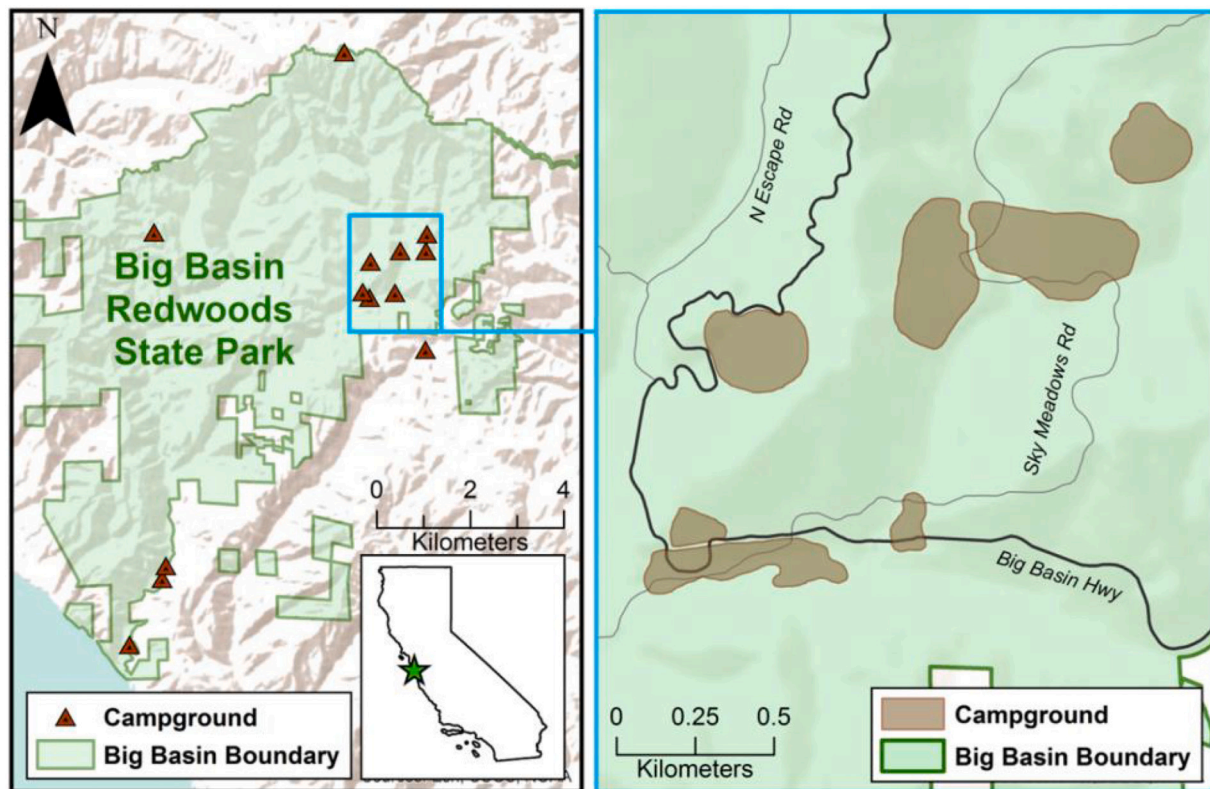


Fig. 1. Map of the study area. The right panel (blue box) shows the campgrounds in which jays were captured. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

measured tarsus length, and collected feather samples from some individuals (see anthropogenic food enrichment and body condition, below). To determine patterns of space use, we fit a subset of individuals with radio transmitters (pre-management: model A1050, post-management: model A1070, Advanced Telemetry Systems), which we attached using backpack-style harnesses made of 0.1" natural tubular spectra tape or 2.5 mm Teflon ribbon (Bally Ribbon Mills).

2.3. Anthropogenic food consumption

We quantified the consumption of anthropogenic food by Steller's jays living in subsidized areas using stable isotope analysis of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in feathers. To determine if anthropogenic food consumption had changed due to management efforts, we compared (1) the proportion of diet composed of anthropogenic food, and (2) the level of anthropogenic food enrichment between pre- and post-management periods. Because anthropogenically-sourced foods are often made up of corn (a C_4 plant) and corn-based byproducts, they are enriched in the heavy isotope of carbon, making them isotopically distinct from natural prey items in western North America where primary production is driven by native C_3 plants (Newsome et al., 2010; West et al., 2016). We also measured $\delta^{15}\text{N}$, which is influenced by a consumer's trophic level with carnivores being more enriched than herbivores in terrestrial landscapes (Kelly, 2000). Analyses of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotopic ratios have been used effectively to distinguish anthropogenic from natural diet items in this system (West et al., 2016), as well as in other systems (Newsome et al., 2010, 2015a; Hopkins et al., 2014). We clipped approximately 50 mm of a newly grown primary flight feather from each jay captured at the end of the breeding season (early – mid-August) during both time periods. These samples reflected breeding season diet because feathers incorporate the isotopic signature of the diet during periods of feather growth (Hobson and Clark, 1992), and jays begin to molt during the latter part of the fledgling provisioning period in late July (authors' personal

observations). We also sampled potential diet sources at Big Basin, including invertebrates, berries, acorns, conifer seeds, and anthropogenic foods, approximately every two weeks during the pre-management period (2011–2013). We rinsed feather samples three times in 2:1 Chloroform:Methanol solution to remove surface contaminants, homogenized them with scissors, and dried them at 55°C for ≥ 72 h. We then weighed and sealed approximately 0.5 mg of each feather sample into a tin capsule. Analysis of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ was conducted at the University of New Mexico Center for Stable Isotopes using a Thermo Scientific Delta V mass spectrometer connected to a Costech 4010 elemental analyzer and a high-temperature conversion elemental analyzer. Results are presented as per mil (‰) ratios relative to international standards, Vienna-Pee Dee Belemnite limestone (C) and atmospheric nitrogen (N). We removed one post-management individual from all isotope analyses because it was never seen in subsidized areas after initial capture, and its territory did not coincide with subsidized areas (based on telemetry data).

In order to understand how the overall diet of jays changed after management efforts began, we estimated the proportional contribution of distinct diet sources to adult jay diets using mixing models in the MixSIAR package (version 3.1.11, Stock et al., 2018) in the R statistical environment (R Core Team, 2020). We grouped diet sources into three distinct groups: anthropogenic (human-derived), mast (e.g., berries and acorns), and invertebrate (West et al., 2016). We did not include marbled murrelet eggs or chicks as a diet source because they likely made up a negligible proportion of the jay diet due to the small number of murrelets and large number of jays in our study area. Additionally, all diet sources included in a mixing model are estimated to have some contribution to the diet, which could lead to overestimation of the importance of murrelets in the diet and underestimation of the importance of more common diet sources (Phillips et al., 2014). To account for tissue-specific isotope discrimination, we adjusted the isotopic values of diet sources using trophic discrimination factors for a wild-caught

passerine with an omnivorous diet similar to Steller's jays: $+3.3\text{‰}$ (SD = 0.04) for $\delta^{15}\text{N}$ and $+3.5\text{‰}$ (SD = 0.1) for $\delta^{13}\text{C}$ (Pearson et al., 2003). We also corrected for differences in elemental concentrations of diet sources by including the average measured elemental concentrations (weight% C, weight% N) for each diet group in our mixing models (Table S1). We used management as a fixed effect in our model, which allowed us to estimate diet proportions for each time period separately and calculate the Bayesian 95% credible interval for the difference in proportion of anthropogenic foods in diets among time periods. We specified the generalist ("uninformative") prior and *process x residual* error structure (Stock and Semmens 2016) and ran three Markov chains (length = 1,000,000, burn-in = 500,000, thinning rate = 500), which yielded an effective sample size of 3000 for each time period (calculated with R package coda, Plummer et al., 2006). We examined trace plots, Gelman-Rubin diagnostic values, and the results of the Geweke test for each chain to determine model convergence.

To determine how the level of anthropogenic food enrichment differed due to management efforts, we compared pre- and post-management mean $\delta^{13}\text{C}$ enrichment of adult jays. We first compared $\delta^{13}\text{C}$ enrichment across pre-management years and then across post-management years individually using ANOVA to confirm that $\delta^{13}\text{C}$ enrichment was not different among the years within each period. We then compared $\delta^{13}\text{C}$ enrichment between pre- and post-management periods using a linear mixed model with a random effect for individual. Because sample sizes were equal in the two management periods, we used Satterthwaite's method in the R package lmerTest (Kuznetsova et al., 2017) to obtain a *p*-value for the effect of management. The variance of $\delta^{13}\text{C}$ enrichment was unequal between pre- and post-management periods (determined through visual inspection); however, sample sizes in pre- and post-management periods were equal, and *F*-tests are robust against violation of the homoscedasticity assumption when sample sizes are equal (Blanca et al., 2018). Additionally, the consequence of violating this assumption is loss of power (increased Type II error), and we were comfortable making a conservative estimate of the difference in anthropogenic food consumption between pre- and post-management years. Results are presented as mean $\pm$ standard error.

2.4. Home range size and overlap

We used telemetry data to evaluate changes in Steller's jay home range size and in the amount of overlap in home range among individuals living in subsidized areas between pre- and post-management periods. We collected telemetry data from mid-May to early August, a period that largely coincides with the breeding season of the Steller's jay in this area. Each year, we found and recorded the location of each radio-tagged individual between 25 and 35 times by hiking on foot and using a telemetry receiver and handheld GPS unit. To fully characterize jay home ranges, we varied the time of day we tracked each individual throughout the season and also collected roost locations (between 10 p.m. and 3 a.m.) for each bird 3–4 times per year.

To assess whether jay home range size increased after management efforts began, we calculated the core area and home range size for each jay, which we defined as the 50% and 95% utilization distributions, respectively, using the adehabitatHR package (Calenge, 2006) in the R Statistical Environment (R Core Team, 2020). We were primarily interested in the home range sizes of jays living in subsidized areas, so we used ArcMap 10.3 to identify jays for which $\geq 50\%$ of their core areas overlapped subsidized areas (West et al., 2016; West and Peery, 2017). Because we had a small sample size of females, we only utilized male home range data for this comparison. We log-transformed all home range sizes for normality, and we used a linear mixed model with management as fixed effects and individual as a random effect, and a likelihood ratio test to assess if there was a difference in log-transformed male home range size between pre- and post-management periods.

We also compared overlap between Steller's jay home ranges in pre- and post-management periods by calculating the Utilization Distribution

Overlap Index (UDOI), a measure of the degree of overlap, for each pair of jays captured in the same campground. A UDOI value of zero indicates no overlap, whereas a value of one indicates complete overlap; however, this statistic can also be greater than one if two utilization distributions are non-uniformly distributed and have a high degree of overlap (Fieberg and Kochanny, 2005). We compared mean UDOI values and the distribution of UDOI values between the first two years of the study, 2011–2012, and the last year of the study, 2019, as a bookend analysis to ensure sample sizes were similar between pre- and post-management periods, as sample size can greatly affect the reliability of comparing UDOI across studies (Fieberg and Kochanny, 2005). We compared UDOI between pre- and post-management periods using a Kruskal Wallis test because UDIs were non-normally distributed and variances were not equal in both periods. We also compared mean UDOI values and the distribution of UDOI values from 2017 and 2018 individually to those from 2019 to ensure that utilizing UDOI values from only 2019 did not skew the results from this analysis. Results are presented as mean UDOI $\pm$ standard error.

2.5. Body condition

We assessed the body condition of jays living in subsidized areas in pre- and post-management periods using feather growth bar width. Each feather growth bar consists of a dark band, produced during the day, and a light band, produced at night, that together indicate feather growth over a 24-hour period (Fig. S1). Feather growth is energetically costly; therefore, the width of growth bars is positively correlated with the nutritional status of a bird during feather growth, with wider growth bars indicating better body condition (Grubb, 2006). We collected a newly grown rectrix from each jay captured in a subsidized area at the end of the breeding season (early to mid-August). In the pre-management period, only 5 rectrices were collected from subsidized areas in Big Basin. However, more rectrices were collected from subsidized areas in Butano State Park, another park located approximately 16 km from Big Basin, where adult jays had similar growth bar width and were similarly enriched in $\delta^{13}\text{C}$ (Table S2; West and Peery, 2017). Therefore, we combined samples from Butano and Big Basin to obtain a larger sample size in the pre-management period. We then scanned or photographed each rectrix to obtain a high-quality image, and three independent observers measured ten individual growth bars from each feather using the program ImageJ (Schneider et al., 2012) to calculate an average growth bar width for each bird. We took the average of measurements from all observers for each feather, and we standardized growth bar width by dividing the growth bar width by tarsus length-cubed (an index of body volume) to correct for body size. Finally, we multiplied all values by 100,000 for ease in reporting the results. To understand how body condition had been affected by jay management, we compared average growth bar width of jays from subsidized areas in pre-management and post-management periods using linear mixed models and a likelihood ratio test. Because we had a priori knowledge that growth bar width may vary among years (West and Peery, 2017), we included random intercepts for year and individual, and we included management as a fixed effect. Results are presented as mean $\pm$ standard error.

2.6. Density and fecundity

To assess the effect of management efforts on the jay population, we used a BACI design to estimate the density of jays in subsidized and unsubsidized areas in the pre- and post-management periods using point count surveys and distance sampling. We conducted monthly 5-min point count surveys at seven points in subsidized areas and seven points in unsubsidized areas during the breeding season (mid-May – mid-August) in pre- and post-management periods. Survey points in subsidized areas were located near the centers of campgrounds, and survey points in unsubsidized areas were located at least 2 km from the

borders of subsidized areas and along roads to facilitate access. We conducted point count surveys between 7:00 and 10:00 a.m. when weather conditions were suitable (i.e., low wind and no rain). We noted whether each detected bird was an adult or a juvenile, as determined by vocalization or plumage characteristics (Hope, 1980; Pyle, 1997). To correct for imperfect detection in our estimates of jay density, we implemented distance-sampling techniques using the package Distance (version 1.0.0, Miller et al., 2019) in the R statistical environment (R Core Team, 2020). For full distance sampling methods in the pre-management period, see the supplemental methods and West and Peery (2017). In the post-management period, we estimated monthly adult jay density and August juvenile density in subsidized areas for each year in one model, and monthly adult jay density in unsubsidized areas each year in a second model because no juveniles were detected in forest areas in the post-management period. For each model, we evaluated seven potential detection functions using AIC, see supplemental methods for details. We assessed the fit of the top models by examining detection function plots and using a Cramér-von Mises goodness-of-fit test, in which a p -value < 0.05 indicates a poor model fit. After estimating adult densities, we used a two-way ANOVA, with the density estimate for each month and year combination as observations, to test for an interaction effect between management (pre- and post-management) and subsidies (subsidized and unsubsidized).

To evaluate whether management efforts affected jay reproduction, we calculated juvenile to adult ratios for subsidized areas in pre- and post-management periods. The juvenile to adult ratio can be used as a snapshot of productivity of a population because it integrates all the components of productivity, including clutch size, nest success rate, and proportion of breeders (Ricklefs and Bloom, 1977; Peery et al., 2007). We used the estimated density of adults in June (to minimize the effects of post-breeding adult movements) and the estimated density of juveniles in August (which is the peak fledging period) to calculate ratios for both pre- and post-management years (West and Peery, 2017), and we used equations from Peery et al. (2007) to estimate the variance and standard error of the juvenile to adult ratio. Results in all sections are presented as mean $\pm$ standard error, unless otherwise noted. We also estimated the collective number of juvenile jays produced annually in subsidized areas by multiplying estimated juvenile densities by the total combined area of all the subsidized areas in which we worked (42.2 ha; Fig. 1).

3. Results

3.1. Anthropogenic food consumption

We analyzed stable isotopes in feathers from 51 adult Steller's jays both before and after management ($n = 102$ total). Stable isotope analyses of feathers indicated that diets had changed since management efforts began: a larger proportion of the jay diet was made up of anthropogenic foods in the pre- than post-management period (95% credible interval for difference between pre- and post-management: 0.31 to 0.50). Specifically, the mean proportion of anthropogenic foods in the diet of jays in subsidized areas decreased from 0.88 (95% credible interval: 0.73 to 0.97) in the pre-management period to 0.47 (95% credible interval: 0.36 to 0.58) in the post-management period (Fig. 2A). We observed a similar trend in $\delta^{13}\text{C}$ enrichment: jays in the post-management period were 2.4‰ ($\pm 0.27\text{‰}$) less enriched than jays in the pre-management period ($F_{1,99} = 79.87$, $p < 0.001$; Fig. 2B). Additionally, there was no evidence of a difference in $\delta^{13}\text{C}$ enrichment within pre-management years ($F_{3,43} = 0.87$, $p = 0.47$) or within post-management years ($F_{2,45} = 0.28$, $p = 0.76$).

3.2. Home range size and overlap

We calculated home range sizes for 25 male jays in the pre-management period and 42 male jays in the post-management period. There was no difference in home range size between pre-management (6.15 ± 0.79 ha) and post-management (6.35 ± 0.60 ha) periods for jays ($\chi^2 = 0.18$, p -value = 0.67). Before management efforts began, male jays exhibited a high degree of home range overlap (0.65 ± 0.11 ; $n = 35$ pairs), and overlap decreased substantially after management efforts had been implemented (0.10 ± 0.02 ; $n = 46$ pairs; Kruskal Wallis p -value < 0.01 ; Fig. 3). Mean UDOI values in 2017 (0.06 ± 0.01) and 2018 (0.09 ± 0.01) were similar to those from 2019.

3.3. Body condition

We collected body condition data for 54 jays living in subsidized areas ($n = 19$ pre-management, $n = 35$ post-management). Average growth bar width was $4.72 (\pm 0.11)$ and $5.04 (\pm 0.16)$ for jays in pre- and post-management periods, respectively. Our likelihood ratio test indicated that body condition was not affected by management efforts ($\chi^2 = 1.13$, p -value = 0.29).

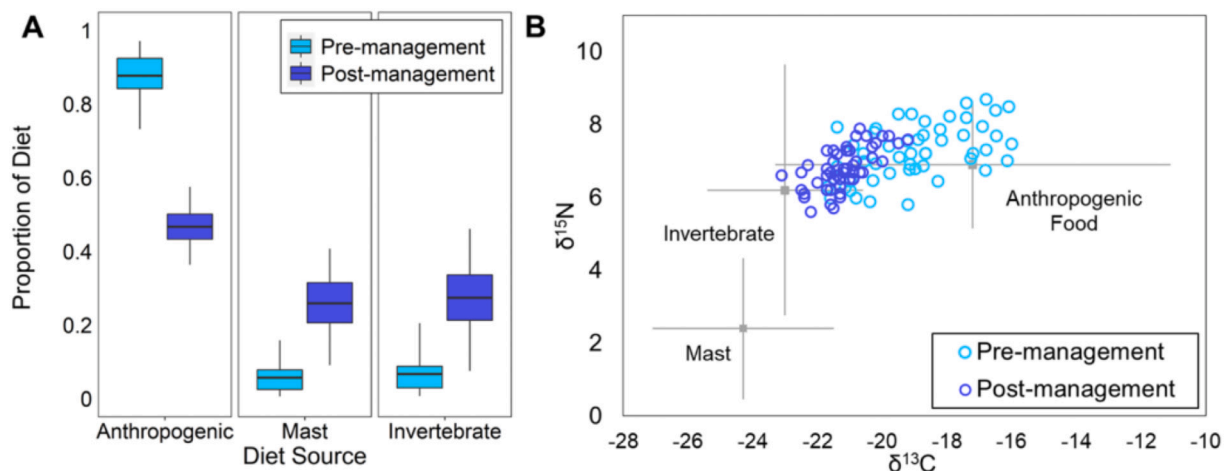


Fig. 2. Jay diet results from stable isotope analysis. (A) Proportional contributions of three diet sources to adult jay diets in pre- and post-management periods. Boxes represent the first and third quartiles, thick lines represent the means, and whiskers represent 95% credible intervals. (B) $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope ratios of individual Steller's jay feather samples in pre- and post-management periods. Results are plotted with each potential diet source for reference.

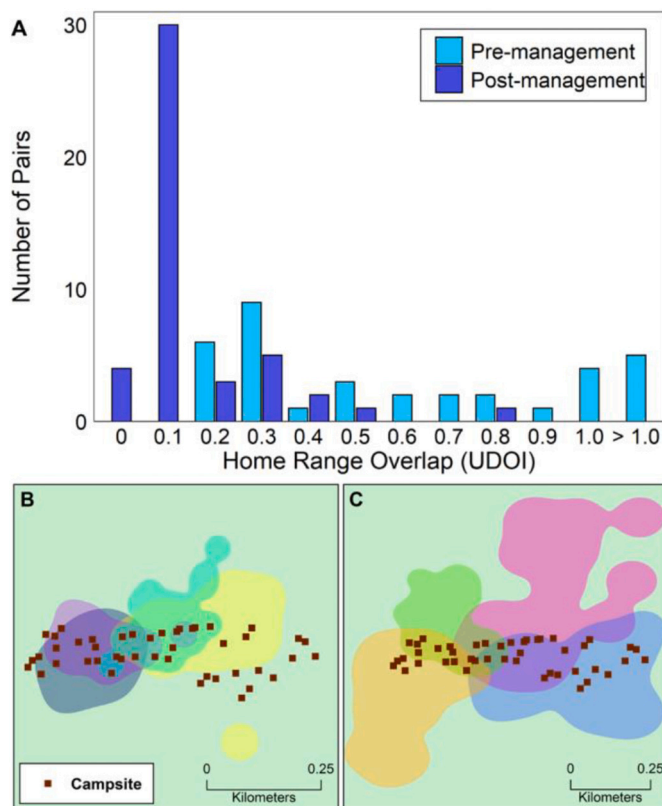


Fig. 3. (A) Results from the Utilization Distribution Overlap Index (UDOI) showing the distribution of home range overlaps between pairs of adult male Steller's jays captured in the same campground in pre- and post-management periods. (B - C) Examples of home ranges for four male Steller's jays in the (B) pre-management and (C) post-management periods. Each differently colored polygon represents the home range (95% utilization distribution) of one jay.

3.4. Density and fecundity

In subsidized areas, the best detection function was the half-normal key function with age as a covariate, and this model fit the data reasonably well (Cramér-von Mises p -value = 0.50). The June density of adult jays in subsidized areas was substantially lower in the post-management period (0.65 ± 0.20 jays/ha) than in the pre-management period (4.33 ± 0.91 jays/ha). In unsubsidized areas, the model with the half-normal key function and with month and year as covariates had the lowest AIC and fit the data reasonably well (Cramér-

von Mises p -value = 0.37). The June density of adult jays in unsubsidized areas was stable between pre-management (0.70 ± 0.22 jays/ha) and post-management (0.58 ± 0.38 jays/ha) periods. Our two-way ANOVA also indicated a significant interaction between management and subsidies ($F_{1,42} = 176.66$, p -value < 0.001, Table S3), which suggests that jay density in subsidized areas declined after management efforts began, while density in unsubsidized areas was relatively stable over the same time period (Fig. 4A).

The August density of juvenile jays in subsidized areas was lower in the post-management period (0.70 ± 0.40 jays/ha) than in the pre-management period (3.3 ± 0.80 jays/ha; Fig. 4A). Juvenile to adult ratios in subsidized areas were slightly higher in the post-management period (1.08 ± 0.33 juveniles/adult) than in the pre-management period (0.76 ± 0.14 juveniles/adult), but the standard errors overlap, indicating that adult jays remaining in subsidized areas after management efforts were implemented had similar fecundity (Fig. 4B). Multiplying estimated juvenile jay densities by the area of subsidized areas indicated that approximately 139 juvenile jays were produced annually in the pre-management period, while only 30 were produced annually in the post-management period.

4. Discussion

Our results indicate that management efforts focused on changing the behavior of visitors to protected areas have reduced anthropogenic food subsidies to Steller's jays, resulting in changes in patterns of space use and density in subsidized areas. Indeed, we observed a substantial reduction in the consumption of anthropogenic foods by jays following the implementation of the visitor education program that led to changes that supported our second hypothesis, specifically that jay density would decrease while body condition and fecundity would remain reasonably stable in subsidized areas. The response of jay populations to management may have been at least partially mediated by the territorial behavior of the jays themselves. The size of jay home ranges did not change between pre- and post-management periods, but the amount of overlap between home ranges decreased, which may suggest that remaining food resources were more easily defensible (Robb et al., 2008) and territorial jays were better able to exclude others from their territories. Despite reduced anthropogenic food consumption, body condition of jays remained similar between pre- and post-management periods, which supports the idea that there was less competition for remaining food resources in the post-management period. It is also possible that anthropogenic foods are of lower nutritional quality than diet sources like mast and arthropods (e.g., Demeyrier et al., 2017; Plaza and Lambertucci, 2017; Townsend et al., 2019), and thus jays in the post-management period maintained high body condition because they ate fewer anthropogenic foods and more mast and arthropods. We note, though, that anthropogenic foods still constituted a significant

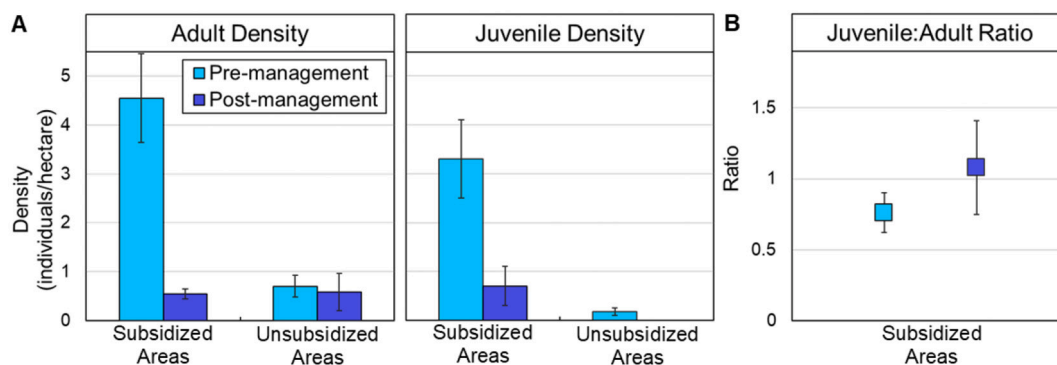


Fig. 4. (A) Jay density estimates from point count surveys in pre- and post-management periods for adults in June and juveniles in August in subsidized and unsubsidized areas. Error bars represent standard errors. No juvenile jays were detected in unsubsidized areas in the post-management period. (B) Estimated juvenile to adult ratios for subsidized areas in pre- and post-management periods.

proportion of jay diets even after management efforts began, indicating that jays remaining in subsidized areas continue to have access to anthropogenic foods despite intensive efforts to eliminate subsidies. Nevertheless, our results provide evidence that management efforts aimed at changing human behavior, when used in tandem with food management and policy enforcement, can constitute a useful conservation tool for reducing the density of subsidized species.

An important limitation of this study is that we could not directly measure the impact of reduced jay densities on murrelet nest success because murrelet nests are difficult and expensive to find and monitor (Peery et al., 2004; Bigger et al., 2006); however, the reduced density of adult and juvenile jays we observed in subsidized areas may lessen the risk of marbled murrelet nest predation by jays. Prior to management efforts, food subsidies at Big Basin were implicated in producing a source population of Steller's jays, where high fecundity resulted in many juvenile jays settling in both subsidized areas and other old-growth areas (West et al., 2019). Importantly, known nest locations of marbled murrelets at Big Basin often coincide with these subsidized areas (Baker et al., 2006), and Steller's jay predation on nests appears to be incidental rather than the result of a specialized search strategy (Vigallon and Marzluff, 2005). Therefore, reducing jay densities in subsidized areas likely lessens the probability of jays coming into contact with and preying on murrelet nests. Further, despite the fact that individual adult fecundity was stable pre- and post-management, there were still significantly fewer juvenile jays being produced overall due to reduced adult densities. Thus, whether subsidized areas in Big Basin still constitute a source population is unclear, but greatly reduced adult and juvenile Steller's jay densities in these areas likely constitute a conservation success for nesting murrelets.

Although we observed reduced densities of Steller's jays in subsidized areas, the long lifespan (Klimkiewicz and Fletcher, 1989) and high survival of Steller's jays (West et al., 2019) begs the question: where did all the jays go? Maintenance of fairly high body condition of jays in subsidized areas and the fact that jays are generalist omnivores capable of exploiting a wide variety of foods (Walker et al., 2020) make it unlikely that any jays died of starvation due to reduced availability of anthropogenic subsidies. Stable densities in unsubsidized areas seem to demonstrate that jays did not simply move away from subsidized areas and into other old-growth areas of the park. The remaining possibilities are that jays moved into other, unsurveyed habitats within Big Basin, such as young forest and chaparral, or that jays left Big Basin altogether. Indeed, West et al. (2019) found that a large proportion of radio-tagged juveniles and even a small proportion of adults dispersed out of Big Basin and into residential areas, where there are presumably food subsidies available year-round in the form of bird feeders and human refuse. While more work would be necessary to distinguish between these possibilities, we believe the most likely scenario is some combination of all three processes. Thus, the potential for jays to return to campground areas if subsidies become abundant again underscores the importance of continuing visitor education and enforcement initiatives and maintaining infrastructure, such as wildlife-proof food lockers, to ensure that anthropogenic food subsidy availability remains low for jays and other wildlife.

There are two caveats to our study; first, we did not directly measure the availability of anthropogenic food to jays and thus we assume that reduced consumption of anthropogenic foods reflects an actual reduction in availability of this resource to jays. Observations of management efforts and visitor behavior at Big Basin support this assumption, and it seems unlikely that jay food preferences would change when they were able to attain high body condition and fecundity by eating anthropogenic foods (West and Peery, 2017; West et al., 2019). The second caveat is that we did not measure body condition, home ranges, or diets of jays in unsubsidized areas because capturing jays in areas outside of campgrounds is logistically and financially challenging and may still result in small sample sizes (West et al., 2016). This raises the crucial question of whether the changes we observed in jay space use and diet in subsidized

areas were due to management efforts or another factor that we did not measure. To our knowledge, no significant changes occurred related to levels of human use or habitat conditions in either subsidized or unsubsidized areas during the study period. However, our study area experienced an unusually severe drought during the jay breeding seasons from 2012 to 2015 (Griffin and Anchukaitis, 2014; Tortajada et al., 2017), which could have resulted in some of the patterns we observed. We believe this scenario is unlikely for several reasons. First, drought conditions would be more likely to negatively affect jays in unsubsidized areas, as those utilizing subsidized areas may be buffered from drought effects by the predictable availability of anthropogenic food (Shochat et al., 2006). This is the opposite of the pattern we observed – jay density in subsidized areas decreased over time, while density in unsubsidized forest areas was stable. Second, drought conditions may have caused jays in subsidized areas to rely more on anthropogenic food resources, resulting in the high $\delta^{13}\text{C}$ enrichment we observed in the pre-management period. However, we collected isotope data from two drought years and two average years in the pre-management period and did not detect a difference in enrichment among any of the four years, indicating drought likely did not affect the diets of Steller's jays in this study. Finally, a study conducted in the Sierra Nevada, California (~300 km from our study site) concurrently with our study found that Steller's jay abundance was not affected by high ambient temperature and responded positively to water deficit (Roberts et al., 2019). For these reasons it seems unlikely that the drought was responsible for the patterns we observed, and, thus, management efforts are the most likely explanation for the changes we documented.

Collectively, our study provides evidence that visitor education can be part of a broader solution to support protected areas' dual mandate to provide the public with recreational opportunities while also protecting biodiversity. Our findings have broad applicability outside our study system: utilization of anthropogenic food subsidies by predators is a global phenomenon that has consequences for the behavior, fitness, and abundance of predators, as well as for the conservation of at-risk species and human-wildlife conflict (Newsome et al., 2015b). Generally, human behaviors that stem from lack of information or lack of outdoor skills, such as intentionally or unintentionally feeding wildlife, are the most amenable to change in response to education programs (Manning, 2003); however, education alone has proven to be an ineffective management tool in other situations (George and Crooks, 2006; Gore et al., 2008; Baruch-Mordo et al., 2011; Dietsch et al., 2018). Indeed, even changing intentions often may not engender genuine behavior change (Webb and Sheeran, 2006). Instead, combining education and enforcement, as well as making compliance with policies easier (e.g., by providing wildlife-proof food lockers) has been shown to be more effective at changing problematic human behaviors (Duncan and Martin, 2002; Manning, 2003; Baruch-Mordo et al., 2011). Human visitation to protected areas is increasing globally (Balmford et al., 2009), and we are just beginning to comprehend the suite of potential impacts this may have on wildlife (Miller et al., 1998; Liu et al., 2001; Reed and Merenlender, 2008; Larson et al., 2016; Bötsch et al., 2018). However, human recreation in natural areas is also important – these spaces provide benefits to human health and well-being (Frumkin, 2001; MacKerron and Mourato, 2013) and essential opportunities for people to feel connected to nature and personally invested in its conservation (Pyle, 2003; Kareiva, 2008; Balmford et al., 2009). Therefore, effective management of protected areas depends on multi-faceted strategies to make species protection and human recreation more compatible.

Ethical considerations

All appropriate guidelines for humane and ethical use of animals in research were followed, and research was conducted under IACUC protocol A005411-R01-A01 and scientific collection permit SC-13714.

CRediT authorship contribution statement

All authors contributed to the conceptualization of the study, E.H. West and K. Brunk collected the field data, E.H. West and K. Brunk conducted analyses, K. Brunk wrote the original draft, and all authors contributed substantially to reviewing and editing the manuscript.

Declaration of competing interest

The funders of this study played no role in the study design, analyses, interpretation of results, or writing of this manuscript. The authors certify there are no known conflicts of interest associated with this publication.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.biocon.2021.109081>.

References

- Baker, L.M., Peery, M.Z., Burkett, E.E., Singer, S.W., Suddjian, D.L., Beissinger, S.R., 2006. Nesting habitat characteristics of the Marbled Murrelet in central California redwood forests. *J. Wildl. Manag.* 70, 939–946.
- Balmford, A., Beresford, J., Green, J., Naidoo, R., Walpole, M., Manica, A., 2009. A global perspective on trends in nature-based tourism. *PLoS Biol.* 7, 1–6.
- Baruch-Mordo, S., Breck, S.W., Wilson, K.R., Broderick, J., 2011. The carrot or the stick? Evaluation of education and enforcement as management tools for human-wildlife conflicts. *PLoS One* 6, 1–8.
- Bautista, L.M., Bravo, C., Ponce, C., Unzué-Belmonte, D., Alonso, J.C., 2017. Food availability but not sex determines morning foraging area size in the Great Bustard *Otis tarda*, the most sexually size-dimorphic bird species. *Ardeola* 64, 289–303.
- Beckmann, J.P., Berger, J., 2003. Using black bears to test ideal-free distribution models experimentally. *J. Mammal.* 84, 594–606.
- Beckmann, J.P., Lackey, C.W., Lackey, C.W., 2008. Carnivores, urban landscapes, and longitudinal studies: a case history of black bears. *Human-Wildlife Conflicts* 2, 168–174.
- Bigger, D., Peery, M.Z., Courtney, S.P., Chinnici, S., Courtney, S.P., 2006. Efficacy of audiovisual and radar surveys for studying Marbled Murrelets in inland habitats. *J. Wildl. Manag.* 70, 505–516.
- Blanca, M.J., Alarcón, R., Arnau, J., Bono, R., Bendayan, R., 2018. Effect of variance ratio on ANOVA robustness: might 1.5 be the limit? *Behav. Res. Methods* 50, 937–962.
- Boarman, W.I., 2003. Managing a subsidized predator population: reducing common raven predation on desert tortoises. *Environ. Manag.* 32, 205–217.
- Bötsch, Y., Tablado, Z., Scherl, D., Kéry, M., Graf, R.F., Jenni, L., 2018. Effect of recreational trails on forest birds: human presence matters. *Front. Ecol. Evol.* 6, 1–10.
- Bruner, A.G., Gullison, R.E., Rice, R.E., Da Fonseca, G.A.B., 2001. Effectiveness of parks in protecting tropical biodiversity. *Science* 291, 125–128.
- Calenge, C., 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. *Ecol. Model.* 197, 516–519.
- California State Parks, 2017. Statistical Report.
- Ciucci, P., Mancinelli, S., Boitani, L., Gallo, O., Grottolli, L., 2020. Anthropogenic food subsidies hinder the ecological role of wolves: insights for conservation of apex predators in human-modified landscapes. *Global Ecology and Conservation* 21, e00841.
- Demeyrier, V., Charmantier, A., Lambrecht, M.M., Grégoire, A., 2017. Disentangling drivers of reproductive performance in urban great tits: a food supplementation experiment. *J. Exp. Biol.* 220, 4195–4203.
- Dietsch, A.M., Slagle, K.M., Baruch-Mordo, S., Breck, S.W., Ciarniello, L.M., 2018. Education is not a panacea for reducing human–black bear conflicts. *Ecol. Model.* 367, 10–12.
- Duncan, G.S., Martin, S.R., 2002. Comparing the effectiveness of interpretive and sanction messages for influencing wilderness visitors' intended behavior. *International Journal of Wilderness* 8, 20–25.
- Fieberg, J., Kochanny, C.O., 2005. Quantifying home-range overlap: the importance of the utilization distribution. *J. Wildl. Manag.* 69, 1346–1359.
- Frumkin, H., 2001. Beyond toxicity: human health and the natural environment. *Am. J. Prev. Med.* 20, 234–240.
- George, S.L., Crooks, K.R., 2006. Testing the efficacy of informational brochures. *Southwest. Nat.* 51, 240–250.
- Goodrich, J.M., Buskirk, S.W., 1995. Control of abundant native vertebrates for conservation of endangered species. *Conserv. Biol.* 9, 1357–1364.
- Gore, M.L., Knuth, B.A., Scherer, C.W., Curtis, P.D., 2008. Evaluating a conservation investment designed to reduce human-wildlife conflict. *Conserv. Lett.* 1, 136–145.
- Green, R.H., 1979. *Sampling Design and Statistical Methods for Environmental Biologists*. Wiley, New York.
- Griffin, D., Anchukaitis, K.J., 2014. How unusual is the 2012–2014 California drought? *Geophys. Res. Lett.* 41, 9017–9023.
- Griffiths, R., Double, M.C., Orr, K., Dawson, R.J.G., 1998. A DNA test to sex most birds. *Mol. Ecol.* 7, 1071–1075.
- Grubb, T., 2006. *Plutichronology: Feather Time and the Biology of Birds* (OUP Oxford).
- Halbert, P., Singer, S.W., 2017. Marbled Murrelet landscape management plan for zone 6.
- Hall, L. A., P. J. Palsbøll, S. R. Beissinger, J. T. Harvey, M. BÉrubé, M. G. Raphael, S. K. Nelson, R. T. Golightly, L. McFarlane-Tranquilla, S. H. Newman, and M. Z. Peery (2009). Characterizing dispersal patterns in a threatened seabird with limited genetic structure. *Mol. Ecol.* 18:5074–5085.
- Hobson, K.A., Clark, R.G., 1992. Assessing avian diets using stable isotopes I: turnover of 13C in tissues. *Condor* 94, 181–188.
- Holt, R.D., 1984. Spatial heterogeneity, indirect interactions, and the coexistence of prey species. *The American Naturalist* 124, 377–406.
- Hope, S., 1980. Call form in relation to function in the Steller's jay. *Am. Nat.* 116, 788–820.
- Hopkins, J.B., Koch, P.L., Ferguson, J.M., Kalinowski, S.T., 2014. The changing anthropogenic diets of American black bears over the past century in Yosemite National Park. *Front. Ecol. Environ.* 12, 107–114.
- Kareiva, P., 2008. Ominous trends in nature recreation. *Proc. Natl. Acad. Sci. U. S. A.* 105, 2757–2758.
- Kelly, J.F., 2000. Stable isotopes of carbon and in the study of avian and mammalian trophic ecology. *Can. J. Zool.* 78, 1–27.
- Klimkiewicz, M.K., Fitcher, A.G., 1989. Longevity records of north American birds supplement 1. *Journal of Field Ornithology* 60, 469–494.
- Kristan, W.B.I., Boarman, W.I., 2003. Spatial pattern of risk of common raven predation on desert tortoises. *Ecology* 84, 2432–2443.
- Kuznetsova, A., P. B. Brockhoff, and R. H. B. Christensen (2017). lmerTest Package: Tests in linear mixed effects models. *Journal of Statistical Software* 82.
- Larson, C.L., Reed, S.E., Merenlender, A.M., Crooks, K.R., 2016. Effects of recreation on animals revealed as widespread through a global systematic review. *PLoS One* 11, 1–21.
- Liu, J., Linderman, M., Ouyang, Z., An, L., Yang, J., Zhang, H., 2001. Ecological degradation in protected areas: the case of Wolong nature reserve for giant pandas. *Science* 292, 98–101.
- MacKerron, G., Mourato, S., 2013. Happiness is greater in natural environments. *Glob. Environ. Chang.* 23, 992–1000.
- Manning, R., 2003. Emerging principles for using information/education in wilderness management. *International Journal of Wilderness* 9, 20–27.
- Marzluff, J.M., Neatherlin, E., 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biol. Conserv.* 130, 301–314.
- Marzluff, J.M., Bowman, R., Donnelly, R., 2001. *Avian Ecology and Conservation in an Urbanizing World*. Kluwer Academic Publishers, Boston, MA.
- Miller, S.G., Knight, R.L., Miller, C.K., 1998. Influence of recreational trails on breeding bird communities. *Ecol. Appl.* 8, 162–169.
- Miller, D.L., Rexstad, E., Thomas, L., Marshall, L., Laake, J.L., 2019. Distance sampling in R. *J. Stat. Softw.* 89, 1–28.
- Naughton-Treves, L., Holland, M.B., Brandon, K., 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annu. Rev. Environ. Resour.* 30, 219–252.
- Newsome, S.D., Ralls, K., Job, C.V.H., Fogel, M.L., Cypher, B.L., 2010. Stable isotopes evaluate exploitation of anthropogenic foods by the endangered San Joaquin kit fox (*Vulpes macrotis mutica*). *J. Mammal.* 91, 1313–1321.
- Newsome, S.D., Garbe, H.M., Wilson, E.C., Gehrt, S.D., 2015a. Individual variation in anthropogenic resource use in an urban carnivore. *Oecologia* 178, 115–128.
- Newsome, T.M., Dellinger, J.A., Pavey, C.R., Ripple, W.J., Shores, C.R., Wirsing, A.J., Dickman, C.R., 2015b. The ecological effects of providing resource subsidies to predators. *Glob. Ecol. Biogeogr.* 24, 1–11.
- Oro, D., Genovart, M., Tavecchia, G., Fowler, M.S., Martínez-Abraín, A., 2013. Ecological and evolutionary implications of food subsidies from humans. *Ecol. Lett.* 16, 1501–1514.
- Pearson, S.F., Levey, D.J., Greenberg, C.H., Martínez del Río, C., 2003. Effects of elemental composition on the incorporation of dietary nitrogen and carbon isotopic signatures in an omnivorous songbird. *Oecologia* 135, 516–523.
- Peery, M.Z., Henry, R.W., 2010. Recovering marbled murrelets via corvid management: a population viability analysis approach. *Biol. Conserv.* 143, 2414–2424.

- Peery, M.Z., Beissinger, S.R., Newman, S.H., Burkett, E.B., Williams, T.D., 2004. Applying the population decline paradigm: diagnosing causes of poor reproduction in the marbled murrelet. *Conserv. Biol.* 18, 1088–1098.
- Peery, M.Z., Becker, B.H., Beissinger, S.R., Burger, A.E., 2007. Age ratios as estimators of productivity: testing assumptions on a threatened seabird, the marbled murrelet (*Brachyramphus marmoratus*). *Auk* 124, 224–240.
- Phillips, D.L., Inger, R., Bearhop, S., Jackson, A.L., Moore, J.W., Parnell, A.C., Semmens, B.X., Ward, E.J., 2014. Best practices for use of stable isotope mixing models in food-web studies. *Can. J. Zool.* 92, 823–835.
- Plaza, P.I., Lambertucci, S.A., 2017. How Are Garbage Dumps Impacting Vertebrate Demography, Heath, and Conservation? *Conservation, Global Ecology and*.
- Plummer, M., Best, N., Cowles, K., Vines, K., 2006. CODA: convergence diagnosis and output analysis for MCMC. *R News* 6, 7–11.
- Prange, S., Gehrt, S.D., Wiggers, E.P., 2003. Demographic factors contributing to high raccoon densities in urban landscapes. *J. Wildl. Manag.* 67, 324–333.
- Pyle, P., 1997. Identification Guide to North American Birds, Part I: Columbidae to Ploceidae. Slate Creek Press, Point Reyes Station, CA.
- Pyle, R.M., 2003. Nature matrix: reconnecting people and nature. *Oryx* 37, 206–214.
- R Core Team, 2020. R: A Language and Environment for Statistical Computing.
- Reed, S.E., Merenlender, A.M., 2008. Quiet, nonconsumptive recreation reduces protected area effectiveness. *Conserv. Lett.* 1, 146–154.
- Ricklefs, R.E., Bloom, G., 1977. Components of avian breeding productivity. *Auk* 94, 86–96.
- Robb, G.N., McDonald, R.A., Chamberlain, D.E., Bearhop, S., 2008. Food for thought: supplementary feeding as a driver of ecological change in avian populations. *Front. Ecol. Environ.* 6, 476–484.
- Roberts, L.J., Burnett, R., Tietz, J., Veloz, S., 2019. Recent drought and tree mortality effects on the avian community in southern Sierra Nevada: a glimpse of the future? *Ecol. Appl.* 29.
- Rodewald, A.D., Shustack, D.P., 2008. Consumer resource matching in urbanizing landscapes: are synanthropic species over-matching? *Ecology* 89, 515–521.
- Rodewald, A.D., Kearns, L.J., Shustack, D.P., 2011. Anthropogenic resource subsidies decouple predator-prey relationships. *Ecol. Appl.* 21, 936–943.
- Schneider, C.A., Rasband, W.S., Eliceiri, K.W., 2012. NIH Image to ImageJ: 25 years of image analysis. *Nat. Methods* 9, 671–675.
- Shochat, E., 2004. Credit or debit? Resource input changes population dynamics of city-slicker birds. *Oikos* 106, 622–626.
- Shochat, E., Warren, P.S., Faeth, S.H., McIntyre, N.E., Hope, D., 2006. From patterns to emerging processes in mechanistic urban ecology. *Trends in Ecology and Evolution* 21, 186–191.
- Stock, B.B., Semmens, B.X., 2016. Unifying error structures in commonly used biotracer mixing models. *Ecology* 97 (10), 2562–2569.
- Stock, B.C., Jackson, A.L., Ward, E.J., Parnell, A.C., Phillips, D.L., Semmens, B.X., 2018. Analyzing mixing systems using a new generation of Bayesian tracer mixing models. *PeerJ* 2018, 1–27.
- Tortajada, C., Kastner, M.J., Buurman, J., Biswas, A.K., 2017. The California drought: coping responses and resilience building. *Environ Sci Policy* 78, 97–113.
- Townsend, A.K., Staab, H.A., Barker, C.M., 2019. Urbanization and elevated cholesterol in American crows. *The Condor: Ornithological Applications* 121, 1–10.
- USFWS, 1997. Recovery Plan for the Marbled Murrelet in Washington, Oregon, and California.
- Vigallon, S.M., Marzluff, J.M., 2005. Is nest predation by Steller's jays (*Cyanocitta stelleri*) incidental or the result of a specialized search strategy? *Auk* 122, 36–49.
- Walker, L.E., Marzluff, J.M., 2015. Recreation changes the use of a wild landscape by corvids. *Condor* 117, 262–283.
- Walker, L., Pyle, P., Patten, M., Greene, E., Davison, W., Muehter, V., 2020. Steller's jay (*Cyanocitta stelleri*), version 1.0. In: *In Birds of the World* (P. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.
- Watson, J.E.M., Dudley, N., Segan, D.B., Hockings, M., 2014. The performance and potential of protected areas. *Nature* 515, 67–73.
- Webb, T.L., Sheeran, P., 2006. Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychol. Bull.* 132, 249–268.
- West, E.H., Peery, M.Z., 2017. Behavioral mechanisms leading to improved fitness in a subsidized predator. *Oecologia* 184, 787–798.
- West, E.H., Henry, W.R., Goldenberg, W., Peery, M.Z., 2016. Influence of food subsidies on the foraging ecology of a synanthropic species in protected areas. *Ecosphere* 7.
- West, E.H., Brunk, K., Peery, M.Z., 2019. When protected areas produce source populations of overabundant species. *Biological Conservation* 238.
- Wilson, W.H.J., 2001. The effects of supplemental feeding on wintering black-capped chickadees (*Poecile atricapilla*) in central Maine: population and individual responses. *Wilson Bulletin* 113, 65–72.

Marbled Murrelet Landscape Management Plan for Zone 6

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PREFACE

It has been recognized by those working to protect the marbled murrelet in the Santa Cruz Mountains that a management plan specific to this region is essential for the long term protection of this species. California State Parks has spearheaded the coordination of a plan with other state and federal agencies, non-profits, and interested parties.

This plan is written with the goal of assisting in the conservation and enhancement of the marbled murrelet population in Zone 6 for, as the Recovery Plan states, “Zone 6 is expected to contribute to recovery and is essential to the species in the short term (50–100 years).”

This management plan will be expanded in the near future to include information that was solicited by the editor but not received in time to include. Chapters still under preparation and scheduled to be included in the next edition are:

- *Forest Management of Second-growth Stands*
- *Implications of Climate Change for Murrelets in Zone 6*
- *Habitat Suitability Assessment in Zone 6*

At that time, additions and simple enhancements to the existing chapters will also be made to make the plan more up to date.

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TABLE OF CONTENTS

Preface.....	i
Acknowledgements	iii
Table of Contents.....	v
Chapter 1 Introduction	1
Conservation Status	1
Available Nesting Habitat.....	1
Population Ecology and Demographics.....	2
Life History and Distribution	2
Conservation Efforts	3
Key Uncertainties	3
Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6	4
Preface.....	4
Relationship of the Santa Cruz Marbled Murrelet Landscape Management Plan to Previous Work of a Similar Nature	4
Potential Breeding Range of the Marbled Murrelet	6
Nesting Habitat Defined.....	7
Platform Scale:	7
Tree scale:	8
Stand scale:	8
Methods for Monitoring Inland Habitat Use by Murrelets	10
A-V Surveys	10
Radar Surveys	10
Radio Telemetry Tracking	11
ARU Monitoring	12
Locations with Confirmed Nesting and Fate of Nests	13
Nesting Chronology in Zone 6	15
Results from Long-term Monitoring at Inland Sites	16
A-V Surveys	16
Radar Surveys	21
Distribution of Suitable Nesting Stands by Watershed	25

Table of Contents

Grouping Stands into Landscape Units for Conservation Management	27
Selecting and Evaluating Important Murrelet Areas	27
Threats to Murrelets and Their Nesting Habitat	30
Data Gaps and Information Needs	30
High Priority Information Needs:	30
Other Information Needs:.....	31
Management Plan Recommendations	32
Recommendations To Protect or Expand Nesting Habitat	32
Recommendations to Monitor Inland Distribution and Use by Breeding Murrelets.....	32
Recommendations to Better Understand the Quality of Murrelet Nesting Habitat	33
Recommendations to Better Share and Archive Zone 6 Murrelet Research and Monitoring Data...	33
Acknowledgments	33
Tables.....	34
Chapter 3 Corvid Predation of Murrelet Nests in Zone 6	68
Introduction	68
Background Information	68
Management of Crows and Ravens to Reduce the Risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains	71
Summary	71
The Common Raven and the American crow	73
Species Descriptions and Overview	73
Raven and Crow Population Trends in the Santa Cruz Mountains	73
Diet and Foraging Behavior	77
Sociality of Ravens and Crows.....	79
Factors Associated with Nest Predation of Murrelets.....	82
Role of Corvids as Murrelet Nest Predators.....	83
Corvid Management to Reduce the Risk of Nest Predation of Murrelets	85
Lethal Control of Crows and Ravens	85
Behavioral Modification.....	88
Reproductive Control.....	89
Reducing Anthropogenic Food Subsidies for Corvids.....	90
Monitoring Program	91
Management of steller’s jays to Reduce the risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains.....	95

Summary.....	95
The Steller's Jay.....	97
Species Description and Overview	97
Distribution and Seasonal Movement.....	98
Steller's jay Population Trends in the Santa Cruz Mountains.....	98
Diet and Foraging Behavior	101
Habitat Use	103
Factors Associated with Nest Predation of Murrelets.....	104
Role of Steller's Jays as Murrelet Nest Predators.....	105
Corvid Management to Reduce the Risk of Nest Predation of Murrelets	107
Management Plan Recommendations.....	111
Recommendations to Monitor Corvid Numbers in State Parks	111
Recommendations to Reduce Availability of Anthropogenic Food Sources for Corvids	111
Recommendations to Learn More About Raven Distribution and Density in or Near Parks, and Raven Foraging Behavior and Diet.	111
Recommendations to Reduce Corvid Numbers in Occupied Stands in State Parks.....	111
Recommendations to Evaluate Effectiveness of All Implemented Projects	112
Acknowledgments	112
Management of Crows and Ravens to Reduce the Risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains.....	112
Management of Steller's Jays to Reduce the risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains	112
Chapter 4 Peregrine Falcon Predation of Marbled Murrelets in the Santa Cruz Mountains.....	113
Historic evidence of peregrine falcon predation on marbled murrelets in the Santa Cruz Mountains:	113
Recent evidence of peregrine falcon predation on marbled murrelets in northern California and Oregon:	115
Peregrine predation on other species of Alcidae:	115
Impacts of Peregrine Predation on Murrelets.....	116
Management Plan Recommendations.....	118
Recommendations to Learn More about Predation by Peregrine Falcons and its Impact on Murrelet Population Demographics	118
Recommendations to Control Predation on Adult Murrelets by Peregrine Falcons	118
Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6	119
Introduction	119

Table of Contents

Characterization of Sound and Noise.....	120
Legal Considerations and Noise	121
Mechanisms of Noise Disturbance in Birds	122
Marbled Murrelet Response to Noise.....	123
Temporal Vulnerability to Noise	128
Marbled Murrelet Exposure to Noise in the Santa Cruz Mountains	128
Management of Noise Impacts to Marbled Murrelets	130
Noise levels	130
Timing of Noise Restrictions	132
Seasonable Variation in Noise Vulnerability	132
Daily Variation in Noise Vulnerability.....	136
Noise Outside the Nesting Period	136
Indirect Effects of Noise.....	137
Management Information Needs.....	137
Management Plan Recommendations.....	138
Recommendations to Mitigate Noise Impacts	138
Chapter 6 Best Management Practices for Reducing Predation on Murrelet Nests	140
Recommended Best Management Practices	142
Reduce/Eliminate Food and Trash Subsidies	142
Interpretive Messaging	142
Enforcement	142
Active Corvid Removal	143
Conditioned Taste Aversion	143
Forest Management.....	143
Noise Management.....	143
Outside of Parks	143
Conditioned Taste Aversion	143
Chapter 7 Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6	145
Introduction	145
Methods.....	146
At-sea surveys.....	146
Estimating Abundance	146
Estimating Juvenile Ratios.....	147

Zonal Relative Abundance Estimates	147
Results	148
Abundance Estimates	148
Juvenile Ratio Estimates.....	150
Zonal Relative Abundance Estimates	151
Prey Resources.....	151
Factors Affecting Prey Availability.....	153
At-sea Distribution	154
Discussion	154
Abundance Estimates	154
Juvenile Ratio Estimates.....	156
Zonal Relative Abundance Estimates	157
Prey Resources and at sea conditions	158
Conclusion	159
Potential At-Sea Threats	159
Management Plan Recommendations.....	160
Recommendations for Monitoring Population Size and Trend	160
Recommendations to Learn More About Murrelet Foraging Behavior and Their Prey Base	160
Acknowledgments	160
References	161
Appendices	191
Appendix A–Historic Occurrences of Murrelets in the Santa Cruz Mountains.....	193
Historic Occurrences of Murrelets in the Santa Cruz Mountains	193
Appendix B–Murrelet Habitat Distribution by Watershed in Zone 6	196
Fall Creek Sub-watershed of the San Lorenzo River Watershed	196
Laguna Creek Watershed	196
San Vicente Creek Watershed.....	196
Scott Creek Watershed	197
Waddell Creek Watershed	198
Cascade Creek Watershed	200
Whitehouse Creek Watershed	200
Gazos Creek Watershed.....	200
Butano Creek Watershed.....	201

Table of Contents

Pescadero Creek Watershed	203
San Gregorio Creek Watershed	204
Tunitas Creek Watershed	205
Purisima and Lobitos Creek Watersheds	205
Pilarcitos Creek Watershed	206
Appendix C—Additional Recommendations from Individual Chapters	209
Chapter 2. Murrelet Inland Distribution and Detection Numbers in Zone 6	209
High Priority Recommendations:	209
Other Recommendations:	209
Chapter 3. Corvid Predation of Murrelets in Zone 6	210
Suggestions for Future Research	210
Chapter 4. Peregrine Falcon Predation of Murrelets in Zone 6	213
Specific Recommendations	213
Chapter 5. Evaluation of Noise Impacts on Murrelets in Zone 6	214
Chapter 7. Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6	215
Research Recommendations	215
Management Recommendations	216
Appendix D-Key Findings from Individual Chapters	217
Key Findings on Murrelet Inland Distribution and Detection Numbers (Chapter 2)	217
Key Findings on Corvid Predation of Murrelet Nests (Chapter 3)	218
Key Findings on Peregrine Falcon Predation of Marbled Murrelets in the S.C. Mountains (Chapter 4)	220
Key Findings on Noise Impacts On Murrelets In Zone 6 (Chapter 5)	221
Key Findings on Murrelet At-Sea Abundance, Productivity, And Prey Resources (Chapter 7)	222

CHAPTER 1 INTRODUCTION

The purpose of this plan is to guide current and future activities by land owners, primarily public agencies, in an effort to minimize impacts to marbled murrelets and to aid in the recovery of the species. The plan will summarize information about the biology of the murrelet in Zone 6, identify threats, and make recommendations for implementing research, monitoring, and other actions to recover the population. These recommendations will include best management practices for land managers of existing and future habitat and the surrounding landscape. The plan will be administered by the California Department of Parks and Recreation (State Parks) in cooperation with the California Department of Fish and Wildlife, and the U.S. Fish and Wildlife Service.

Funding for the various components of this plan came from California State Parks, Oil Spill Natural Resource Damage Assessment (NRDA) Restoration Funds, and a Section 6 Grant from the U.S. Fish and Wildlife Service. Technical support was provided by the California Department of Fish and Wildlife and individual consulting biologists hired by the California State Parks.

CONSERVATION STATUS

Due to loss of habitat from logging and other factors, the marbled murrelet population from Washington state south had declined to the point where the murrelet was listed in 1992 as "threatened" on the U.S. Endangered Species Act, and in the same year in California, as "endangered" on the California Endangered Species Act. Critical habitat was designated in 1995 (USFWS 1995). A federal Recovery Plan was prepared in 1997 (U.S. Fish and Wildlife Service 1997) which divided the murrelet's

breeding range into six conservation zones. Zone 6 includes the forested coastal zone from San Francisco City and County south to Point Sur in Monterey County and up to 24 km inland.

This landscape management plan only focuses on the northwest quarter of the Santa Cruz Mountains, from Santa Cruz north to San Francisco and inland as far as the summit of the range, which is also the watershed divide between the Pacific Ocean and the San Francisco Bay. The entire known breeding range of the marbled murrelet in Zone 6, encompassing 181,000 acres, is found within this area. References in this plan to "murrelets within Zone 6" or to "murrelets in the Santa Cruz Mountains" refer only to this smaller area (Chapter 2, this Plan). Most of the suitable murrelet nesting habitat in Zone 6 is found in state parks or other public lands, where logging has not occurred (Chapter 2, this Plan).

AVAILABLE NESTING HABITAT

Murrelet nesting habitat in the Santa Cruz Mountains is comprised of old-growth forest and older second-growth forest that contains suitable nest platforms (described in Chapter 2, this Plan). All old-growth and most older second-growth stands within the breeding range were mapped using stereo analysis of aerial photos. About 10,000 acres of old-growth habitat exists of which the most (4,400 acres) is found in Big Basin Redwoods State Park (Singer, 2003; Table 2-9, page 58, this Plan). About 3,100 acres of older second-growth habitat was also mapped, but this did not include an estimated 2,000 additional acres on public lands that was not mapped (Table 2-8, page 50, this Plan).

Suitable habitat is not evenly distributed throughout the breeding range, but is clustered

Chapter 1 Introduction

into seven aggregations of habitat stands with intervening non-habitat lands. These have been designated as Important Murrelet Areas and are shown on Figure 2-16 (page 29, this Plan).

POPULATION ECOLOGY AND DEMOGRAPHICS

The murrelet population that breeds in Zone 6, which numbers approximately 650 individuals (Chapter 7, this Plan) is genetically distinct from all other populations. (Friesen et al. 2005, Peery et al. 2008a).

This population is almost certainly declining as determined by the following three different lines of evidence: (1) at-sea counts of adults and juveniles conducted since 1996 have found a juvenile: adult ratio that is too low to support a sustainable population (Chapter 7, this Plan); (2) the success rate of 19 documented nests where the outcome was known is only 16 percent (Chapter 2, this Plan); and (3) inland audio-visual murrelet surveys found that the number of mean daily total detections at the once-largest breeding site (Big Basin Redwoods State Park) to have declined significantly since 1991, at least through 2006 (Chapter 2, this Plan).

The cause or causes of the presumed population decline were investigated as part of several telemetry-based research projects. During 1997-1998 and 2000-2002, 117 murrelets were radio-tagged after being captured at sea in or near Año Nuevo Bay offshore of the Waddell Creek murrelet flyway (Burkett 1999, Peery et al. 2004a, b). Peery et al. (2004a) examined three multiple competing hypotheses that would explain the poor reproduction rate of murrelets in Zone 6. The three hypotheses were the availability of prey at sea, the availability of nesting sites, and the rate of nest predation. They found that nesting habitat was not a limiting factor but that the population was most likely limited by a consistently high rate of nest predation and limited food availability in some

years. Unfortunately this information came with a price—there were 11 known mortalities of radio-tagged birds during this research effort (Peery et al. 2006).

At-sea bird counts are currently the best available measure of population size and have been conducted in most years since 1999. However, they lack the statistical rigor to reveal a slow decline, having only 80% power to show an 8 percent annual decline (Peery et al. 2009; Chapter 7, this Plan).

Peery and Henry (2010b) looked at the problem of murrelet nest failure in more detail, focusing on corvid (raven and jay) predation which had been identified previously as a major problem (Chapter 3, this Plan). They conducted a population viability analysis and concluded that reducing nest predation by corvids could lead to a stable population (Chapter 3, this Plan).

A key to reducing corvid impacts will likely require reducing predation rates in state and county parks that contain unnaturally high raven and jay densities due to the availability of anthropogenic food sources in campgrounds, picnic areas, and day use areas (Chapter 3, this Plan).

LIFE HISTORY AND DISTRIBUTION

The marbled murrelet (*Brachyramphus marmoratus*) is a seabird, about the size of a robin that breeds from the Aleutian Islands in Alaska along the Pacific Coast south to Santa Cruz County, California. From Southeast Alaska south it requires old-growth conifers for nesting. Murrelets lay only one egg and usually nest once a year although they may re-nest if the first nest failed during the incubation period. Incubation lasts about 30 days, with the adults sharing incubation in 24-hour shifts. The nestling stage lasts about 28-30 days, and the chick fledges at dusk by flying alone directly to the ocean

(Nelson and Hamer 1995, Singer et al. 1995). Murrelets are believed to exhibit breeding site fidelity, do not nest in years when their ocean prey are scarce, and in suitable years, not every individual of breeding age will nest (Chapter 2, this Plan).

CONSERVATION EFFORTS

Recently implemented management activities in parks, such as the installation of animal-proof garbage cans in camping and day use areas, installing food storage lockers at all campsites, a strictly enforced prohibition against feeding wildlife, implementation of a Conditioned Taste Aversion program (i.e., artificial murrelet eggs made to taste bad) for jays, and on-going public education efforts (i.e., the Crumb Clean Campaign) may have already begun to reduce corvid nest predation and increase murrelet numbers (Chapter 3, this Plan). Two lines of developing evidence tend to support this. They are: (1) A-V survey total murrelet detection numbers at Big Basin have shown an upward trend over the last three years (Chapter 2, this Plan), and (2) the 2016 at-sea count of murrelets has shown an improved juvenile : adult ratio (Chapter 7, this Plan). While neither of these changes is statistically significant at this point in time, it is hoped that these changes will continue into the future. Nevertheless, it must be acknowledged that Zone 6 is at risk of local extirpation.

KEY UNCERTAINTIES

While predation of murrelet nests by corvids is known to be a serious problem, the relative impact of jays versus ravens is not well understood. The importance of other nest predators, such as raptors and rodents, is also poorly known. Likewise, the extent of predation on adult murrelets by peregrine falcons that nest along two murrelet flyways is unknown, but probably significant. Resolving these

uncertainties and translating new knowledge into effective management actions will be key to recovering the Zone 6 murrelet population.

Increased human population growth and new types of land use activities can be expected to occur in the Santa Cruz Mountains. Visitation rates at old-growth parks, which contain most of the remaining murrelet habitat, will likely increase. New types of forestland recreation, such as recreational drone use, may become popular, and may be more disruptive to nesting murrelets. These and other changes will create new uncertainties in how to best manage the landscape for murrelets.

Global climate change brings with it a new suite of uncertainties. What will be its effects on at-sea prey resources, on the frequency and severity of harmful algal blooms at sea, and directly or indirectly on the future quality and quantity of potentially suitable nest trees (i.e. drought, fire, new tree diseases, etc.)?

To deal with these uncertainties, the plan will fund new research to identify new adverse impacts, assess their severity, and develop effective mitigation measures. Through the process known as adaptive management, the plan will use the new information generated to consult with the California Department of Fish and Wildlife and the U.S. Fish and Wildlife Service to adjust management measures as deemed appropriate.

CHAPTER 2 MURRELET INLAND DISTRIBUTION AND DETECTION NUMBERS IN ZONE 6

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PREFACE

The marbled murrelet (*Brachyramphus marmoratus*) was listed as endangered by the state of California in 1992, and in that same year was listed as Threatened by the U.S. Fish and Wildlife Service. Critical habitat was designated in 1995 (USFWS 1995) a recovery plan was prepared in 1997 (USFWS 1997), and a Recovery Implementation Team was formed in 2012. These actions provide the basis for this work and give guidance to its direction.

The marbled murrelet Recovery Plan (USFWS 1997) created six recovery zones for the murrelet stretching from the Canadian border to Point Sur in Monterey County. This chapter is focused on the Santa Cruz Mountains which contain the full extent of the murrelet breeding range in Zone 6. References in this chapter to "Zone 6" or to the "Santa Cruz Mountains" refer only to this smaller area.

RELATIONSHIP OF THE SANTA CRUZ MARBLED MURRELET LANDSCAPE MANAGEMENT PLAN TO PREVIOUS WORK OF A SIMILAR NATURE

Information on the inland distribution and detection numbers of murrelets in the Santa Cruz Mountains was first compiled in the marbled murrelet section of the Santa Cruz Mountains Redwoods Conceptual Area Protection Plan (CAPP) prepared for the California Wildlife Conservation Board by the Sempervirens Fund (Sempervirens Fund 2012). That planning effort delineated older second-growth forest habitat on private lands, and incorporated the existing map of old-growth stands (Singer, 2003). All nests found to date in Zone 6 (Baker et al. 2006, Binford et al. 1975) and all areas where evidence of

nesting has been found have been in old-growth or older second-growth stands. Consequently, they provide a good estimate of available murrelet habitat within the CAPP area, which is about 75% of the murrelet breeding range in Zone 6.

The CAPP area includes all of the murrelet breeding range south of the San Gregorio Creek watershed. Both old-growth forest and older second-growth forest were delineated by high resolution stereoscopic analysis of large scale aerial photos¹.

The habitat delineation done for the CAPP map did not include mapping of older second-growth forest stands on public lands. Parks with large areas of old-growth habitat typically do not have much older second-growth habitat. So, most of the unmapped older second-growth forest likely is to be found within Pescadero Creek County Park, Purisima Redwoods Open Space Preserve, and to a lesser extent, Butano State Park and the Fall Creek unit of Henry Cowell State Park. The greatest extent of older second-growth forest is in Pescadero Creek County Park where the land north of Pescadero Creek, about 1,000 acres, was not logged until 1968–1971. Selective harvest was used and many residuals were left (Western Ecological Services, 1983).

The CAPP report also looked at the size, distribution, and nature of the surrounding landscape of these habitat patches. Giving consideration to the type and extent of murrelet use of each patch, groupings of the best habitat patches found in close proximity to each other were made, and these were called "Important Murrelet Areas", and then prioritized as to their habitat value.

¹ For methodology see Moore and Singer, 2014.



Figure 2-1. Nesting Range of the Marbled Murrelet in Zone 6

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

This report uses the CAPP report as a foundation, but then builds on it using new information including field mapping of habitat stands on private timberland, information on murrelet distribution and use outside of the CAPP area, and a more thorough analysis of the existing information to create a revised habitat map² and new recommendations. This new effort covers the entire breeding range of the marbled murrelet in Zone 6 as we understand it to be at this time—an area of 181,000 acres.

For the GIS habitat map prepared to accompany this plan, the habitat north of San Gregorio Creek is based on the existing old-growth stand map of Singer (2003) and a map of older second-growth stands (referred to as suitable murrelet habitat) on the Mid-Peninsula Regional Open Space District preserves prepared by H.T. Harvey in 2007 (H.T. Harvey 2007). Preparation of this plan did not include additional mapping of older second-growth forests from aerial photos, but this omission is not a serious problem. North of San Gregorio Creek, murrelet A-V surveys associated with THP reviews found many fewer areas of murrelet activity than to the south. Older second-growth forest in or near the murrelet use areas is only likely to be important at the Purisima and El Corte de Madera Open Space Preserves where murrelets are present, and these type of stands have been mapped, as mentioned above.

POTENTIAL BREEDING RANGE OF THE MARBLED MURRELET³

The presence of murrelets and suitable murrelet breeding habitat has been used to define the potential breeding range of this species (Figure 2-1 page 5). The most important murrelet breeding sites on public land were known by the late 1980s. From

1985 to 1995, dawn surveys and informal observations found breeding areas (based on occupied behavior) to exist at Big Basin State Park, Portola State Park, Cascade Creek, McDonald County Park, Jones Gulch YMCA camp, Pescadero Creek County Park, the Butano Colony residential tract, Gazos Mountain Camp, Purisima Creek Open Space Preserve, and the North Slope old-growth stand in Butano State Park (Carter and Erickson 1988, The Habitat Restoration Group 1992, Singer and Carter, 1992, Singer and Fiedler 1994, Singer et al. 1991, and Singer, unpublished data, 1994).

Morning transect surveys were conducted by the U.S. Forest Service in both the northern and southern Santa Cruz Mountains to document areas where murrelets were absent (Paton and Ralph 1990). Mapping of all remaining old-growth forest stands in the Santa Cruz Mountains was completed by 2003 (Singer 2003), and was very important in delineating the potential breeding range, as 16 of the 17 known nest trees in Zone 6 were found in old-growth forest (Baker et al. 2006, Binford et al. 1975).

The potential breeding range of the marbled murrelet in the Santa Cruz Mountains runs from the Pilarcitos Creek watershed above Stone Dam in the north to the Fall Creek Unit of Henry Cowell State Park in the south—a distance of about 60 kilometers (37 miles). (Figure 2-1 page 5). The summit ridge is assumed to be the eastern boundary as there are no known occurrences east of this feature and suitable nesting habitat is very limited. Within this range, nesting has only been documented on suitable nest trees within redwood or Douglas-fir forests. The amount and distribution of suitable habitat by watershed is given in Appendix B of this Plan.

² For a copy of the GIS habitat stands map, which was too large to include here, contact the editor.

³ Efforts to locate murrelet nesting areas are described in Appendix A along with the historic occurrences of murrelets in Zone 6.

The northernmost breeding site occurs within a large old-growth Douglas-fir forest found on water supply watershed lands owned by the San Francisco Public Utilities District. The area used for nesting is not open to the public. The southern-most documented breeding stand is found in a small old-growth redwood- Douglas-fir stand and adjoining stand with residual old-growth Douglas-fir trees in the Fall Creek Unit of Henry Cowell State Park. Being within a state park, it is open to the public and a trail passes through the middle of the stand, but is otherwise undeveloped. Although there has been occasional discussion of possible suitable habitat in the Big Sur region, there is currently no evidence that murrelets ever nested there.

NESTING HABITAT DEFINED

Marbled murrelets are considered to be solitary nesters, but their nests are often loosely grouped in the same stand (Marshall et al. 2006), where a stand is considered to be “a contiguous group of trees sufficiently uniform in age-class distribution, composition, and structure, and growing on a site of sufficiently uniform quality, to be a distinguishable unit” (Helms 1998, USFWS 1995). Such stands are referred to as breeding sites, and may have formed as the result of breeding site fidelity—a trait common to most members of the alcid family (Birkhead 1977, Divoky and Horton 1995).

In general, murrelets nest in trees with old-growth structural features that include a relatively flat "platform" big enough to support an egg within the upper 3/4th of the live crown. In Zone 6, these platforms are only found in redwood or Douglas-fir trees. But a suitable "platform" is more than just a space big enough to hold an egg. To make for a successful nest, it must provide concealment for the nest, it must be a defensible space for the chick, and it must allow ready access to the parents as they fly in and fly out. Nest site requirements can only be described fully by looking at the platform scale, the tree scale, and the stand scale of existing nests as

found in either the Santa Cruz Mountains (Baker et al. 2006) or elsewhere in the redwood region (Golightly, Hamilton, and Hebert 2009, Hebert and Golightly 2006). Unfortunately, the sample size for these two studies is quite low—19 nests and 10 nests, respectively.

Platform Scale:

The platform must be relatively flat or be depressed in the center and be big enough (15.25 cm. or larger, i.e. 6 inches) to hold a murrelet egg. Locally, 80% of all nest platforms were found on large limbs, and 12% on broken tree-tops, the latter being found primarily in redwoods. Additionally, one nest was found on an abandoned squirrel nest (Singer, unpublished data) and one nest was found on an abandoned stick nest, most likely from a band-tailed pigeon (*Patagioenas fasciata*) (Singer, et al. 1991). The smallest platform used in the Santa Cruz Mountains was 28 centimeters (11 inches) in diameter, but, as mentioned above, the sample size is small. Murrelet nests in Oregon and Washington have been found on much smaller platforms (Nelson 1997). For the purpose of assessing the suitability of forest stands as nesting habitat for the murrelet in the Santa Cruz Mountains, the California Department of Fish and Wildlife (CDFG 2003) has set 15.25 cm (6 inches) as the minimum suitable size.

Suitable platforms do not require a layer of moss, and the platform floor may be collections of tree detritus, lichen layers, or on bare bark. Redwood limbs in our area do not normally support moss. Baker et al. (2006) found that for 15 nest branches measured, the mean cover of moss on redwood was only 5.6%, and the mean cover of moss on Douglas-fir nest limbs was 59%.

The combination of physical conditions that make for an optimal nest site have not been fully investigated. These may include close-in vertical cover, position close to the trunk or a vertical branch (Nelson and Hammer 1995), and a horizontal open

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

area next to the landing pad. The juxtaposition of all three conditions on the same branch, along with suitable platform size, may be unusual enough to make high-quality nest sites a limited resource and thus be responsible for the apparent high fidelity shown by murrelets to their nesting platforms (Hebert and Golightly 2006).

Nelson and Hamer (1995) found that nests located next to the tree bole generally had the lowest predation rate. Anecdotal observations of jay-chick interactions at 3 nests in Big Basin State Park saw that chicks could more easily defend themselves from jays if the nest cup was up against or within about 0.25 meter of a "wall" formed by the bole or the "trunk" or a reiteration (Singer, unpub. data). Such a location prevents jays from attacking a chick simultaneously from both sides of the nest. Two nests on the Father Tree that were visited by jays but near a "wall" were both successful. One nest with a chick on a Douglas-fir tree that was situated out on a branch without a "wall" nearby, was taken by jays (Singer et al. 1991, Singer, Suddjian, and Singer 1995).

Tree scale:

Baker et al. (2006) measured nest trees associated with 19 of the 20 known nests in Zone 6 which were in 16 different nest trees. They found that 41% of the nest trees were redwoods and 59% were Douglas-firs, and that Douglas-firs contained more suitable nest platforms than redwoods. They found that vast majority of murrelet nests (15 of their 16 studied stands) were in old-growth trees as was also the case in Redwood National and State Parks in Northern California (Golightly, Hamilton, and Hebert 2009) in a study of 10 trees. One nest was not included in the Baker et al. study. It was found on a large branch in an old-growth Douglas-fir at a height of 45 meters (148 feet) (Binford et al. 1975).

Baker et al. (2006) compared their nest trees with randomly-selected nearby non-nest trees and found that nest trees had a larger diameter (dbh) and were

located closer to a stream than non-nest trees, and that a simple logistic model using these two parameters was able to correctly classify 71 percent of all nest sites. The Redwood National and State Parks study also found that murrelets preferred the larger trees in a stand for nesting, but not necessarily the largest tree.

The requirement for large diameter trees may be indicative of their ability to provide such important nest site conditions as good vertical cover, more favorable microclimate, and larger platform size (Baker et al. 2006). Larger trees are also more likely to have reiterated branches and favorable limb topography, such as broad cracks or hollows.

The finding that proximity to a stream is important is not surprising, since the tallest trees in the Santa Cruz Mountains are found at locations with year-round water availability, and the largest trees might also be associated with good water availability (Moore and Singer 2014).

Stand scale:

Murrelet researchers typically use a different (and artificial) definition of "stand" when describing trees growing near a nest tree. Both the Santa Cruz Mountains study (Baker et al. 2006) and the northern California study (Golightly et al. 2009) considered a "stand" to be the area in the immediate vicinity of the nest tree or the comparative non-nest tree, within a radius of 25 meters in Zone 6, and approximately 28 meters in the northern California study. This definition was used for the purpose of measuring attributes of each nest site, and is not the traditional definition of a forest stand which is used in other parts of this chapter.

In terms of nest site attributes in the Santa Cruz Mountains, murrelet nests were preferentially located in old-growth stands (true sense of the word) but also occurred in harvested stands with residuals present (Baker et al. 2006). They were also in stands found in the lower two-thirds of the slope, and especially in the lower one-third of the slope. In the

Santa Cruz Mountains, the largest trees are known to occur in canyon bottoms or lower slopes where soils are deeper and more soil water is available during the dry season (Moore and Singer 2014). In northern California, Golightly, Hamilton, and Hebert (2009) found that "distance to nearest paved road was the best habitat correlate of nest site use at the stand scale", with nests being more common far from roads. They also found that nest sites were in stands with lower canopy heights than random stands, although this finding was not supported by the Santa Cruz Mountains study.

In northern California, the "number of down logs [in a stand] was the best habitat correlate of marbled murrelet nest success and nests were more likely to be successful in stands with a greater number of downed logs" (Golightly et al. 2009). They speculated that stands with more down logs would have more openings in the canopy, which might mean better access for murrelets to their nest sites. However, redwood logs can persist for more than 500 years on the forest floor so may not be indicative of present day canopy openings. Instead they may just be more evidence that murrelets prefer old-growth stands for nesting, since large down logs are one of the characteristics that define an old-growth stand (Franklin and Spies 1991).

Stand size, in the traditional definition of a forest stand, is apparently not a limiting factor, as occupied behaviors have been observed in stands as small as 7 acres as at the Butano Creek stand (Table 2-9 page 58) (California Department of Fish and Game, 2002). However murrelets nesting in small stands would be more susceptible to edge effects. Other stand parameters that are sometimes considered as favoring nesting, such as stands with a large number of platforms or stands with larger sized platforms, have not been verified for the Santa Cruz Mountains. Murrelets are known to have a high degree of breeding site fidelity and return to the same stands each year for nesting and may also return to the same tree or the same nest platform

(Burger et al. 2009, Divoky and Horton 1995). At Big Basin, the same murrelet pair nested three years in a row in the same tree (and likely four years based on eggshells found under the tree in a fourth year), alternating between two different nest sites (Singer, Suddjian, and Singer 1995). In Redwood State and National Parks, one nest was re-used for seven out of 10 years (Golightly and Schneider 2011). Burger et al. (2009) found only 18% reuse of murrelet nest trees in large old-growth stands in British Columbia, but speculated re-use of nest stands might be higher. They also found re-use of nest trees to be higher in small old-growth stands, and most habitat stands in the Santa Cruz Mountains would fall into that category. Hebert et al. (2003) observed replacement laying in a murrelet nest after the first egg was predated. The re-nesting took place in the same nest with the egg being laid about two to four weeks after the initial egg loss.

This degree of site fidelity may now be working against the species since a new and very effective murrelet nest predator has entered the scene in Zone 6—the common raven. Until the 1980s, the raven was virtually absent from the Santa Cruz Mountains. Since then it has undergone a rapid range expansion and is now common in forested regions of the range (Suddjian 2003a Chapter 3, this Plan). Ravens, and corvids in general, are known to be important nest predators (Burger et al. 2009, Peery and Henry 2010b, Ekanayake et al. 2015, Chapter 3, this Plan).

Corvids are believed to have the capability to return to nest sites they predated in the current or previous year (chapter 3, this Plan). If this is true, the high nest site fidelity exhibited by marbled murrelets could now be working against them in nesting habitats with a high density of ravens.

Laying a replacement egg in the same nest would seem to be counterproductive in these type of breeding sites. Not only is it likely that ravens can "remember" nest locations, they can also easily flush an adult murrelet off a nest (Singer et al. 1995, 1991,

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

unpub. data). In northern California, the nest cup monitored by Golightly and Schneider (2011) that was reused in seven out of 10 years, failed in five out of those seven years due to predation, resulting in a 29% nest success rate. In contrast, the Band-tailed Pigeon (*Patagioenas fasciata*), another forest tree scrape or platform nesting species, is known to have a much higher nest success rate. In a study in western Oregon that monitored 134 nests, the nest success rate was 69% (Keppie and Braun 2000). This fidelity of murrelets to nest sites known to predators does not bode well for the future of murrelets in nesting areas with high numbers of those predators, such as Big Basin.

Another nest predator whose presence in Big Basin was increasing about the same time as the raven was the Red-shouldered Hawk (*Buteo lineatus*). David Suddjian noted an increase in abundance of this species from 2000 to 2004 (Suddjian 2005b). In 2005, he made several detections of this species on murrelet surveys and saw a juvenile at the Wastahi Campground area. In 2006, he found 7 breeding pairs in the park, in 2007, 9 pairs; in 2008, 3-4 pairs; and 2009, he found 3-4 breeding pairs. These were all in the East Fork Waddell Creek Watershed (Suddjian 2006, Suddjian 2010).

METHODS FOR MONITORING INLAND HABITAT USE BY MURRELETS

Four different methods have been used to monitor inland activity in Zone 6. These are audio-visual (A-V) surveys by ground observers, radar surveys using modified marine radar, radio telemetry of tagged birds, and the use of acoustic recording units (ARUs). The pros and cons of all but radio-tagging, which is no longer used in this area because of the risk of harm to the birds, are discussed in Table 2-1 page 11.

A-V Surveys

A-V surveys are the most prevalent monitoring technique in use in Zone 6. They were first used at Big Basin State Park in the late 1970s (Singer,

unpublished data). A precise protocol for their use was developed in the late 1990s (Evans Mack et al. 2003) and today, protocol-level A-V surveys are the main method used to identify stands where murrelets are nesting. They are routinely required by the California Department of Forestry when a timber harvest is proposed on lands containing potentially suitable murrelet habitat as determined by the California Department of Fish and Wildlife.

Radar Surveys

Radar surveys were conducted in Zone 6 from 1998 to 2010 (Colclazier and Singer, 2010; Colclazier, Stumpf, and Singer 2010; Singer 1999; Singer and Hammer 1999b, 1998). Early radar surveys located four murrelet flyways, and then intermittently monitored their use over time. The flyways are shown in Figure 2-16 page 29 and the results are discussed later in this chapter.

Radar is a potential tool for monitoring inland use by murrelets, however, it has some limitations that must be taken into consideration. First of all, radar is seldom, if ever, able to census 100% of the murrelets using the flyway being sampled. There are three main reasons for this. The first one is radar clutter. Clutter is defined as unwanted echoes from the ground or trees that block part of the radar screen. At the Gazos Canyon site (Double Low Gazos) where the most surveys were undertaken, this clutter blocked about 25% of the screen which means that portion of the sky would not be covered. The amount of clutter varies from location to location, so the key to finding a good radar location is to find a site with less clutter. Clutter can be reduced by close-in topography that reduces ground return of the radar signal or by a clutter screen.

A second factor is the distribution of birds over the landscape. Favorable topography is needed to concentrate murrelets into a small enough corridor of sky that can be sampled adequately. The ideal location would be a narrow canyon with steep sides and bordered by high ridges. Such topography acts

to funnel the birds into a confined flyway. If the canyon is too shallow, murrelets coming from offshore areas to the north or south might take a direct route to the canyon and cross over the ridge to enter it before heading up canyon.

The third reason is the vertical width of the radar beam. Simultaneous surveys by radar and A-V observers found that ground observers could see few, if any, of the murrelets being tracked by radar as they passed overhead. A corollary observation made was that murrelets seen by ground observers were usually flying too low to be detected by radar (Colclazier et al. 2010). Consequently, some murrelets can pass over radar survey stations without being detected. However, despite all of these limitations, the coefficient of variation associated with radar data is always much lower than that associated with A-V surveys, as shown in Table 2-1 page 11 and Table 2-2 page 12.

Between 2000 and 2010, A-V surveys and radar surveys were conducted in July of the same year in 7 years of the 11-year period in Gazos Creek Canyon. Seven radar surveys were done each year and six A-V surveys. The radar station was located about 2 km. downstream of the A-V survey station. Table 2-2 page 12 compares the coefficient of variability values for the two types of surveys.

Radio Telemetry Tracking

Radio telemetry has also been used to track murrelet movements in Zone 6. During the breeding seasons of 1997, 1998, and 2000–2003, 117 murrelets were caught at sea and radio-tagged. (Burkett, unpublished data; Peery et al. 2006b, Peery et al. 2004). Radio telemetry has the potential to find nests in different areas, but only if the birds were captured and tagged in the ocean at varied locations. The majority of the nests found by this technique were in Big Basin State Park because most of the birds were

Table 2-1. Pros and Cons of Different Inland Survey Methods

Method	PROs	CONs
A-V Surveys	<ul style="list-style-type: none"> • Can detect visual behaviors indicative of nesting • Can be used to locate new murrelet use areas • Can detect all type of murrelet sounds and at a greater distance than ARUs • More expensive than ARUs, but less expensive than radar surveys 	<ul style="list-style-type: none"> • Not suited for detecting trends in murrelet usage when using total detections or occupied behavior detections. But trends may at times be detected by analyzing behaviors tightly associated with active nesting such as single silent birds below one canopy • Not well suited for locating murrelet flyways
ARU Surveys	<ul style="list-style-type: none"> • Well suited for areas where access is difficult • Records calls daily for a whole season, giving much larger sample size • Less expensive than A-V or radar surveys • Can detect wing sounds which are indicative of nesting 	<ul style="list-style-type: none"> • Cannot detect visual behaviors that indicate if nesting is occurring. • Distance of call detectability is less than for A-V surveys • Not well suited for detecting flyways as birds call infrequently in flyways • Some false positive and false negative detections will occur
Radar Surveys	<ul style="list-style-type: none"> • Detects actual birds and not artifacts like calls or short flight segments • Can detect birds in the dark, in clouds, and at heights and distances beyond capability of other methods. • Suitable for detecting trends in murrelet usage • Well suited for locating new use areas at a course scale or for locating flyways. 	<ul style="list-style-type: none"> • Cannot detect nesting behaviors • Requires topography that funnels birds into beam area • Requires vehicle access and a suitable clearing in the forest • More than twice the expense of A-V surveys or ARU surveys

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

tagged in Año Nuevo Bay which is the at-sea staging area for Big Basin nesters. However, if birds are tagged at other ocean locations, there is the risk that they might be tracked inland to nest locations that are inaccessible, thereby preventing confirmation and the investigation or measurement of most nest site parameters. A significant amount of potentially suitable nesting habitat is on private lands.

A significant disadvantage of radio telemetry is that it has the potential to harm or kill the murrelets that are tagged, or more commonly, alter their behavior as has been documented for murrelets and other alcids (Peery and Henry 2010b, Whidden et al. 2007, Peery et al. 2014, Peery et al. 2006b, and Ackerman et al. 2004). All ten nests found by radio telemetry failed (Table 2-5 page 38), with two failures attributed to nest predation. The other losses were due to unknown causes which could have included factors related to the radio-tagging of one parent.

ARU Monitoring

Acoustic recording units (ARUs) are the most recent monitoring method being used in Zone 6. These are digital sound recorders that can be left in the woods for the entire season and programmed to record all sounds generated during the murrelet's dawn (and/or

dusk) activity period. A computer program can then isolate and tally all murrelet vocalizations and wing sounds that were detected. These devices have recorded wing sounds even when a human observer was not present to inadvertently illicit them (Cragg et al. 2015, McKown and Singer, unpub. data).

These devices were first used in Zone 6 in 2010 in a comparison test with A-V surveys at seven different sites (Borker et al. 2015). In 2013 and 2015, ARUs were deployed at various spots in the San Vicente Redwoods property and were able to verify that the southern stand of old-growth forest on the Laguna tract had murrelet presence (McKown and Fleishman, 2015). ARUs are not a good tool for determining occupied behavior because most below-canopy flights are silent. However, as mentioned above, they can detect the less frequent wing sounds which are an indicator of occupied behavior (Cragg et al. 2015, McKown and Singer, unpublished data). ARUs could also be used to monitor corvid vocalizations.

ARUs have one big advantage over A-V surveys in that they can record murrelet calls each day for the entire breeding season thereby reducing variability. The combination of season-long ARU monitoring with several A-V surveys during the season probably

Table 2-2. Comparison of Within-Year Variability Between Radar and A-V Surveys at Gasos Creek Canyon¹

<u>Year</u>	<u>A-V Detections</u>			<u>Radar Detections</u>		
	<u>Mean Total</u>	<u>S.D.</u>	<u>C.V.</u>	<u>Mean Total</u>	<u>S.D.</u>	<u>C.V.</u>
2000	57.33	26.14	0.46	44.86	11.68	0.26
2001	64.67	31.70	0.49	31.00	3.00	0.10
2002	52.00	23.05	0.44	18.50	5.32	0.29
2004	44.70	10.97	0.25	42.86	5.31	0.12
2006	79.70	37.33	0.47	39.86	2.04	0.05
2008	71.83	35.52	0.49	29.57	9.45	0.32
2010	66.00	22.99	0.35	40.43	7.04	0.17

¹For complete results of all A-V and radar surveys in Gazos Creek Canyon, see Singer, 2010; and Singer and Colclazier, 2010.

provides the best measure of murrelet breeding activity at any site. Advantages and disadvantages of ARU use are given in Table 2-1 page 11.

LOCATIONS WITH CONFIRMED NESTING AND FATE OF NESTS

There are four types of evidence of nesting that are more conclusive than occupied behavior. These are eggs or eggshell fragments, chicks on the ground, grounded fledglings, and adult birds seen carrying a fish. Records of these first three types better show where nesting is occurring than the few known nests. However grounded juveniles could be found some distance from their nest.

There have been 63 documented instances of nesting in Zone 6, 20 nests, 6 eggshells, 2 chicks, and 35 grounded fledglings.(Table 2-4 page 34). The oldest record of nesting was a grounded fledgling found in 1957 in Portola State Park (Anderson 1972). The most recent evidence of nesting was in 2016 when grounded fledglings were found at Portola State Park, Big Basin State Park, and in Whitehouse Creek Canyon. The last actual nest found was in 2002 in the Bloom's Creek Campground area of Big Basin State Park (Suddjian, 2003c).

These data are presented in Table 2-4 page 34, and the general location of actual nests is plotted in Figure 2-2 page 14. Fifteen (15) of the 35 juveniles listed in Table 2-4 page 34 were found in Big Basin State Park as were 14 of the 20 documented nests. This is not surprising for several reasons. For one, Big Basin is where most of the nest searching was done. Secondly, Big Basin, with its high visitation rate, is where a grounded fledgling would have the greatest chance of being encountered by a human, and lastly, nests located by radio telemetry were from birds captured and tagged in Año Nuevo Bay which is the staging area for murrelets that nest in Big Basin.

Two types of murrelet nests are unique to Zone 6. The first was a 1991 Big Basin nest found in an old band-tailed pigeon nest comprised of sticks and tree

litter on a large horizontal branch (Singer et al. 1991). The second was a 1995 Big Basin nest in an abandoned squirrel nest consisting of a large platform of twigs and shredded redwood bark (Singer, unpub. data). Information about these and all other documented nests can be found in Table 2-5 page 38.

Data from Baker et al. (2006) and Binford et al. (1975) combined document 20 known nests, 17 known nest trees, and 16 cases where the location of the nest platform was known initially. Eighty-one percent (81%) of the nest platforms were on large limbs and 19% were on broken tops. Two open nest cups were each reused once in different years (Baker et al. 2006, Singer et al. 1995). Nest site parameters for the 10 nests found by radio telemetry were lost some time after 2006, so data from those nests could not be included in Table 2-5 page 38.

For other physical evidence of nesting, the fate of the nesting event is known in many cases. When a grounded fledgling was found (35 times), it can be assumed that the nest was successful and probably located nearby although the exact location of the nest can't be determined. In addition, three successful fledglings were seen or inferred, so the number of known-to-be-successful nests in the period from 1957 to the present is 38. Of the failed nesting attempts, the cause of the failure is known for 16 nests. At least 7 nests were predated, 3 by ravens, 2 by raptors, one by jays, and one by an unknown bird. Nine (9) nests failed by unknown causes, which likely included predation, other natural events, and human-caused events perhaps aided by the radio-tagging of 10 nesting birds in this database. Of the 19 documented nests from 1991 to the present, but excluding the 1974 nest where the chick was collected, only three were successful, for a success rate of 16% (Table 2-5 page 38).

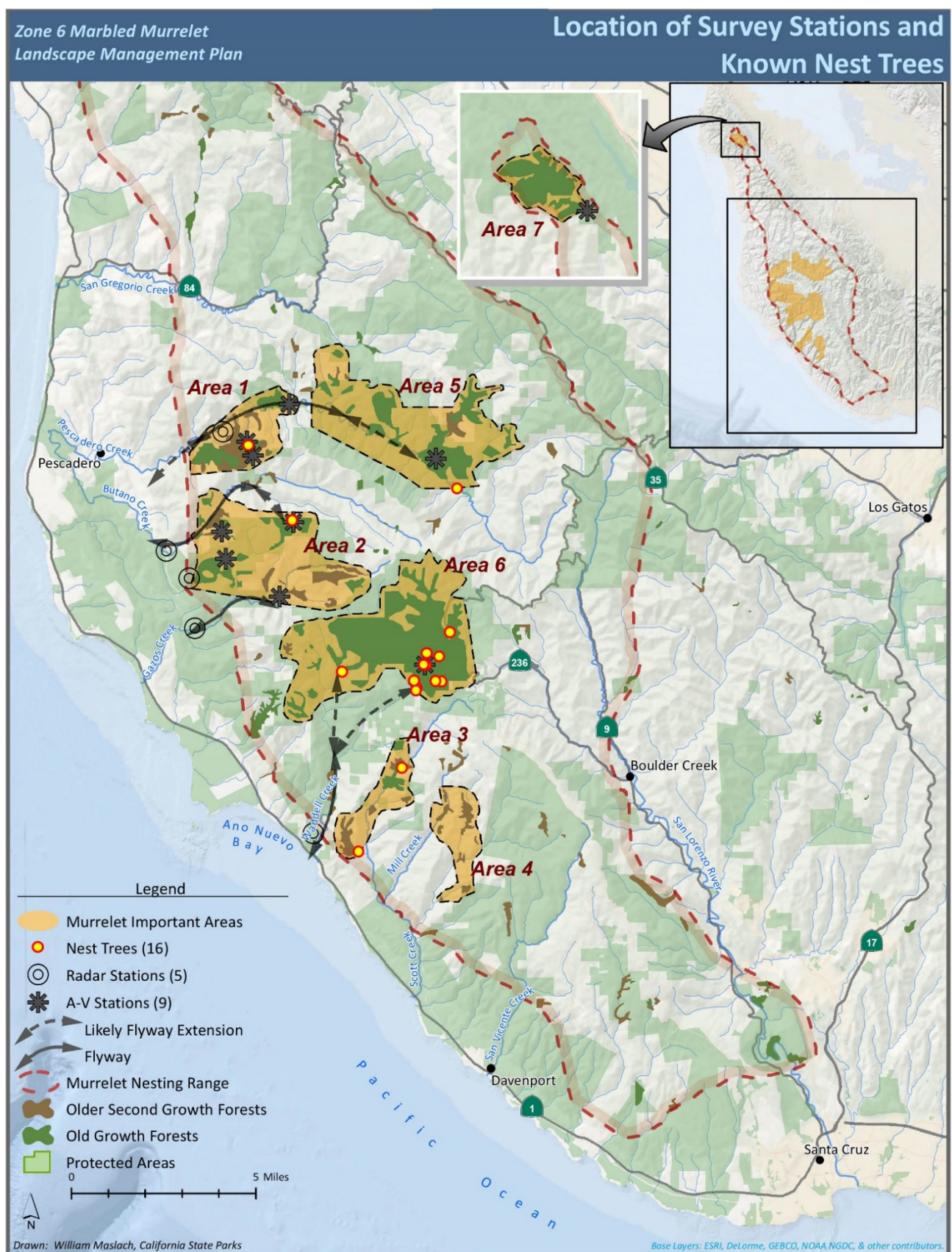


Figure 2-2.. Location of Survey Stations and Known Nest Trees

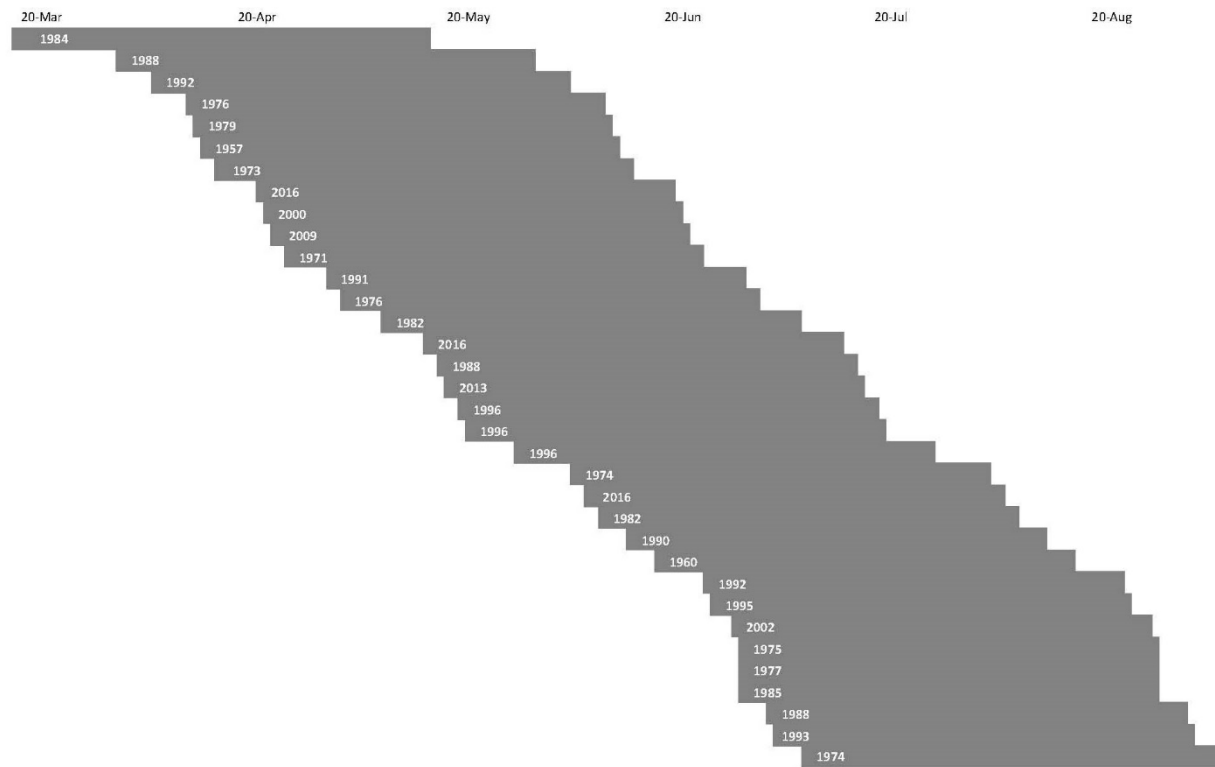


Figure 2-3. Nesting Chronology for Zone 6 (Based on 30 grounded fledglings, 3 successful nests and 1 nest near completion.

documented for seven watersheds in the Santa Cruz Mountains from the Purisima Creek watershed in the north, to the Scott Creek watershed in the south. Most nests were in the Waddell Creek watershed (Big Basin) with 34, followed by Pescadero with 14, and Butano (including Little Butano) with 7. The other 7 nest sites were scattered among 7 watersheds—Gazos Creek, Purisima Creek, San Gregorio Creek, and Scott Creek.

NESTING CHRONOLOGY IN ZONE 6

Figure 2-3 shows the nesting chronology in Zone 6 based on data from Table 2-4 page 34. For grounded fledglings, the date of discovery is assumed to be within one day of the fledge date, and the egg-laying date is assumed to be 60 days prior.

The breeding season is defined by the earliest known nesting and latest known fledging dates. Data from Figure 2-3 shows that nesting begins as early as March 18 and the last fledging occurs in mid-September. This nesting season is similar to that

found elsewhere in the southern half of the murrelet's range (McShane et al. 2004) and largely falls within the period given in the Pacific Seabird Group forest survey protocol of March 24 to September 15 (Evans Mack 2003).

Since there is no evidence of synchrony of breeding in Zone 6, different pairs start a nest at different times during the same season. However, it is unlikely that a pair would wait until July to lay their first egg and initiate nesting. It is more likely that murrelets start nesting in late March or April and that the late fledging birds are the result of a replacement egg laid after the failure of the first nest.

Replacement laying, i.e. laying of a new egg after the first egg fails, is common in other parts of the murrelet's range (McFarland Tranquilla et al. 2003) and is believed to be common in Zone 6 as well (Peery and Henry 2010). However, research by Hebert et al. 2003) found it to be less common in northern California.

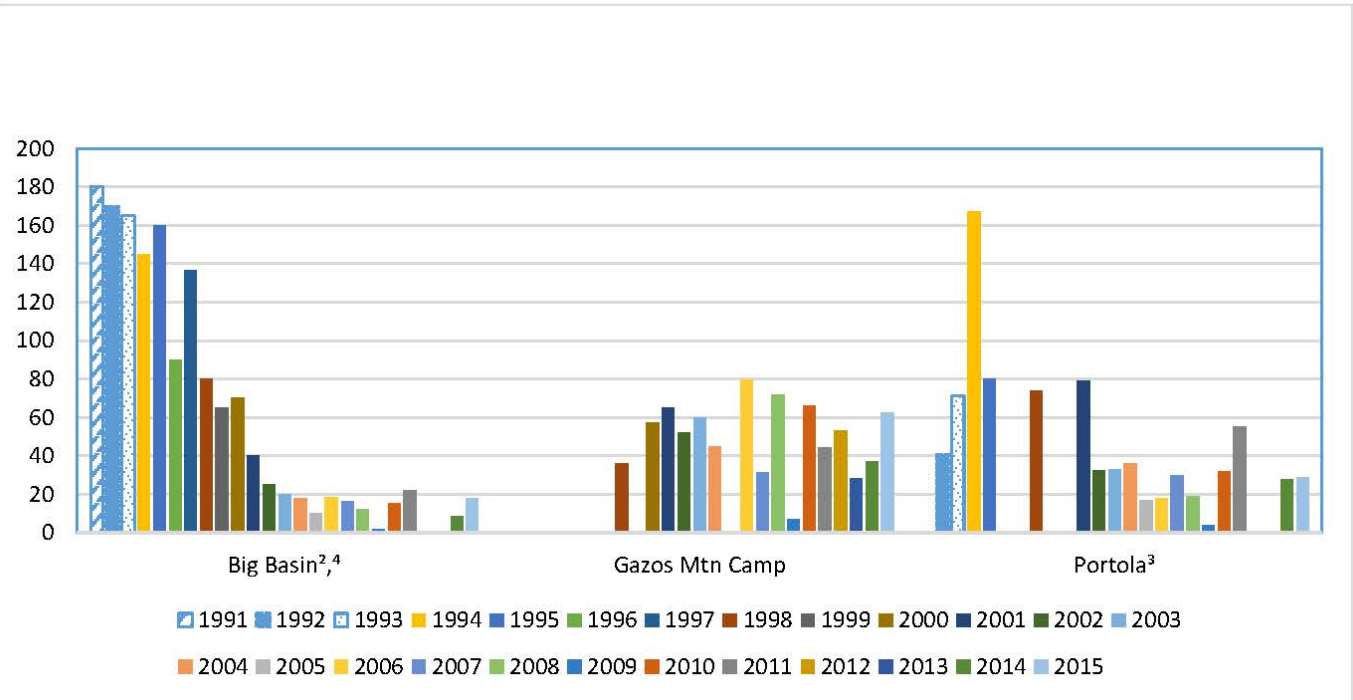


Figure 2-4. Mean Total A-V Detections from Long-term Monitoring

Figure 2-3 page 15 shows that almost half of the documented fledglings were from August or September, suggesting they were the result of re-nesting, and also suggesting that failure rate of initial nests (based on this limited data from 1957 to 2013) was about 50 percent. Research studies using radio-tagged birds both here and in northern California have shown the current nest failure rate to be much higher (Peery and Henry 2010, Hebert and Golightly 2006, and Peery et al. 2004).

RESULTS FROM LONG-TERM MONITORING AT INLAND SITES⁴

A-V Surveys

Information on A-V monitoring sites is given in Table 2-6 page 41 and results are summarized in Table 2-7 page 44 which also shows the survey effort at each station. The location of A-V survey

stations are shown on Figure 2-2 page 14, along with the location of nest site occurrences. The three sites surveyed for the longest duration (those that began prior to 2003) will be discussed more fully here. These sites and their date of initialization are: (1) Big Basin (Redwood Meadow) (1991); (2) Portola (Peters Creek Bridge) (1992 with gaps); and Gazos (Gazos Mountain Camp in Butano State Park) (1998). The survey effort at Big Basin was much greater than at the other two sites. (Table 2-7 page 44). Total detections recorded each year from these three stations are shown in Figure 2-4 page 16 and Figure 2-6 page 17. At two of these sites, A-V surveys have been successful in documenting (to a high likelihood) trends in murrelet use levels, these are Big Basin and Gazos.

⁴ Statistical analysis of Gazos data are from Comfort, 2016.

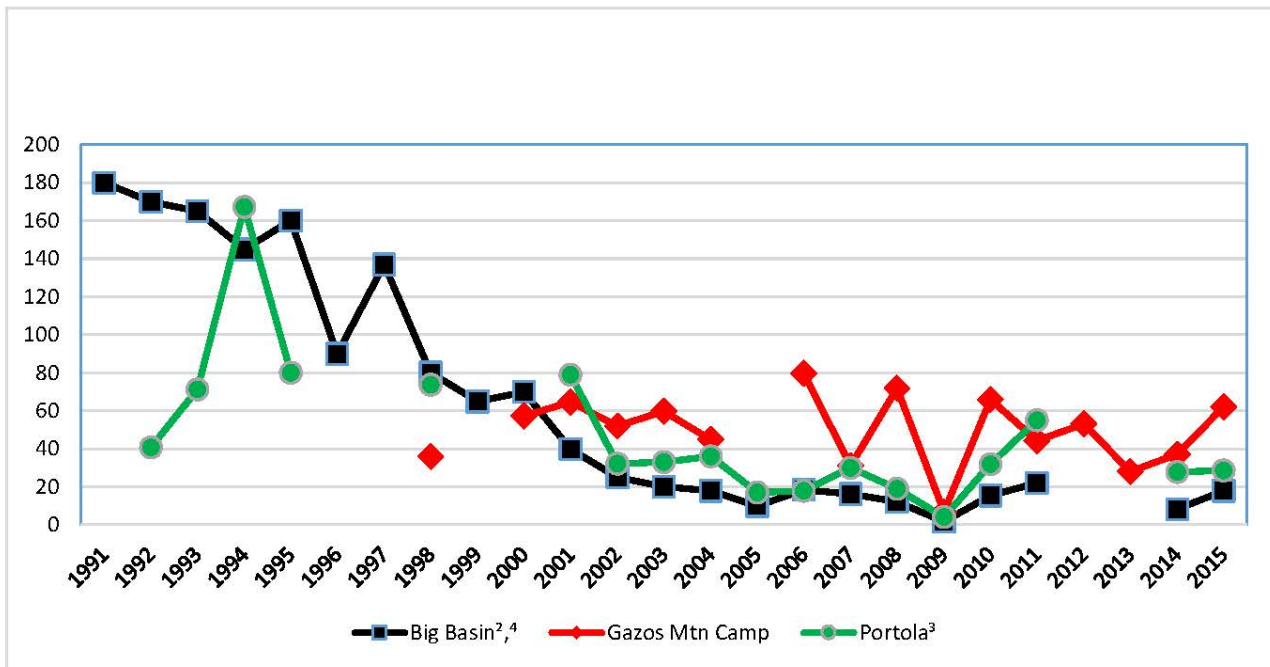


Figure 2-6. Mean Total A-V Detections from Long-term Monitoring

At Big Basin, murrelet use has dropped dramatically, while at Gazos, the breeding effort has remained at a constant level (although this is not based on total detection numbers as shown in Figure 2-4 page 16 and Figure 2-6 page 17.

With the exception of Big Basin mentioned above, total detections and occupied behavior detections have very little capability to determine long-term trends in murrelet use because of their high day-to-day variability (Bigger et al. 2006a, 2006b) Figure 2-5 page 17 shows total detections at Gazos with a

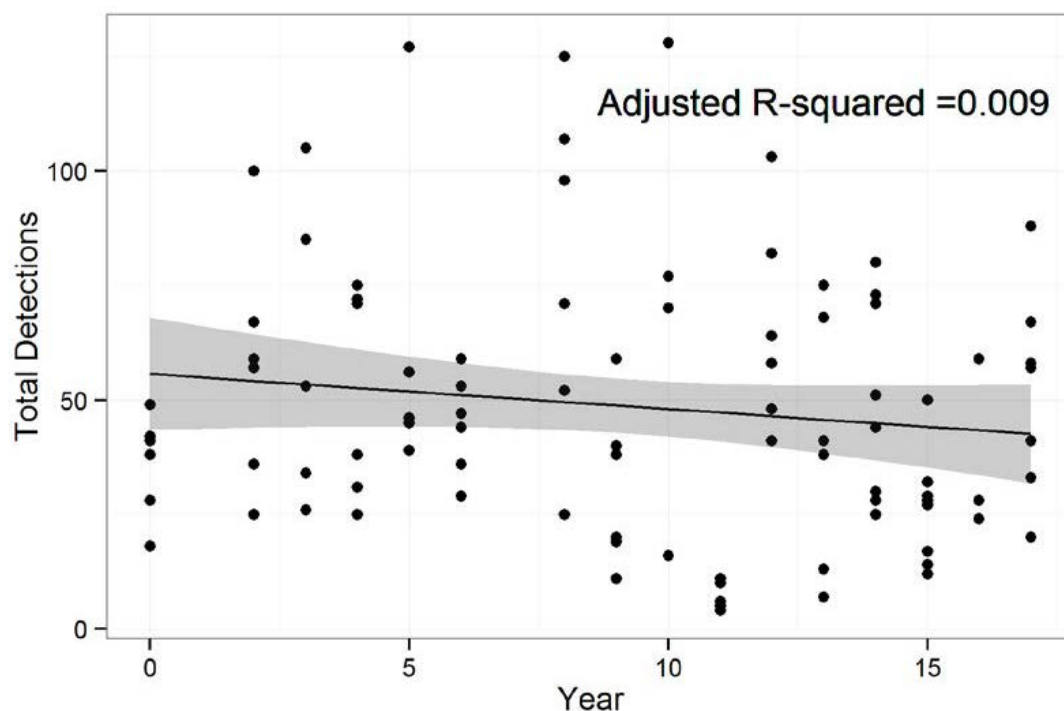


Figure 2-5. Daily A-V Detections, Gazos Mountain Camp, 1998-2015

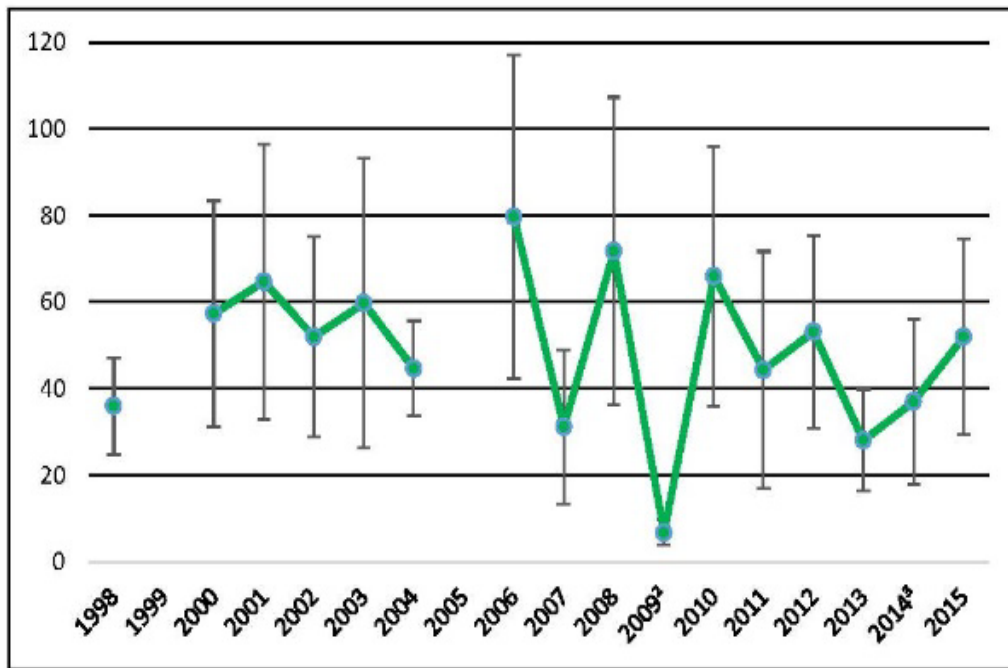


Figure 2-7. A-V Detection Means, with Error Bars, Gazos Mountain Camp, 1998-2015

dot representing each daily value. Clearly, total detections from the limited number of surveys done at this station are not a very helpful metric. The exception to this rule is when many more surveys have been done and detections make a very dramatic and fairly regular decline. That was the case at Big Basin which will be discussed later.

Detections of below one-canopy flights and single silent birds flying below one-canopy height (SSBBC detections) are a better metric to use for statistical analysis (Burger and Bahn 2004, Comfort 2016a, and Singer 2015b). Because SSBBC detections are detections of birds that defend a nest site over the course of the breeding season, their detections have less day-to-day variation than total detections which include non-breeding birds which will move from site-to-site on different days. Studies elsewhere have shown that below-canopy flights associated with nesting murrelets are not necessarily associated with an active nest and will continue even after a nest has failed (Manley 1999 as summarized in Plissner et al. 2015). Unfortunately,

long-term data on SSBBC detections is only available for Gazos Mountain Camp.

Gazos

Gazos Mountain Camp has been surveyed 6–7 days per year in mid-season in every year since 1998 with two exceptions (Singer, 2015a). In addition to recording total detections and occupied behavior detections (which usually trend with total detections), SSBBC detections were also recorded. Figure 2-7 page 18 shows the means and standard deviation of total detections each year at Gazos.

Figure 2-8 page 19 shows the simple linear trend model for SSBBC detections at Gazos over the past 18 years. This graph shows a much tighter grouping of daily values than in Figure 2-5 page 17, but it still does not have a statistically significant effect of year as the P value=0.113. However, use of a generalized additive model (GAM) which is more sophisticated, found there to be a statistically significant positive effect of year (P=0.006). (Figure 2-9 page 19). The slight increase in SSBBC numbers over time may or

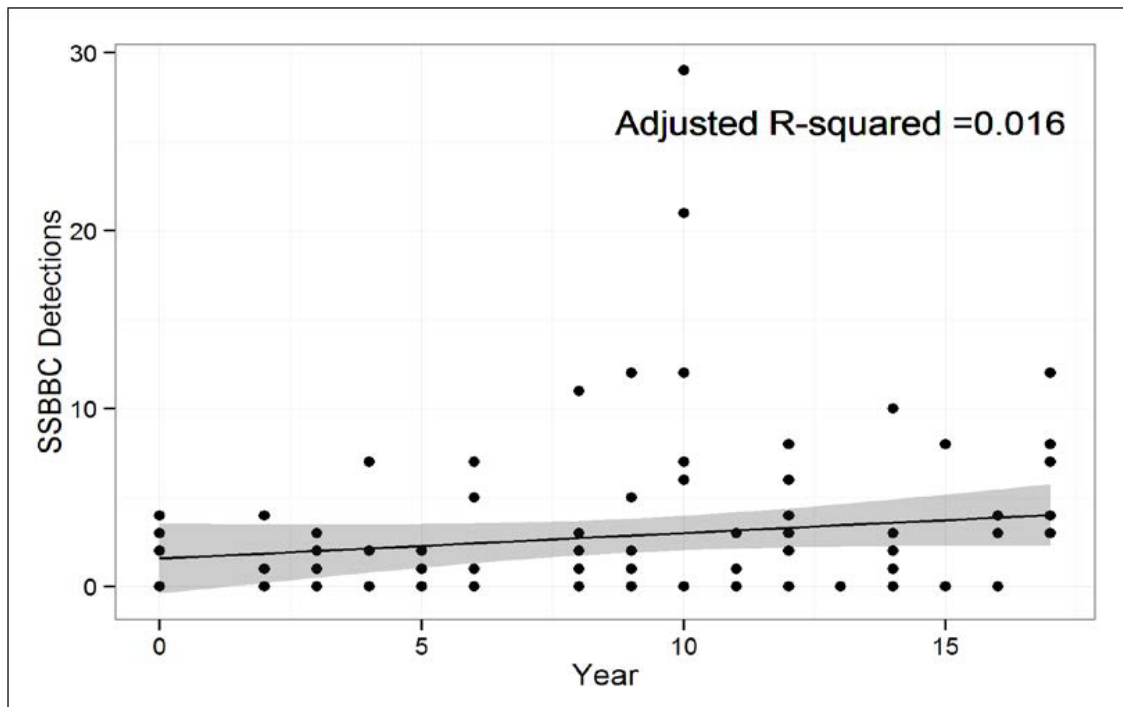


Figure 2-8. Daily SSBBC Detections, Linear Model, Gazos, 1998-2015
(Note: SSBBC=Single silent birds below on canopy)

may not be real, but at least it signifies that breeding effort (using SSBBC as a proxy) has not declined at Gazos (Comfort 2016a). Thus the decline observed at Big Basin has not occurred at Gazos and is probably not a zone-wide decline.

A large number of A-V surveys were done by Mike Duffy and Matt Greene in 2011 and 2012 on the Redwood Empire property adjacent to and upstream of the Gazos Mountain Camp property (CDFW 2013). These surveys in conjunction with the seven

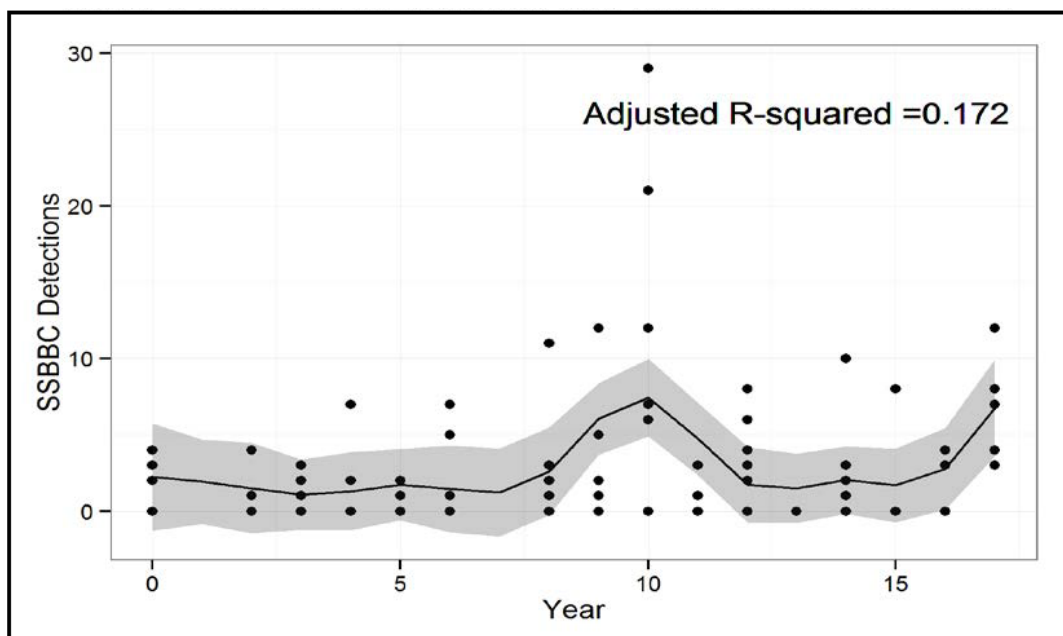


Figure 2-9. Daily SSBBC Detections, GAM Model, Gazos, 1998-2015

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

surveys per year done at Gazos Mountain Camp, have shown that most murrelets using the Gazos Creek Canyon do not fly upstream beyond the Middle Gazos stand which is about 2.0 km (1.25 miles) upstream of Gazos Mountain Camp (Duffy, pers.comm.).

The most likely conclusion is that murrelets are not using Gazos Creek Canyon as an alternate flyway between the ocean and Big Basin State Park.

Portola:

A-V surveys began at Peters Creek Bridge in Portola in 1992, and have continued through 2016, but there are significant gaps in coverage, such as 1996, 1997, 1999, 2000, 2012, and 2013 (Table 2-6 page 41 and Table 2-7 page 44). Three surveys were done in mid-season of each year. None of the raw data is available and data for SSBBC detections are not available. The results of total detection means recorded each year are shown in Figure 2-10 page 20. A simple linear regression was run on the data and found no statistical evidence for a relationship between year and total detections (Comfort 2017).

Big Basin

A-V surveys began at Big Basin State Park in 1991 and have continued through 2016 with a few gaps in coverage (Table 2-6 page 41 and Table 2-7 page 44). In the early years, murrelet activity levels in Big Basin were higher than anywhere else in Zone 6. Dawn A-V survey means in Redwood Meadow, the main Big Basin station that is still used today, were always more than 100 total detections, and some single days had more than 300 total detections (Singer, unpub. data). Due to such high detection rates, this site was historically used as the local training site for protocol-level A-V surveyors. That all changed about 1998, when the mean dropped to 78.6, and by 2005 it had dropped to 8.4. (Figure 2-11 page 21). This unprecedented decline was well documented by David Suddjian who did 247 surveys in the Redwood Meadow and adjacent parking lot over the 1991 to 2009 period (Suddjian 2003c, 2006, 2009a, 2010). An overlapping series of A-V surveys (3 per year) was conducted in Redwood Meadow from 2003 to 2015 and at four other sites within the park from 2003 to 2011 (Shaw 2011, Singer 2015). Detections at the other Big Basin sites were always

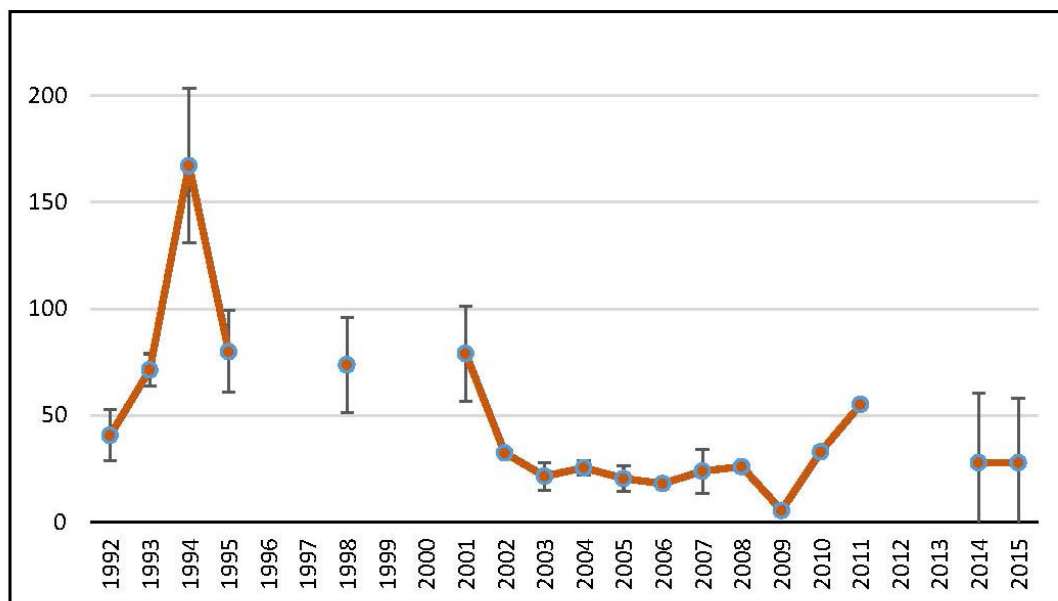


Figure 2-10. Mean Total A-V Detections, Portola State Park, 1992-2015

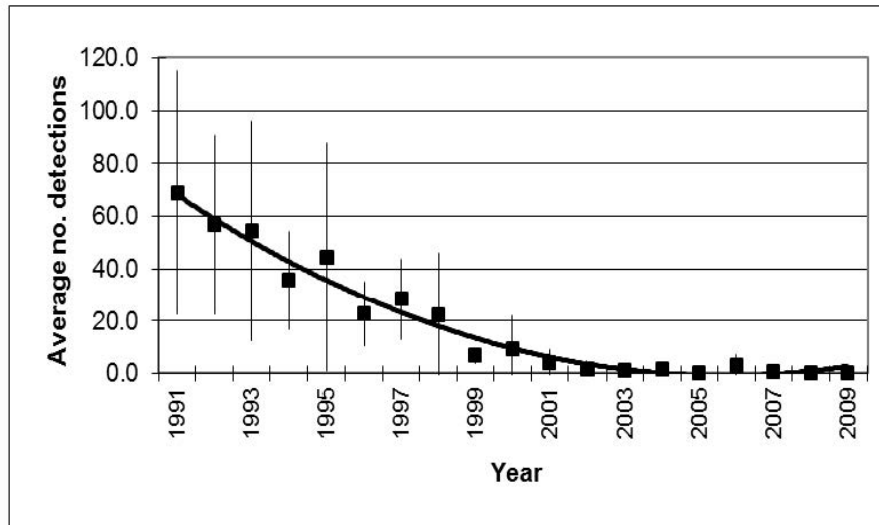


Figure 2-11. Mean Total A-V Detections, Big Basin, 1991-2009 (data from D.L. Suddjian)

less than at Redwood Meadow, hence these sites were discontinued in 2014.

What caused the decline in murrelet numbers in Big Basin is not known, but an increase in raven numbers occurred concurrently with the decline and they have been shown to be effective predators of murrelet nests (Chapter 3, this Plan). Decreased recruitment of young, perhaps in combination with significant adult mortality from peregrine falcons that nest along the murrelet flyway into the park, could have caused the decline (Chapter 4, this Plan). Another possible explanation is that, in the face of the increased predation risk, murrelets switched their breeding location from Big Basin to a nearby area such as Gazos Mountain Camp or Scott Creek, and so the number of birds flying into the Basin was greatly reduced. However there was no corresponding sign of an increase in numbers at Gazos.

Data from a large number of A-V surveys on Redwood Empire timber lands in the upper Gazos Watershed in recent years suggests that the birds flying into the Gazos Creek Watershed are not the same birds nesting in Big Basin, as there have been no detections of birds flying over the ridge into Big Basin or vice-versa. Murrelets are known to have a

high degree of breeding site fidelity, so it is unlikely they would start nesting somewhere else if suitable nest trees were still present in their natal stand.

Recent A-V surveys in the Basin continue to observe occupied behaviors and in the last three years total detection numbers have increased slightly. Both of these are signs of hope for Big Basin.

Radar Surveys

Surveys using modified marine radar can be used inland to locate murrelet flyways, compare the number of murrelets using different flyways, and if enough surveys are done, determine trends in murrelet use over time.

The first use of modified marine radar to detect murrelets in the Santa Cruz Mountains was by Singer and Hamer in 1998 (Singer and Hamer 1999). During the period 1999 to 2010, 5–10 radar surveys were done each year (Singer and Colclazier 2010, Colclazier et al. 2010). Surveys during the first few years were exploratory in nature, testing the feasibility of the method in the terrain of the Santa Cruz Mountains (trying out valley floor, hillside, and ridge-top locations), testing the ability of the radar operator to separate murrelet targets from other local birds that could be confused with murrelets on radar,

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

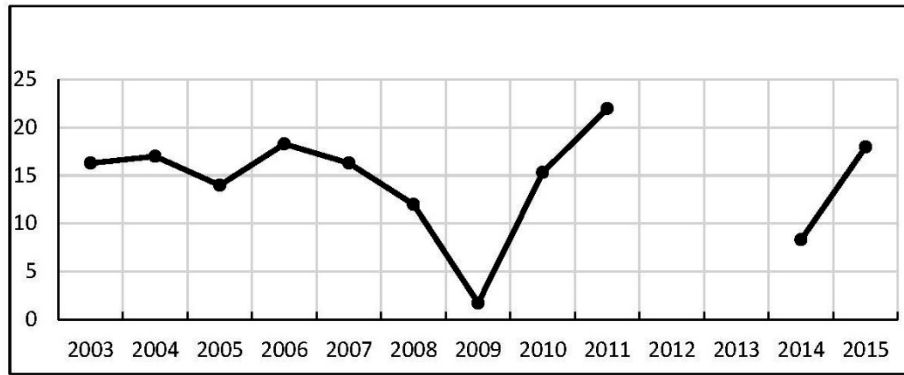


Figure 2-12. Mean Total A-V Detections, Big Basin, 2003-2015

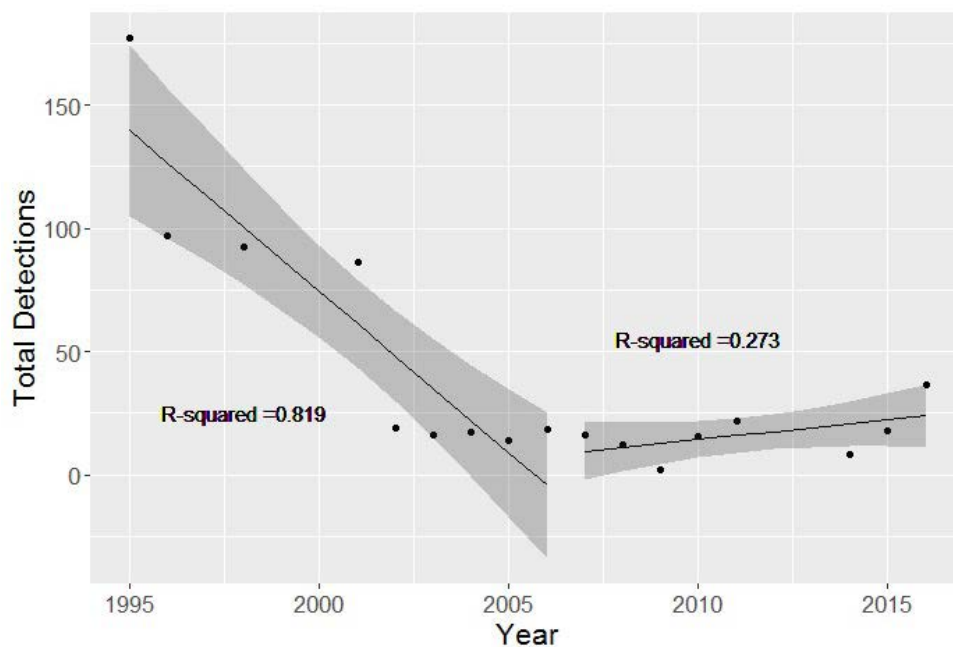


Figure 2-13. Trends in total A-V detections at Big Basin State Park both before and after the onset of efforts to control corvid numbers in 2006. The trend line from 1995 to 2006 is statistically significant ($F_{1,7} = 31.57, p < 0.001$). The trend line from 2007 to 2016 is not (Comfort 2017).

and attempting to locate murrelet flyways (Singer and Hamer 1998).

Flyways are travel corridors that are regularly and repeatedly used by murrelets to fly from the ocean to their inland breeding sites and vice-versa. They are typically located in canyons or river valleys with high ridges that funnel birds into a route that follows the stream upstream. The downstream starting point of a flyway was determined by radar detections of a number of murrelets moving in a parallel alignment with the direction of the stream. Upstream end

points were determined either by the location of the most inland breeding site along the valley, or where a confining canyon ends in more than one tributary containing potential breeding areas that have not been surveyed. To be classified as a flyway, the route must be used by more than just a few murrelets, and the birds must be detected flying in both directions.

Ultimately four murrelet flyways were found by radar.(Figure 2-2 page 14). From north to south these are Pescadero Creek, Butano Creek, Gazos

*Table 2-3. Radar Survey Effort in the Santa Cruz Mountains 1998–2010
Number of Surveys¹*

Year	Station				
	Butano	Little Butano	Pescadero	Waddell	Gazos
1998	-	1	-	2	0
1999	1	-	-	1	0
2000	1	1	2	-	7
2001	3	2	-	4	7
2002	4	-	4	4	7
2003	-	-	-	-	0
2004	-	-	-	-	7
2005	-	-	-	-	0
2006	-	-	-	-	7
2007	-	-	-	-	0
2008	-	-	-	-	7
2009	3	3	3	3	3
2010	-	-	-	-	7
TOTAL=	12	7	9	14	45

¹Excluding those done after August 1.

Creek, and Waddell Creek. An additional radar survey station was established on Little Butano Creek.

One flyway, Gazos Creek, was selected for regular murrelet monitoring with the goal of detecting any trend in murrelet numbers over time, and it was monitored annually initially, then biannually, from 1999 to 2010 with 7 radar surveys per year. The three other flyways were surveyed only intermittently—with 7–18 surveys done at each site, most occurring from 1999 to 2009 (Table 2-3 page 23).

Figure 2-14 page 24 shows mean yearly total radar detections at all five sites and Figure 2-2 page 14 shows the locations of the radar survey stations. It can be seen from Figure 2-14 page 24 that more murrelet use occurred in the Pescadero, Waddell, and Gazos sites than at the Butano and Little Butano sites. A more complete comparison including statistical analysis of the data can be found in Colclazier et al. (2010) who also tested for any long-

term trends in use at each site. They found that there weren't enough years surveyed and/or number of surveys done per year to allow detection of any long-term trends in murrelet numbers at any site including Gazos which was surprising. The problem at Gazos was that detections were part of a cyclical trend rather than the simple linear trend that the researchers were expecting.

Detecting statistically-significant trends with radar data is difficult if the population is declining only slowly. In a study done in northern California, Bigger et al. (2006) found that to detect a 2.5% annual decline with 80% power over 10 years (i.e., an overall population decline of 22%) in a large and widespread murrelet population, four radar surveys would be needed each year at each of 22 sites, for a total of 88 surveys per year. If the site were smaller, a smaller effort would suffice. Other, perhaps more cost-effective, uses of radar would include using radar to locate new watersheds being used by

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

murrelets or using radar to compare the relative use levels of different watersheds.

More radar surveys were done at Gazos than at any other flyway. Gazos Creek canyon was chosen for long-term radar monitoring because it contains Gazos Mountain Camp. This parcel was purchased, in part, with oil spill mitigation money, and the Apex Houston Trustee Council made additional money available to monitor marbled murrelet use of the property.

The monitoring site selected, officially known as Double Low Gazos, but referred to here as simply Gazos, was 2.3 miles (3.7 km) downstream of the Gazos Mountain Camp. It was the best site available, but was located near the mouth of the canyon with no confining high ridgeline on the north side. The original goal was to have the statistical rigor to detect a 10% annual population decline with 90% power. Based on June 1999 data, a power analysis showed that six years with 7 surveys per year could achieve this goal (Singer and Hamer 1999a). In subsequent years the goal was changed to be more relevant - to detect a 5% annual decline

with 80% power since a 10% annual population decline over 6 years would mean that the total population would have decreased by about 25% over that time period. The surveys were done in July.

Seven years of radar surveys were done with the goal of being able to detect a 5% annual change in murrelet numbers at 80% statistical power. After seven years of surveys that goal was not reached due to higher than expected year to year variability in the data. As more years of data were collected, it became apparent that the detection numbers weren't following a simple linear trend, instead there was a cyclical trend in play, with periods of several "high" years followed by periods of several "low" years (Verschuyl 2008, Singer and Colclazier 2010, Stumpf 2010).

Interestingly, there was also a cyclical pattern in total A-V detections at Gazos Mountain Camp during this same period (Rominger 2010). The cyclicity in the A-V data set was annual and disappeared once more years of data were collected. The early cyclicity was attributed to high annual variation in the data (Comfort 2016). No cyclical

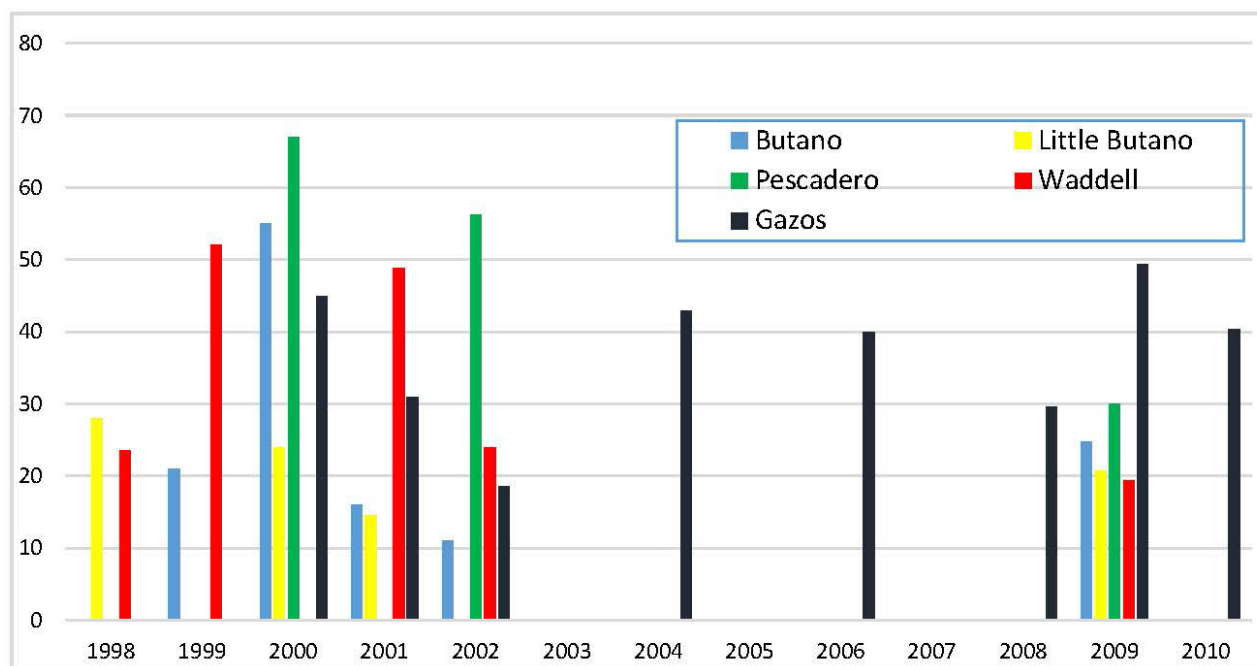


Figure 2-14. Means-Total Radar Detections at Five Stations

trends were detected at other radar or A-V survey stations.

A consequence of having a cyclical trend rather than a linear trend is that cyclical trends are more difficult to detect than linear trends and power estimate tables are based on simple linear trends and are not accurate for populations that experience cyclical trends.

One could speculate that a cyclical trend in numbers of murrelets flying inland could make sense in a biology context if, by chance, several years of poor at-sea conditions alternated with several years of good at-sea condition. Since the inshore conditions that make for good or poor years for murrelets are largely unknown.(Chapter 7, this Plan) this is a possibility. Years with poor at-sea conditions may depress breeding effort, or might only support early season nesting and not re-nesting. If the latter situation were to occur, radar surveys which are done in July, such as these, could have missed the entire nesting effort. If future radar monitoring efforts are to occur in Zone 6, they should consider more surveys and expansion of the sampling period to include the month of June.

At sites with better topography and where simple linear trends are in play, radar is still a useful tool in determining trends in murrelet numbers. There is much less within-year variability in radar data sets than in A-V survey data sets (see Figure 2-15 page 26).

Of the five radar stations used, the stations on the Waddell Creek flyway and the Pescadero Creek flyway had the best topography for the purpose of concentrating murrelet movements into a corridor that could be easily scanned with radar. Other

murrelet flyways might exist along Pilarcitos Creek or Scotts Creek, but these areas have not been surveyed by radar.

DISTRIBUTION OF SUITABLE NESTING STANDS BY WATERSHED⁵

Much of the information on the distribution and abundance of murrelets on private land in the Santa Cruz Mountains has been obtained from A-V surveys and habitat assessments done on proposed timber harvests starting in 1992 under the direction or at the request of the California Department of Fish and Wildlife (CDFW), although not every proposed harvest site was visited.

The Department would then use this information to re-direct harvest activities or require mitigation measures that would effectively protect marbled murrelets and their habitat. Without this effort, murrelets in Zone 6 would likely be in a much worse situation than they are in now.

The remaining suitable murrelet nesting habitat in Zone 6 (old-growth and older second-growth forests), using 10 acre stands as the minimum size, and excluding older second-growth forest on public lands, is found in 109 different stands or stand complexes. These stands vary widely in size. There are five large stands (> 500 acres), all of which have occupied behavior. There are 81 small stands (< 50 acres), 16 of which have occupied behavior, and 35 intermediate-sized stands, 18 of which have occupied behavior. (Table 2-8 page 50 and Table 2-9 page 58).

The location of these stands is shown on a new map that was based on the CAPP report (Sempervirens Fund 2012) but revised and expanded to cover the entire breeding range in Zone 6 as it is currently

⁵ Information on murrelet presence or occupancy for each stand were largely drawn from the CDFW Marbled Murrelet database, THP consultation letters from the CDFW, pre-harvest A-V surveys done by John Bulger,

David Suddjian, and others; radar and A-V survey monitoring programs supported by oil spill mitigation funds, and information gathered by the author and included in the Sempervirens Fund CAPP report.

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

known. The map is too large to include in this report but can be requested from the editor. The new map shows the location of all potentially suitable murrelet stands greater than 10 acres in size. Both old-growth and older second-growth stands were originally delineated by stereoscopic review of large scale aerial photos. More detailed information about how the stands were delineated can be found in Moore and Singer (2014) and Sempervirens Fund (2012).

The five largest stands, consisting of old-growth forest, are Big Basin State Park (4,406 acres), Portola State Park (974 acres), Upper Pilarcitos

Creek (1,135 acres), Butano State Park (622 acres), and Pescadero Creek County Park (530 acres). Table 2-9 page 58 gives information on the size, ownership, and extent of murrelet activity in each stand. Table 2-10 page 63 shows watersheds that contain the greatest acreage of remaining murrelet habitat, and lists the most important breeding areas located within each watershed.

The majority of the remaining habitat stands found in the Santa Cruz Mountains have large amounts of edge and are surrounded by rural residences, recreation sites, agricultural lands, commercial lands, and roads. This heavy human footprint leads

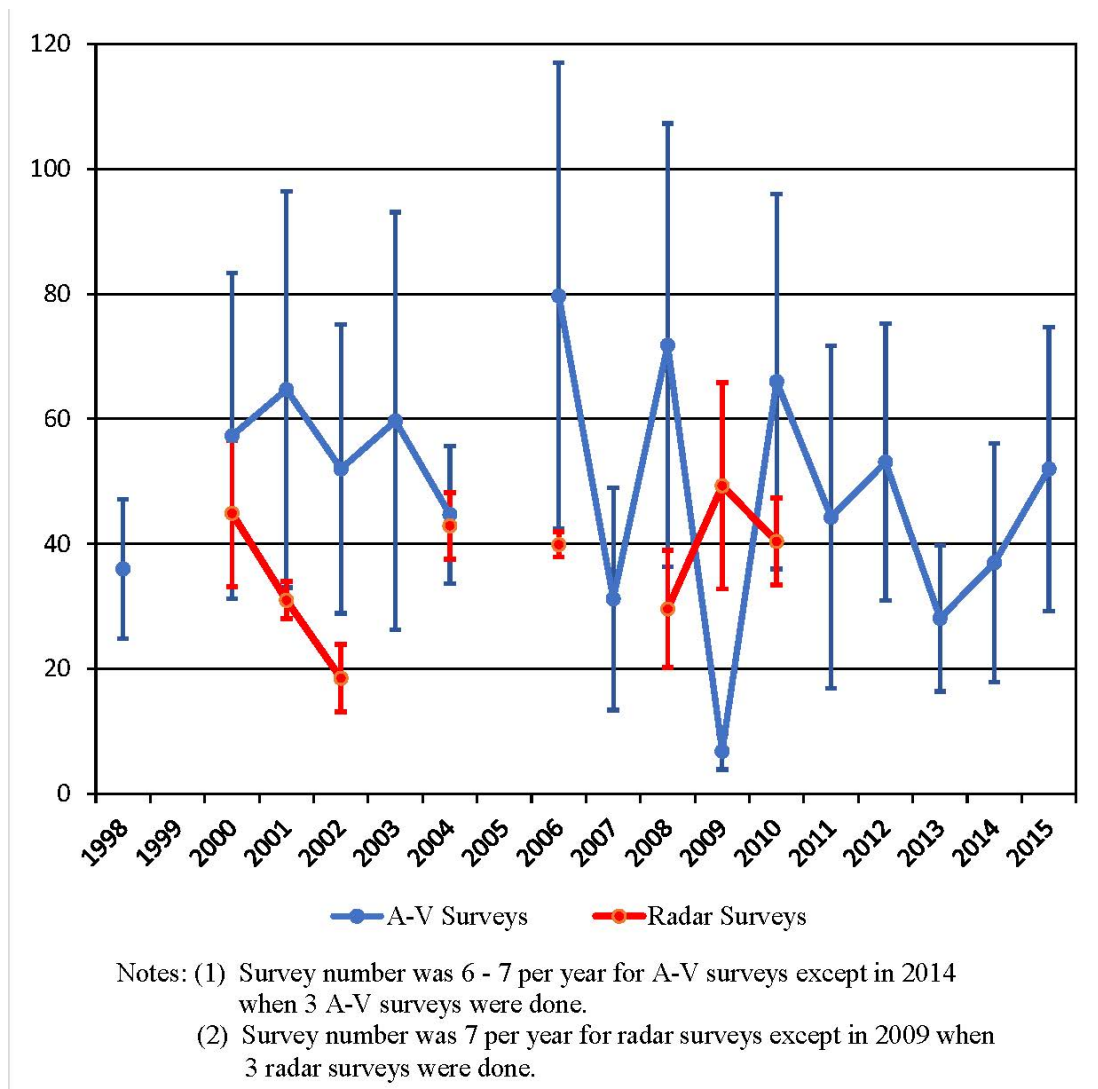


Figure 2-15. Radar and A-V Results with Standard Deviation for Gazos, 1998 - 2015

to elevated numbers of murrelet nest predators in or near murrelet habitat. Remnant habitat patches surrounded by managed timberlands and far from other human land uses provide the best remaining habitat. These areas are typically unimproved areas of state and county parks, and relatively remote timber company lands with suitable nest trees, where harvesting has been prohibited or tightly controlled. Stands that fall into this category include remote areas of Big Basin, Portola, and Butano state parks, the SFPUD lands on Upper Pilarcitos Creek, and the Scott Creek and Pescadero units of Big Creek Lumber Company. There also exist some fairly large stands that have never been surveyed, namely, the Michelson property on Pescadero Creek and the Boyer Creek "A" stand in the Big Creek Watershed. (Table 2-9 page 58 and Table 2-8 page 50).

A significant number of the known murrelet breeding sites in Zone 6 have not been surveyed in 10–15 years and their current status is unknown. New A-V surveys are needed in these areas to determine if they still support murrelets or if murrelets have stopped using them. This is especially true for small areas on the periphery of the breeding range. These areas may support only one or a few breeding pairs so might be the first to disappear in an overall decline of the Santa Cruz Mountains population. Examples of sites that fall into this category can be found at Fall Creek, Purisima Open Space Preserve, and upper Pescadero Creek.

Loss of these areas might provide an early indication Loss of murrelets from these areas might provide an early indication that the overall population is in trouble, as they might be subject to local extirpation if the population as a whole is contracting. Re-surveys of these areas could provide helpful information on the status of the population as a whole.

GROUPING STANDS INTO LANDSCAPE UNITS FOR CONSERVATION MANAGEMENT

Selecting and Evaluating Important Murrelet Areas

The combination of old-growth and older second-growth stands with residuals provide a good estimate of total habitat within the murrelet breeding range in Zone 6. The size and distribution of old-growth stands in the Santa Cruz Mountains have been known for some time (Singer, 2003). Older second-growth stands include those on private lands located for the CAPP project (Sempervirens Fund 2012), those delineated on Midpeninsula Regional Open Space District lands by Harvey and Associates (2007) and estimates of the amount of older second-growth in both Pescadero Creek County Park and other sites whose acreage was estimated. When added together, these areas total more than 15,000 acres of suitable murrelet nesting habitat in the Santa Cruz Mountains.

The watersheds that contain the most murrelet habitat are listed in Table 2-10 page 63. Many stands have documented murrelet activity occurring on or near them. Some have not been surveyed and may or may not have murrelet presence. However even stands that don't have murrelet presence now will be important in the long-term for the recovery of the murrelet in California (Pacific Seabird Group 2010) and locally, especially if they are large. At present, murrelet numbers in the Santa Cruz Mountains are so low that they are not limited by the availability of nest sites (Peery and Henry 2010). However there appears to be the need for more high-quality nesting sites, specifically those sites with a low density of nest predators, and several older second-growth stands with residuals may provide this kind of high quality nest site.

Seven broad areas that are especially valuable for murrelets have been located within the Zone 6 breeding range. These areas are designated as "Important Murrelet Areas" and are defined as those areas containing one large occupied nesting stand or

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

a combination of nesting stands of various sizes. The seven Important Areas and their acreages, from south to north, are: (1) Mill Creek–Big Creek (1,740 acres), (2) Scott Creek (1,739 acres), (3) Big Basin (8,640 acres), (4) Butano–Gazos (6,394 acres), (5) Lower Pescadero (2,606 acres), (6) Middle Pescadero–Portola (7,214 acres), and (7) Upper Pilarcitos (1,642 acres). Table 2-11 on page 65 further describes these Areas and Figure 2-16 on page 29 maps their locations.

Important Murrelet Areas were first mapped for the CAPP project (Sempervirens Fund 2012) but the boundaries and size of these areas were revised for this report in order to incorporate new and more accurate information that became available. Table 2-11, page 65, describes nesting habitat conditions and murrelet activity levels in each Area along with a similarly-based rating for the Upper Pilarcitos Creek Important Murrelet Area which was not included in their project area. Privately-owned stands within the best of these Important Murrelet Areas should be given the highest priority for protection, either by acquisition, conservation easement, or by other means.

Only three of the seven Important Murrelet Areas could be considered to be remote from human development. A major two-lane highway runs through the Lower Pescadero area. Minor paved roads border or run through the Middle Pescadero–Portola area and the Butano–Gazos area. The Big Basin area has a state highway running through the eastern portion, although the western part is a wilderness area. Only the Scott Creek and Mill Creek Area and the Upper Pilarcitos Creek Area are free of paved roads.

Three of the Important Murrelet Areas consist primarily of private lands, one is a mixture of public and private lands, and three consist primarily of public lands. Two of the seven areas (Mill Creek–Big Creek and Upper Pilarcitos Creek) have not had documented physical evidence of murrelet nesting

such as an actual nest, eggshell fragments, or a grounded fledgling found, but occupied behavior has been regularly detected in the Upper Pilarcitos Area. The Mill Creek–Big Creek Important Murrelet Area is too remote and private to have allowed much, if any, searching. All seven areas are high priority for conservation/protection.

Delineation of Important Murrelet Areas was based on degree of habitat fragmentation, stand size, number of stands and their proximity to each other, condition and use of lands in the non-habitat landscape matrix, the location of murrelet flyways, and murrelet activity levels at known nesting stands. In each case (except for the Mill Creek–Big Creek Area), the Area had at its core a large occupied stand. Nearby suitable habitat stands were included in the area as long as they were accessed via the same murrelet flyway, there were no blocking high ridges, and the intervening non-habitat areas had a compatible land use. The requirement to be “near” was sometimes waived if the intervening habitat was all managed timberland and the area was remote from human disturbances. Each area thus consists of one or more core habitats and several outlying satellite habitat stands. This is the next-best configuration to having one large contiguous habitat area, when such an area is not available (Harris 1984).

Several studies have indicated that nest predation rates are higher in fragmented stands than in larger contiguous stands. Malt and Lank (2009) studied the effect of stand size and type of edge on murrelet nest predation rates in old-growth forest in coastal British Columbia. They created artificial murrelet nests on suitable murrelet nest platforms and monitored their fate with cameras. Nest predators detected at these sites included raptors, corvids, deer mice, and squirrels. They found that the likelihood of nest disturbance was 2.5x greater at hard edges (such as changes from timberland to agricultural use) than at interior sites. They recommended the protection of larger stands since they will minimize the amount of

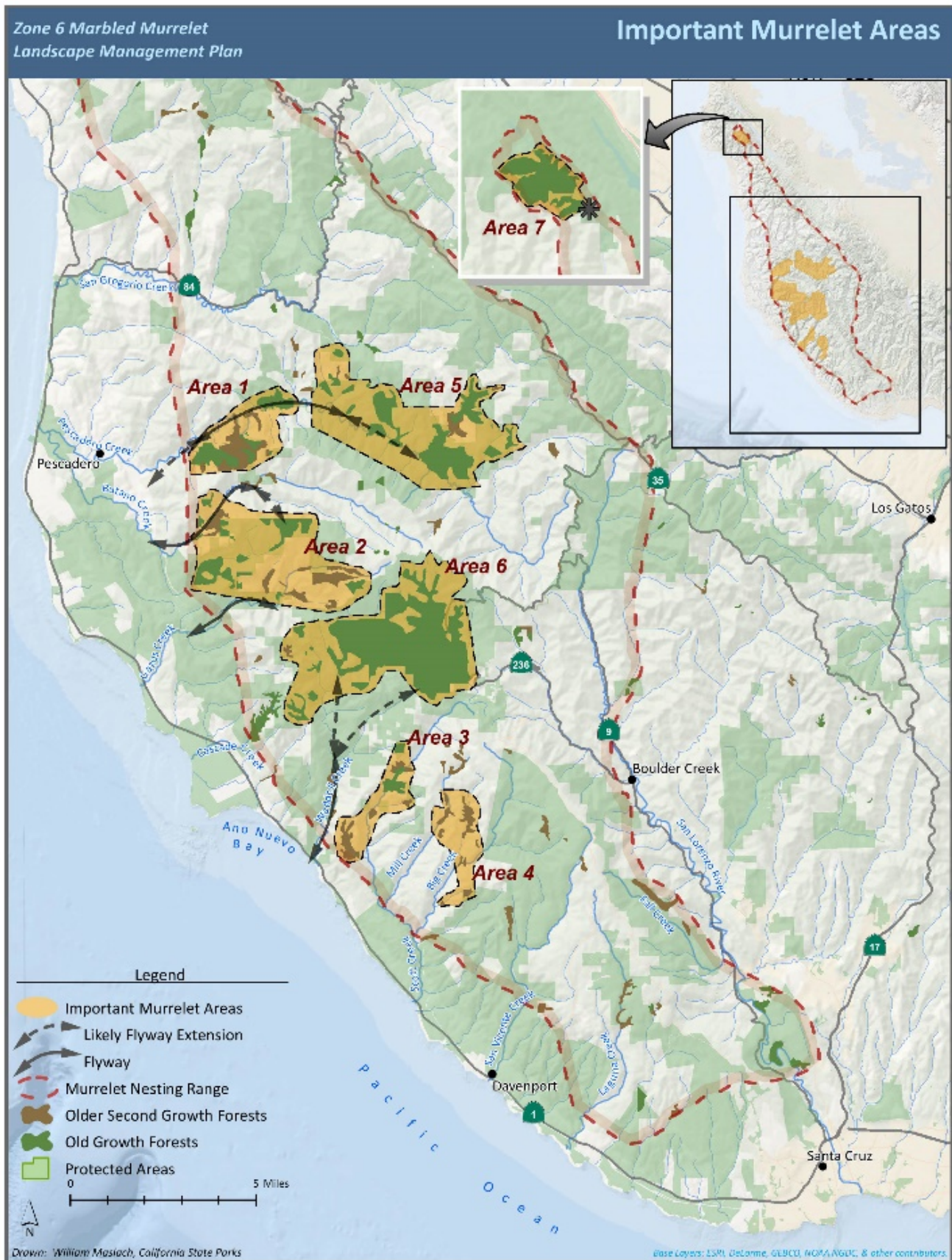


Figure 2-16. Important Murrelet Areas

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

habitat exposed to hard edge effects. They went on to say, "when larger patches are not available, we recommend designating many smaller reserves that are embedded in a matrix of regenerating forest."

Large stand size is also important for ecological integrity and to preserve rare or sensitive species. Large stands are more resistant to detrimental edge

effects, such as high winds, increased ambient air temperature and increased solar irradiation (Harris 1984). Unfortunately, large old-growth forest stands are rare in the Santa Cruz Mountains. There are only six old-growth stands larger than 150 acres and four older second-growth stands larger than 150 acres in Zone 6 (Table 2-8 page 50 and Table 2-9 page 58).

THREATS TO MURRELETS AND THEIR NESTING HABITAT

1. Loss of habitat in important murrelet breeding areas due to fire, windstorm, or other events causing tree failure. Crown fires will kill old-growth Douglas-firs and burn off potential nest branches on redwoods. Old-growth redwoods primarily die by falling. They can fall if hit by another falling tree, or if shaken out of balance by an earthquake or a severe windstorm. Although new platforms in the form of broken tops are sometimes created by these catastrophic events, there is usually a net loss of nesting platforms.

For these reasons all remaining large stands of old-growth or older second-growth forest needs to be protected. It is likely that optimal murrelet habitat will be found in large stands or in clustered groups of moderate-sized stands within a matrix of older second-growth stands.

2. Degradation of habitat in important murrelet breeding areas due to encroachment of incompatible land uses on surrounding lands and within the overall landscape matrix. Such land uses as farms, vineyards, recreation sites, and residential developments will attract more murrelet nest predators to the area.
3. Predation of adults by peregrine falcons. The potential for high rates of adult predation exist if peregrine nests are located along murrelet flyways or close to one, as is the case in the Waddell Creek Watershed and the South Fork Butano Creek Watershed.
4. Loss of residual Douglas-fir potentially-suitable nest trees in older second-growth stands. These trees were not harvested during early-day logging operations and many of them have now reached the end of their normal life span. There are few trees in the younger age class that is slightly smaller in size, to replace them. As they fall, the number of nesting sites will be reduced.
5. Increases in intensity of disturbances associated with new types of recreational activities, such as flying recreational drones in nesting stands, inland aggregation sites (meadows and forest clearings), or in murrelet flyways.

DATA GAPS AND INFORMATION NEEDS

High Priority Information Needs:

1. Field studies on Peregrine Falcons. Studies are needed to determine their nest distribution in relation to murrelet flyways and breeding areas, and their impact on murrelets (i.e., how many adult birds do they take each year?). If a significant impact, possible mitigation measures could be explored and presented for action.
2. Surveys (either radar or A-V) to determine murrelet activity levels in the Scott Creek old-growth stands. The last surveys there were done in 2002. Investigate the possibility that breeders at Big Basin, in the face of high nest failure rates and high adult predation from peregrine falcons nesting along the flyway to Big

Basin, have broken with their tendency for site fidelity and moved their nesting area to Scott Creek. John Bulger reported observing a possible murrelet flyway from Año Nuevo Bay directly to the Lair Gulch area, passing over a small ridge. It might be possible to do radar surveys along this flyway.

3. A-V surveys on large parcels of suitable habitat that have never been surveyed before. Surveys should be done at the Michelson property on Pescadero Creek, stands in El Corte de Madera Open Space Preserve stands “A” and “B”, Boyer Creek “A” stand, Mill Creek “A” and Mill Creek “B” stands on the Lockheed-Martin property.
4. A-V or ARU surveys on important occupied stands that have not been checked for 10 years or longer. These stands would include: Hidden Gulch-BCL, Dearborn Valley-BCL, Purisima Creek Open Space Preserve, Scott Creek-BCL, Scott Creek–Locatelli, Cascade Creek, and the western part of Big Basin.

Other Information Needs:

1. An Assessment of the impact of the Lockheed Fire on murrelet habitat in the Mill Creek and Boyer Creek watersheds. There is also the need to conduct A-V surveys in these watersheds.
2. Long-term radar monitoring of the Waddell Creek flyway and also the largest remaining murrelet flyway in Zone 6—the Pescadero Creek Flyway. Consider modifying the usual survey protocol (dawn surveys during July) to include additional radar surveys at dawn and at dusk during June to provide better coverage of the breeding season. In early season, the only murrelets detected would likely be active nesters. Consider the use of stationary automatic radar monitors that can detect and store murrelet tracks on a daily basis.
3. A field study to provide quantification of tree, branch, and platform conditions at forest stands associated with the best breeding sites—Butano (Little Butano Creek) and Gazos Mountain Camp in Butano State Park.
4. A-V re-surveys of small occupied sites that are remote from other sites, and haven’t been checked in a long time, such as Pescadero Creek-Water Tank Creek, and Fall Creek—“A”.
5. Remote observation of more active murrelet nests to provide more information on nest site parameters and the relationship of those parameters to nest predation events.

MANAGEMENT PLAN RECOMMENDATIONS

Recommendations To Protect or Expand Nesting Habitat

1. Encourage land trusts, land conservancies, and other government agencies to acquire or protect by easement privately-owned occupied nesting habitat within Zone 6. Also encourage acquisition or protection by easement of suitable buffer lands bordering occupied murrelet stands. Assist potential conservation buyers by providing maps showing Important Murrelet Areas and maps of occupied nesting sites with the greatest murrelet use.
2. Explore the formation of a partnership with the San Mateo County Resource Conservation District to instigate a private landowner murrelet education program within the Pescadero Creek Watershed. The program would seek to educate land owners within Important Murrelet Areas of land use management techniques that minimize the availability of food subsidies for ravens and jays, such as proper garbage management. A murrelet “ranger” would be hired to: (1) identify sites that provide food subsidies for corvids, (2) develop suitable alternative land use practices for those sites (murrelet habitat BMPs), and (3) meet with land owners to encourage and assist with their implementation. Outreach efforts would focus on youth camps, ranchettes, horse stables, farms, vineyards, recreation sites, and residential areas.
3. Protect publicly-owned occupied nesting stands from new disturbances or new activities that bolster corvid populations by prudent placement of recreational improvements and new developments. Require mitigation measures that protect nesting murrelets from increased levels of nest depredation.

Recommendations to Monitor Inland Distribution and Use by Breeding Murrelets

1. Continue inland A-V surveys in at least three of the four long-term stations with 5 surveys per year in July, with special attention to flight behaviors associated with nesting individuals.
2. If permission from the landowner can be obtained, do Acoustic Recording Unit (ARU) surveys in occupied habitat on privately-owned timberland at Scott Creek and in the Pescadero Watershed at Hidden Gulch. These stands have not been surveyed since 2002.
3. Use automatic continuous-recording radar tracking devices to capture and census murrelet flights in the Waddell Creek and Pescadero Creek murrelet flyways as part of a long-term monitoring effort. Daily radar sampling should allow for statistically valid trend analysis of murrelet use within each watershed from year to year.
4. Conduct A-V or ARU surveys at known occupied stands that haven’t been surveyed for several years. Stands to consider are these: Fall Creek Unit of Henry Cowell State Park; Purisima Creek Open Space Preserve; North Slope stand in Butano State Park; Cascade Creek; and the West Waddell Wilderness Area in Big Basin State Park.
5. Initiate a citizen-scientist program using volunteers to collect raven information in Important Murrelet Areas. Information would include foraging observations and the location of nests, juvenile roosts, and food bonanzas.
6. Conduct research, perhaps using artificial murrelet nests, to identify all significant murrelet nest predators, including potential mammalian predators, in Big Basin and Butano State Parks. Such a study would give park managers a better understanding of which predators are of greatest concern.

Recommendations to Better Understand the Quality of Murrelet Nesting Habitat

1. Conduct a comparison study of nest platform conditions in heavily-used occupied stands and also lightly used occupied stand in an attempt to determine what makes an optimal nesting site for murrelets.

Recommendations to Better Share and Archive Zone 6 Murrelet Research and Monitoring Data

1. Store copies of all research and monitoring data, including raw data, in a site where it can be safely stored for the long-term and made available to murrelet researchers when needed. Both digital and hard-copy data (paper documents, video tapes, etc.) should be stored. State Parks Department should be asked to provide a temporary site for archiving data, but the long-term archive should be under the control of a local, science-based nonprofit public benefit corporation with an endowment for operation and maintenance. Digital data can be stored on the cloud and perhaps utilizing storage space on the cloud provided as a donation from a large Silicon Valley computer corporation.

ACKNOWLEDGMENTS

This chapter would be much less complete without the pioneering field work of David Suddjian. On behalf of the entire murrelet research community, I want to thank him for his efforts. I also wish to thank Robynn Swan of the California Department of Fish and Wildlife, Bill Maslach, and Emily Comfort. Robynn provided important new information on habitat locations and murrelet occurrences. Bill produced the stand habitat map and also the first iteration of the figures. Emily provided statistical analysis on the limited data that was suited for such a review. Thanks also go to those who reviewed and commented on this chapter—Martin Raphael, Laird Henkel, and Zach Peery. Their comments were often helpful

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

TABLES

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence^{1,2}

<u>Type of Evidence</u>	<u>Map ID</u>	<u>Date Discovered</u>	<u>General Location</u>	<u>Specific Location if known</u>	<u>Comment</u>
Juv	J-1	6/15/1957	Portola St Pk	In creek, swimming area.	
Juv	J-2	8/18/1960	Big Basin Park	Campground A	
Juv	J-3	6/27/1971	Portola St Pk	Unknown	
Juv	J-4	summer, 1972	Portola St Pk	Unknown	
Juv	J-5	6/17/1973	Big Basin Park	Opal Creek, in the water	
Juv	J-6	7/xx/1973	Memorial Park	Campsite 1, Azalea Flat	
Nest	N-1	8/7/1974	Big Basin Park	J Camp, Campsite J-1	Chick collected
Juv	J-7	9/9/1974	Big Basin Park	Huckleberry Campground	
Juv	J-8	8/31/1975	Loma Mar	Near Post Office, in rain puddle in driveway	
Juv	J-9	6/12/1976	Big Basin Park	Opal Creek, 60' from restrooms	
Juv	J-10	7/4/1976	Big Basin Park	Hwy 236 near H camp	
Juv	J-11	8/31/1977	Big Basin Park	Sky Meadow Rd, between Huckleberry & Wastahi	
Juv	J-12	6/14/1979	Big Basin Park	Redwood Trail, near Opal Cr bridge	
Juv	J-13	7/11/1982	Memorial Park	Legion Flat, by restroom, at "Memorial" A-V station	
Juv	J-14	8/11/1982	Big Basin Park	Unknown	
Juv	J-15	5/1983 or 5/1984	San Mateo Co Honor Camp	swimming area in Pescadero Creek - inholding within Pescadero Creek Co. Park	
Juv	J-16	5/18/1984	Big Basin Park	Bloom's Cr Campground, site 120	
Juv	J-17	8/31/1985	Loma Mar	Unknown. Just outside Memorial Co. Park	
Juv	J-18	1986	Harrington Creek, San Gregorio Watershed	alluvial flat above creek, at abandoned mill site.	
Juv	J-19	6/2/1988	Harrington Creek, San Gregorio Watershed	at headwaters, along creek	
Egg-shell	E-1	6/28/1988	Butano Park	On Little Butano Creek trail, downslope from campfire center	No nest found
Juv	J-20	7/19/1988	Memorial Park	Campsite B-6	
Juv	J-21	9/3/1988	Big Basin Park	Jay Camp, near tent cabins	

Murrelet Inland Distribution And Detection Numbers in Zone 6 **Chapter 2**

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence^{1, 2}

<u>Type of Evidence</u>	<u>Map ID</u>	<u>Date Discovered</u>	<u>General Location</u>	<u>Specific Location if known</u>	<u>Comment</u>
Chick	C-1	5/20/1989	Big Basin Park	Connector Trail to Waddell Cr Trail	
Nest	N-2	6/3/1989	Big Basin Park	Opal Creek picnic area, nest tree	predated by raven
Nest	N-3	6/28/1989	Big Basin Park	Waddell Creek, road to Sewage Treatment Plant	predated by steller's jay
Juv	J-22	8/15/1990	Big Basin Park	Skyline to Sea Trail, at N Escape Rd	
Nest	N-4	5/5/1991	Big Basin Park	Redwood Trail, in Father Tree (#1)	Successful fledge, 7/3
Nest	N-5	5/24/1992	Big Basin Park	Redwood Trail, in Father Tree (#2)	Successful fledge, 6/7
Juv	J-23	8/25/1992	Big Basin Park	Sewage Treatment Plant Road	
Egg-shell	E-2	5/8/1993	Big Basin Park	Below the Father Tree	Probable raven predation
Juv	J-24	9/5/1993	Big Basin Park	In Huckleberry Campgr, near Union Creek	
Nest	N-6	5/7/1994	Big Basin Park	Redwood Trail, in Father Tree (#3)	nest failed
Egg-shell	E-3	6/9/1994	Big Creek Lumber Property, Pescadero	Dearborn Valley Station P-7	
Egg-shell	E-4	6/13/1994	Butano Park	North Slope grove, near Station A-3	
Egg-shell	E-5	7/24/1994	Butano Park	North Slope grove, WNW of Station A-3	
Nest	N-7	6/28/1995	Big Creek Lumber Property, Pescadero	Hidden Gulch near Station J	predated by raven
Juv	J-25	8/27/1995	Dearborn Park Community	Two puncture wounds in its back. Commercial nursery not far from Big Creek Lumber's Dearborn Valley property.	
Nest	N-8	6/8/1996	Big Basin Park	Redwood Trail, in Father Tree (#4)	nest failed after only 1 week
Nest	N-9	7/9/1996	Big Basin Park	Leask Grove tree, Opal Creek	Successful fledge, 7/21
Juv	J-26	7/22/1996	Butano Park	North slope grove near Station B-4	Took flight when approached
Juv	J-27	7/29/1996	Big Basin Park	Sequoia Trail at connector road to Jay Camp	

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence^{1, 2}

<u>Type of Evidence</u>	<u>Map ID</u>	<u>Date Discovered</u>	<u>General Location</u>	<u>Specific Location if known</u>	<u>Comment</u>
Nest	N-10	xx/xx/1997	Big Basin Park	Berry Creek Falls	radio-tagged bird, failed
Nest	N-11	xx/xx/1997	Portola St Pk	near Iverson Creek	radio-tagged bird, predated by Red-Sch Hawk
Nest	N-12	xx/xx/1997	Big Creek Lumber Property, Scott Creek	Lair Gulch	radio-tagged bird, failed
Juv	J-28	xx/xx/1997	Gazos Creek	On the creek, 2.5 miles from ocean	dead, Ref= CDFW letter
Nest	N-13	6/13/2000	Butano Park	North slope grove near Station B-4	radio-tagged bird, failed
Juv	J-29	6/23/2000	Butano Park	North slope grove near Station A-4	
Nest	N-14	xx/xx/2001	Scott Creek	Locatelli stand near Big Creek Lumber property	radio-tagged bird, predated by raptor
Nest	N-15	xx/xx/2001	Big Basin Park	Bloom's Creek Campground, #1	radio-tagged bird, failed
Nest	N-16	xx/xx/2001	Big Basin Park	East Fork Waddell #1	radio-tagged bird, failed
Nest	N-17	xx/xx/2001	Big Basin Park	East Fork Waddell #2	radio-tagged bird, failed
Nest	N-18	xx/xx/2001	Big Basin Park	Opal Creek #2	radio-tagged bird, failed
Nest	N-19	xx/xx/2001	Big Basin Park	Sempervirens Creek	radio-tagged bird, failed
Chick	C-2	7/2/2002	Big Basin Park	Chick seen being carried by raven, in Opal Creek Picnic area, near jct. of North Escape Rd. & Gazos Creek Rd. Nest never located.	predated by raven
Nest	N-20	7/15/2002	Big Basin Park	Bloom's Cr Campground #2, near campsite #125.	predated by raven
Juv	J-30	8/30/2002	Purisima Open Space Preserve	near confluence of Soda Gulch & Purisima Creek.	
Egg-shell	E-6	5/25/2005	Big Basin Park	North Escape Rd. in Hundred Acre Woods. Nest location and outcome unknown.	No signs of predation
Juv	J-31	6/25/2009	Butano Canyon Road	Unknown	
Juv	J-32	7/19/2013	Big Basin Park	Unknown	
Juv	J-33	6/22/2016	Portola St Pk	In the creek on Nature Loop Trail	

Murrelet Inland Distribution And Detection Numbers in Zone 6 **Chapter 2**

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence^{1, 2}

<u>Type of Evidence</u>	<u>Map ID</u>	<u>Date Discovered</u>	<u>General Location</u>	<u>Specific Location if known</u>	<u>Comment</u>
Juv	J-34	7/15/2016	Big Basin Park	North Escape Rd.	
Juv	J-35	8/8/2016	Whitehouse Canyon Road		

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-5. Characteristics of the 20 Known Marbled Murrelet Nests in Zone 6

	NAME	DATE FOUND/ HOW/ NEST STAGE	I/N ¹	DATE ENDED/ OUTCOME	TREE SP/ dbh(cm)/ ht (m)	LIVE CROWN (Vert. Extent) (m)	STAND CANOPY COVER (%)	PLATFORM TYPE/ POSITION/ Ht above ground, etc.	NEST DIST FROM TRUNK (cm)	SOURCE
1	Jay Camp (BBSP)	8/7/1974 Chick in nest found by tree pruner	N	8/7/1974 Nest & chick collected. World's 1st MAMU tree nest	Doug-fir dbh=167; ht=61	27	Open	On 41 cm dia, moss-covered branch. 45 m above the ground. Located in middle of the live crown.	6.8	Binford et al, 1975; Singer, 2014
2	Opal Creek #1 (BBSP)	6/10/1989 Stake-out. Bird 1st seen flying into tree on 06/03/1989	I	6/24/1989 Predation by CORA that took young embryo. Failed.	Doug-fir broken top; dbh=210; ht=61.2	30	40%	In abandoned bird nest of twigs, at ht of 43.7m; probably BTPI. Located on 47.7 cm dia, moss- covered branch & next to several vertical limbs (reiteration)	122	Singer et al, 1991; Singer, 2014
3	Waddell Creek (BBSP)	6/28/1989 Ground observation of incubating adult	I	7/31/1989 Predation by STJA that took young chick. Failed.	Doug-fir dbh=196; ht=61.2	50	25%	On 36.3 cm dia, moss-covered branch, at ht of 38.5m. A depression in branch.	61	Singer et al, 1991
4	Father Tree #1 (BBSP)	5/7/1991 Stake-out with ground observers	I	7/3/2003 Successful. Young observed to fledge at 2054. First MAMU nest in a redwood. First observation of fledging.	Redwood dbh=533; ht=79.2	70	40%	On a 61 cm dia bare branch, at ht of 41.1m above ground. In a depression in branch.	0	Singer et al, 1995
5	Father Tree #2 (BBSP)	5/24/1992 Stake-out with ground observers	I	6/7/1992 Successful. Young observed to fledge at 2046 hr.	Redwood dbh=533; ht=79.2	70	40%	On a 42 cm dia bare branch, at ht of 53.2m above ground. In a 3.8 cm deep groove, with green twig directly above.	0	Singer et al, 1995
6	Father Tree #3 (BBSP)	5/7/1994 In 1991 nest cup. Found by stake-out	I	5/24/1994--5/27/1994 Failed. Probable predation.	Redwood dbh=533; ht=79.2	70	40%	Nest located in 1991 nest cup	0	Singer et al, 1995
7	Hidden Gulch (BCL-Pescadero)	6/28/1995 Ground observer, responding to raven activity.	I	6/28/1995 Taken by CORA at 2018 hrs.	Doug-fir dbh=unk; ht=55-60	unk	unk	unk	unk	Suddjian, 1996

Table 2-5. Characteristics of the 20 Known Marbled Murrelet Nests in Zone 6

	NAME	DATE FOUND/ HOW/ NEST STAGE	I/N ¹	DATE ENDED/ OUTCOME	TREE SP/ dbh(cm)/ ht (m)	LIVE CROWN (Vert. Extent) (m)	STAND CANOPY COVER (%)	PLATFORM TYPE/ POSITION/ Ht above ground, etc.	NEST DIST FROM TRUNK (cm)	SOURCE
8	Father Tree #4 (BBSP)	6/7/1996 Discovered by ground observer, after eggshell found below tree.	I	prior to 06/14/1996 Failed in egg stage. Probable predation.	Redwood dbh=533; ht=79.2	70	40%	Nest in 1992 nest cup. On a 42 cm dia bare branch, at ht of 53.2m above ground.	0	Singer, unpub. data
9	PNT-66 (BBSP)	7/9/1996 Stake-out with ground observers; Chick on nest	N	7/21/1996 Successful. Young fledged at 15 min. past sunset.	Redwood dbh=174; ht=48.8	32	51%	On old squirrel nest of shredded redwood bark. Platform was 40.6x50.8 cm, at ht of 31.7m above ground	0	Singer, unpub. data
10	Berry Creek Falls (BBSP)	?/?/1997 Radio-tagged bird	I	?/?/1997 Failed in incubation stage. Possible predation	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Burkett et al. 1999
11	Portola State Park (near Pescadero Ck Co Pk)	?/?/1997 Radio-tagged bird	I	?/?/1997 Failed. Predated by RSHA.	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Burkett et al. 1999
12	Lair Gulch (BCL-Scott Ck)	?/?/1997 Radio-tagged bird. Found in nestling stage.	N	?/?/1997 Failed. Possible predation	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Burkett et al. 1999
13	North Slope Grove (Butano State Pk)	?/?/2000 Radio-tagged bird. Egg laid between June 8 - June 13.	I	7/27/2000 Failed. Unhatched egg. Possible predation of adult.	Redwood D.M.	D.M.	D.M.	On broken top, 51.5 m. above ground. Eggshell fragments and bones found indicating prior year use and likely nest predation. Other Data Missing (D.M.)	D.M.	Suddjian, 2003a; Peery et al., 2004
14	Locatelli OG Grove (Scott Creek)	?/?/2001 Radio-tagged bird	N	?/?/2001 Failed. Chick taken by raptor	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Peery et al., 2004

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-5. Characteristics of the 20 Known Marbled Murrelet Nests in Zone 6

	NAME	DATE FOUND/ HOW/ NEST STAGE	I/N ¹	DATE ENDED/ OUTCOME	TREE SP/ dbh(cm)/ ht (m)	LIVE CROWN (Vert. Extent) (m)	STAND CANOPY COVER (%)	PLATFORM TYPE/ POSITION/ Ht above ground, etc.	NEST DIST FROM TRUNK (cm)	SOURCE
15	Bloom's Creek Campground #1 (BBSP)	?/?/2001 Radio-tagged bird	I	?/?/2001 Failed. Incubation stage (Possible predation)	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Peery et al., 2004
16	East Fork Waddell #2 (BBSP)	?/?/2001 Radio-tagged bird	I	?/?/2001 Failed. Incubation stage (non-viable egg)	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Peery et al., 2004
17	East Fork Waddell #1 (BBSP)	?/?/2001 Radio-tagged bird	I	?/?/2001 Failed. Incubation stage (Possible predation)	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Peery et al., 2004
18	Opal Creek #2 (BBSP)	?/?/2001 Radio-tagged bird	I	?/?/2001 Failed. Incubation stage (Possible predation)	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Peery et al., 2004
19	Sempervirens Creek (BBSP)	?/?/2001 Radio-tagged bird	N	?/?/2001 Failed. Nestling state (no sign of predation)	D.M.	D.M.	D.M.	Data Missing (D.M.)	D.M.	Peery et al., 2004
20	Bloom Creek Campground #2 (BBSP)	7/15/2002 Ground observer	I	7/15/2002 Failed. Raven ate chick	Doug-fir dbh=204; ht=45-48	unk	unk	On ca. 30cm branch, located ca. 28m above the ground.	unk	Suddjian, 2003c

¹Nest Stages: I= incubation; N= nestling

Table 2-6. Important Marbled Murrelet Breeding Areas-Their Physical Characteristics and A-V Survey History

Note: This Table lists the most important sites along with those that have a history of A-V survey coverage. It does not include every site where occupied behaviors have been observed.

Site Name	Stand ID #	Watershed	Owner	Stand Size & Condition	Disturbance of Surrounding Landscape	Main A-V Station & Secondary Stations
Big Basin State Park--Redwood Meadow	BIBA-2 & FRPO-5	Waddell	California State Parks	4560 A. of old-growth in entire park, but only eastern 1/3 of park has been covered by A-V surveys.	High --due to campgrounds and picnic areas. Heavy visitor use of this area on weekends.	Main: Redwood Meadow, 1991-2011 and 2014-2015. Separate Suddjian data set, 1991 - 2009. Other stations: 1995-2011 = 100 A. Woods, Blooms Creek, Huckleberry and Sempervirens Campgrounds.
Butano State Park--Gazos Mountain Camp 110 A.	FRPO -10 & FR-7 (part)	Gazos	California State Parks	Station in second-growth, but 10 A. old-growth stand & older second-growth stands nearby that provide suitable nesting habitat.	Low	Main: The Meadow , 1998, 2000-2004, 2006-2015 Others: None
Butano State Park--Girl Scout Creek 80 A.	FRPO-6	Butano	California State Parks*	53 A. of old-growth on 80 A. parcel acquired in 2012. Easement acquired on 53 A. of older second-growth in camp itself.	High--adjacent to Butano Girl Scout Camp	Main: Station #1, 2002, 2007-2011. Stations #2,3,4, 2007-2011.
Butano State Park--Little Butano Creek	FRPO-9 (part)	Butano	California State Parks	Station in second-growth, but old-growth stands to east and west.	Low at main station, which is 0.75 miles from campground. High at Ben Reis station located in campground.	Main: Little Butano Creek, aka "Butano", 2003-2011 and 2014-2015. Ben Reis station, 2003-2011, near campground.
Butano State Park--North Slope of Butano Ridge	FRPO-9 (part)	Butano	California State Parks	260 A. of old-growth on north-facing slope of Butano Ridge, bordering Big Creek Lumber property.	The downslope Big Creek Lumber property was clearcut between 1955-1965, leaving only 4 seed trees per acre as widely-spaced residuals.	Station B-4 in park, 7 other stations in park and 11 stations outside park on Big Creek Lumber lands. Those associated with flyways into the park. Surveys done 1992 - 2001. No recent surveys.

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-6. Important Marbled Murrelet Breeding Areas-Their Physical Characteristics and A-V Survey History

Note: This Table lists the most important sites along with those that have a history of A-V survey coverage. It does not include every site where occupied behaviors have been observed.

Site Name	Stand ID #	Watershed	Owner	Stand Size & Condition	Disturbance of Surrounding Landscape	Main A-V Station & Secondary Stations
Dearborn Park	LAHO-8 (south part)	Pescadero	Big Creek Lumber	45 A. of old-growth surrounded by older second-growth & very close to a 72 A. old-growth stand.	Moderate--Dearborn Park community & Pescadero Road developments.	Main: Station P-7. Total of 10 stations. Surveys done 1992-2001. No recent surveys.
Hidden Gulch	LAHO-8 (north part)	Pescadero	Big Creek Lumber	72 A. of old-growth surrounded by older second-growth & very close to a 45 A. old-growth stand.	Moderate--Dearborn Park community & Pescadero Road developments.	Main: Station J. Total of 17 stations. Surveys done 1992-2001. No recent surveys.
Jones Gulch YMCA Camp	LAHO-6 (north part) LA-2, LA-9	Pescadero	San Francisco YMCA	LA-2: 14 A. of older second-growth. LA-9: 28 A. of older second-growth. LAHO-6: approx. 20 A. of old-growth.	High--youth camp	Main: Valley of the Giants in old-growth. Secondary: McCormick Creek.
Memorial County Park	LAHO-5	Pescadero	San Mateo County Parks	240 A. of old-growth in heavily developed park with campground & picnic areas	High	Main: Memorial on Pescadero Creek. Secondary: Sequoia, in Sequoia campground.
Pescadero Creek County Park	near MIHI-5	Pescadero	San Mateo County Parks	Park is a mix of small old-growth stands & more extensive older second-growth stands.	Low--no campgrounds other than trail camps; no picnic areas.	Main: Dark Gulch #1. Secondary station: Rhododendron Creek #1.
Portola Redwoods State Park	MIHI-4 BIBA-1	Pescadero	California State Parks	965 A. of old-growth in entire park.	High to Low. Main survey station located next to campground. Other parts of park are fairly remote from human developments.	Main: Peters Creek bridge 1992-1995, 1998, 2000-2004, and 2006-2015. Also separate Suddjian data set: 1992-95, 1998, 2001-2008. Other: Iverson Creek.
Purisima Creek Redwoods Open Space Preserve	12 km downstream of WOOD-1 on Soda Gulch	Pescadero	Mid-Peninsula Regional Open Space District	Preserve is mostly older second-growth with 2 small stands of old-growth. Station located in older second-growth.	Moderate. Residential developments border east edge of preserve.	Station LP-1 on road at confluence of Soda Gulch with Purisima Creek. Other stations in Purisima canyon.

Table 2-6. Important Marbled Murrelet Breeding Areas-Their Physical Characteristics and A-V Survey History

Note: This Table lists the most important sites along with those that have a history of A-V survey coverage. It does not include every site where occupied behaviors have been observed.

Site Name	Stand ID #	Watershed	Owner	Stand Size & Condition	Disturbance of Surrounding Landscape	Main A-V Station & Secondary Stations
Scott Creek-- BCL Lair Gulch	PO-2	Scott	Big Creek Lumber	184 acres of old-growth forest with residuals.	Low	Main: Station 2. Four other stations. Surveys done in 1999 and 2001. No recent surveys.
Scott Creek-- BCL Upper	Not mapped	Scott	Big Creek Lumber	About 100 acres of older second- growth with residuals located adjacent to and downstream of BCL's old-growth stand.	Low	Main: Station 2. Four other stations. Surveys done in 2001 only. No recent surveys.
Upper Pilarcitos Creek	MOMO-1	Pilarcitos	San Francisco Public Utilities District	870 A. old-growth Douglas-fir stand.	Low--no public access	Multiple nearby stations grouped together in reports. Surveys done in 1992 and then yearly from 2005 to 2015.

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-7. Marbled Murrelet Activity Levels at Breeding Areas with A-V Survey History

(Note: Areas with little or no survey data excluded. Other OB detection sites not included.)						
Site & Station Name	Approximate Station Coordinates (UTM Zone 10)		Station Location	A-V Station History	Mean & Range of Reported Activity Levels (TD=Total Detects; OB=Occ beh)	Confirmed Evidence of Nesting*
	Easting	Northing				
Big Basin State Park -- Redwood Meadow	569004	4114173	Across from Park HQ on east side of meadow	Immense survey effort of 289 surveys, 1991-2015. Two overlapping data sets by different observers.	<u>1995-2001</u> : n=4 surveys/yr. TD=133 (86-177). OB=33 (8-64). <u>1991-2001 Suddjian set</u> : n= 7-11 surveys/yr. TD = 118 (83-325). OB= 32 (12-166). <u>2002-2011</u> : n=10 surveys/yr. TD=15 (1.7-22). OB=2 (0-9). <u>2002-2009 Suddjian set</u> : n= 14-18 surveys/yr. TD= 11 (9-134). OB= 1 (0.2-1.6) <u>2015</u> : n=5 surveys/yr. TD=18 (1-59). OB=2 (1-6).	YES - 12 nests (2 re-used). Some eggshells & many grounded fledglings found. Some birds seen with fish. One tree landing heard in 2015.
Butano State Park -- Gazos Mountain Camp	562653	4117091	Meadow (former recreational field, south of pond)	Single station. First survey in 1998. Surveyed from 1998-2004 and 2006-2015. Total = 16 years. Radar surveys done downstream from 2000 - 2010.	<u>1998-2001</u> : n=5-7surveys/yr. TD=53 (18-105). OB=15 (3-43). <u>2002-2011</u> : n= 7surveys/yr. TD=51 (4-128). OB=13 (0-48). <u>2012-2015</u> : n=7surveys/yr. TD=38 (14-88). OB=10 (0-56). <u>2015</u> : n=7surveys/ yr. TD=52 (20-88). OB=16 (4-56).	NO - No nests, eggshells or grounded juveniles found, but immediate surrounding not suitable habitat. Old-growth stand is across creek. Several years had observations of bird carrying fish.

Table 2-7. Marbled Murrelet Activity Levels at Breeding Areas with A-V Survey History

(Note: Areas with little or no survey data excluded. Other OB detection sites not included.)						
Site & Station Name	Approximate Station Coordinates (UTM Zone 10)		Station Location	A-V Station History	Mean & Range of Reported Activity Levels (TD=Total Detects; OB=Occ beh)	Confirmed Evidence of Nesting*
	Easting	Northing				
Butano State Park -- Girl Scout Creek	560250	4119990	Station 1= On the south half of the parcel, just south of Girl Scout Creek	First detected in 2002. Surveys at 1-4 stations in 2002 and from 2007-2011. Total of 39 surveys. Total at main station (#1) = 24. No recent surveys.	At Station 1 only: <u>2002</u> : n=4 surveys. TD=28 (4-59). OB=5 (1-10). <u>2011</u> : n=7 surveys. TD=6 (2-9). OB=<1 (0-2). <u>2002, 2007-2011</u> : n=24 surveys/yr. TD=12 (0-59). OB= 2 (0-14)	NO - No nests, eggshells or grounded juveniles found. No birds seen with fish. However, branch landings heard in 2 yrs, some wing sounds, and one jet plane sound heard.
Butano -- Little Butano Creek (aka Butano Service Road)	560500	4118792	1.2 km east of campground. Located on north-facing hillside above Little Butano Creek.	Single station. First used 2003. Surveyed from 2003-2011 and 2014-2015.	<u>2003-2011</u> : n=3 surveys/yr. TD=40 (18-68). OB= 8 (2-22). <u>2014</u> : n=3 surveys. TD=78 (36-42). OB= 29 (23-34). <u>2015</u> : n=5 surveys. TD=63 (26-125). OB=22 (10-35).	NO - No nests, eggshells or grounded juveniles found. No birds seen with fish in 2014, 2015, but no records for previous years. An impressive 28 wing sound detections on one day in 2014, and 20 on one day in 2015.
Butano State Park -- North Slope	563238	4120362	16 stations - 8 inside Park & 8 outside on flyways.	First detected in 1990. Surveys done 1992-2001, a total of 943 surveys. No subsequent surveys.	<u>1992-2001: Inside Park</u> : TD=11 (1-30). OB=2 (0-5).	YES - Nest found in 2000. Eggshell fragments found in 2 locations in 1994. Grounded fledglings found in 1996 and 2000. Seven observations of birds with fish, 1991-2006. Repeat surveys needed.

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-7. Marbled Murrelet Activity Levels at Breeding Areas with A-V Survey History

(Note: Areas with little or no survey data excluded. Other OB detection sites not included.)						
Site & Station Name	Approximate Station Coordinates (UTM Zone 10)		Station Location	A-V Station History	Mean & Range of Reported Activity Levels (TD=Total Detects; OB=Occ beh)	Confirmed Evidence of Nesting*
	Easting	Northing				
Dearborn Park Big Creek Lumber Sta. P-7	561492	4123314	On a west-facing slope in the upper watershed of Dearborn Creek, Pescadero watershed.	First surveys in 1993 -- 10 stations. Surveys done 1993-2001. No recent surveys.	All stations combined <u>1993-2001</u> : n= 9 yrs. TD=13 (6-25). OB=<1 (0-3).	YES - No nests were found, but eggshells were found near station P-7. Also, several tree landings were noted.
Hidden Gulch -- Big Creek Lumber Station J	561217	4123876	Near stream in Hidden Gulch, tributary to Pescadero Creek, just south of Spaulding Curve.	First surveys in 1993 -- 17 stations. Surveys done 1993-2001. No recent surveys.	All stations combined <u>1993-2001</u> : n= 9 yrs. TD=44 (24-64). OB=3 (2-6).	YES - One nest found in 1995 near Station J. Also several tree landings were noted.

Table 2-7. Marbled Murrelet Activity Levels at Breeding Areas with A-V Survey History

(Note: Areas with little or no survey data excluded. Other OB detection sites not included.)						
Site & Station Name	Approximate Station Coordinates (UTM Zone 10)		Station Location	A-V Station History	Mean & Range of Reported Activity Levels (TD=Total Detects; OB=Occ beh)	Confirmed Evidence of Nesting*
	Easting	Northing				
Jones Gulch YMCA Camp -- Valley of the Giants	565038	4126607	At head of a small tributary that drains into Jones Gulch. Stand extends into Pescadero Creek County Park.	Main station surveyed once in 1993. Other stations in McCormick Creek (2nd growth with residuals) surveyed in 2003 and 2004, but no occupied behavior there.	<u>1993</u> : n=3 at 2 stations. TD=41 (30-67). OB=4 (0-7). No recent surveys.	NO - No direct evidence of nesting at Valley of the Giants, but is likely if activity levels have remained high. Repeated surveys needed.
Memorial County Park -- Memorial	563092	4125544	In Legion Flat picnic area bordering Pescadero Creek at old dam site.	Surveys done 1993-2011 and 2014.	<u>2003-2011</u> (n=3/yr). TD=3 (1-11). OB=<1 (0-1). <u>2014</u> : 3 surveys. TD=10 (1-27). OB=8 (0-23).	YES - Several grounded fledglings found over the years. High activity level in 2014 due to one day with 23 detections, including 20 OB. Both other days = no detections. Tree landing seen in 2014.
Pescadero Creek County Park -- Dark Gulch #1	565657	4124529	On Haul Rd at Dark Gulch crossing	Main station surveys done in 2015. Total of 8 stations & 17 surveys at 2 sites. Two surveys done at other sites in 1994 - Tarwater Creek & Shinglemill Gulch.	<u>Dark Gulch station: 2015</u> : n=4 surveys. TD= 36 (5-85). OB=8 (2-15). Park includes half of Valley of the Giants stand which was surveyed from Jones Gulch YMCA camp. Both 1994 surveys had occupied behavior.	YES - Grounded fledgling found at Sheriff's Honor Camp (inholding) in 1983 or 1984.

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-7. Marbled Murrelet Activity Levels at Breeding Areas with A-V Survey History

(Note: Areas with little or no survey data excluded. Other OB detection sites not included.)						
Site & Station Name	Approximate Station Coordinates (UTM Zone 10)		Station Location	A-V Station History	Mean & Range of Reported Activity Levels (TD=Total Detects; OB=Occ beh)	Confirmed Evidence of Nesting*
	Easting	Northing				
Portola State Park -- Peters Creek Bridge	569472	4123141	Peters Creek Bridge Station is located just outside campground on the bridge. After 2014 station moved 50 m to Old Tree Trail Parking lot.	First detected in 1956. 3 surveys/ yr 1992-93, 2014. 5 surveys in other years. Continuous surveys from 2003 to date, except for 2012 and 2013.	<u>1992-1993</u> : TD=61 (41-71). OB=4 (3-4). <u>2003-2011</u> : TD= 28 (5-55). OB=4 (0-17). <u>2014-2015</u> : TD=28 (27-28). OB=4 (2-6).	YES - Nest found in 1997 by radio-tagging bird at sea. Grounded fledglings found in 1957 (on creek), 1971, 1972.
Purisima Creek Redwoods -Open Space Preserve -- Station LP1.	558023	4143188	On the service road at confluence of Purisima Creek & Soda Gulch.	First detected in 1992. 1992: 3 surveys at different stations, including LP1. 1996: 4 surveys at different stations, including LP1. 2001: 1 A-V survey simultaneously with radar survey on hillside, 1.2 km northwest of Station LP1.	<u>1992</u> : 3 surveys. TD=2 (1-2). OB=0. <u>1996</u> : 4 surveys. TD=6 (0-24). OB=6 (0-23). Eight stop-and-go tree landings by one pair on tree unsuitable for nesting. <u>2001</u> : 1 A-V survey. TD=4. OB=0. 2001: 1 radar survey. TD=8.	YES - No nests found, but grounded fledgling found in 2002 near Station LP1.

Table 2-7. Marbled Murrelet Activity Levels at Breeding Areas with A-V Survey History

(Note: Areas with little or no survey data excluded. Other OB detection sites not included.)						
Site & Station Name	Approximate Station Coordinates (UTM Zone 10)		Station Location	A-V Station History	Mean & Range of Reported Activity Levels (TD=Total Detects; OB=Occ beh)	Confirmed Evidence of Nesting*
	Easting	Northing				
Scott Creek -- BCL Lair Gulch Station 2	565748	4106263	In Lair Gulch about 1km upstream from its confluence with Scott Creek.	Nest found in 1997 by radio-tagging bird at sea. 1999: 15 surveys at 8 stations. 2001: 12 surveys at 5 stations.	Five different stations combined. <u>1991</u> : 15 surveys. TD=9. OB=1. <u>2001</u> : 12 surveys. TD=1 (0-2). OB=<1 (0-1).	YES - Nest found in 1997 by radio-tagging bird at sea. Tree landings in 2001 and 1991.
Scott Creek -- BCL Upper	566999	4108418	Station 2 on main stem of Scott Creek about 400m downstream of BCL's old-growth stand.	Surveyed once in 2001. Total of 11 surveys at 5 stations.	Station 2. <u>2001</u> : 8 surveys. TD=6 (3-14). OB=4 (0-11).	NO - No nests found, but tree landing and flybys seen at potentially suitable nest tree. Nest found on adjacent Locatelli old-growth parcel in 2001 by radio-tagging bird at sea.
Upper Pilarcitos Creek -- Stone Dam (S.F.P.U.D.)	553437	4153208	Several close stations located in the vicinity of Stone Dam on Upper Pilarcitos Creek.	A-V surveys began in 2005 and have been continuous through 2015. Murrelet activity levels appear to be low, but fairly consistent.	<u>2015</u> : 7 surveys. TD=4 (0-15). OB= regular. NOTE: Data presented in a way that doesn't allow comparison with other A-V survey results.	NO - No direct evidence of nesting, but duration of study suggests birds must be nesting.
*Confirmed evidence of nesting is a physical nest site, chick, egg, eggshell, grounded fledgling, murrelet seen carrying fish.						

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-8. *Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range*

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
PO-5	Franklin Point	Año Nuevo Creek "A"		Año Nuevo Creek	18.06	No	Linear stand of older second-growth in bottom of canyon only. Probably not well suited for marbled murrelets due to too much edge.	None	Unk	None
SA-1	Santa Cruz	Baldwin Creek "B"		Baldwin Creek	32.93	No	Boundaries uncertain as photos not clear. Older photo images from 9/29/09 used to help fix boundaries. Extends into Wilder Ranch State Park.	CDFG, Suddjian	NP	1992: 1-92NTMP004 1992: 1-92-139-SCR
DA-1	Davenport	Berry Creek "A"		Scott Creek	26.65	No	On Cal Poly's Swanton-Pacific Ranch. Significant fire damage from the Lockheed Fire.	CDFG,	P	2007: 1-07-NTMP-020
DA-2	Davenport	Berry Creek "B"		Scott Creek	5.68	No	Located on old slide scar. Some Lockheed Fire damage to stand.	None	Unk	None
BI-1	Big Basin	Big Creek-Cemex		Scott Creek	10.54	No	Located at northern-most tip of Cemex property.	None	Unk	2001: 1-01-011-SCR
DA-3	Davenport	Big Creek "A"		Scott Creek	7.75	No	Two stands. Boundary expanded from that of CDFG. Within Lockheed Fire zone, but no fire damage.	CDFG	Unk	None
DA-4	Davenport	Big Creek "B"		Scott Creek	22.51	No	Two stands. Within Lockheed Fire zone, but no fire damage.	CDFG	Unk	None
DA-5	Davenport	Boyer Creek "A"		Scott Creek	125.66	Yes	About 150 acres in size, it is one of only a relative few older second-growth stands that are larger than 100 acres. It is the largest older second-growth stand in the Big Creek Watershed. Lower 1/3 is within Lockheed Fire boundary but no apparent damage.	CDFG	Unk	None
LA-1	La Honda	Butano Ck-West Butano Ridge		Butano Creek	11.32	No	Stand located just below the ridge line.	CDFG, Suddjian, part of SRL old-growth	Unk	None

Murrelet Inland Distribution And Detection Numbers in Zone 6 **Chapter 2**

Table 2-8. Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
FR-4	Franklin Point	Butano Creek-Sinnott		Butano Creek	29.11	Yes	Purchased by Semp Fund in 2011, half had been logged in 2008. Low MAMU activity levels present, but Suddjian observed OB in 2011.	CDFW Database & THP Files, Sempervirens Fund	OB	2008: 1-08-044-SMO
FR-4	Franklin Point	Butano Creek-Sinnott		Butano Creek	28.15	Yes	Purchased by Semp Fund in 2011, half had been logged in 2008. Low MAMU activity levels present, but Suddjian observed OB in 2011.	Suddjian, last visited in 2007	OB	2008: 1-08-044-SMO
FR-1	Franklin Point	Butano Creek "D"		Butano Creek	127.74	Yes	About 100 acres in size, it is one of only seven older second-growth stands larger than 100 acres found in the CAPP area. Adjoins previously mapped old-growth (Singer, stand #FRPO-6).	CDFG, part of SRL old-growth	OB	1991: 1-91-337-SMO
WO-2	Woodside	El Corte de Madera OSP-"A"	3	El Corte de Madera	65.74	Yes	Three small stands. Never surveyed for murrelets.	Mapped by H.T. Harvey and Assoc. for MROSD in 2007.	Unk	None
WO-3	Woodside	El Corte de Madera OSP-"B"	3	El Corte de Madera	67.51	Yes	Three small stands. Never surveyed for murrelets, but birds seen leaving the property.	Mapped by H.T. Harvey and Assoc. for MROSD in 2007.	P	None
FE-4	Felton	Fall Creek-"A"	2	San Lorenzo River	189.94	Yes	Mostly within Fall Creek Unit of Henry Cowell State Park, older 2G and OG mixed.	Suddjian, last visited in 2007	OB	None

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-8. *Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range*

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
FR-5	Franklin Point	Gazos Creek-"A"		Gazos Creek	59.80	Yes	About 100 acres on Slate Creek and owned by Big Creek Lumber. Uncertain boundary due to mediocre photo quality.	CDFG, Suddjian, part of SRL old-growth	OB	None
FR-6	Franklin Point	Gazos Creek-"B"		Gazos Creek	5.86	No	Tributary canyon to North Fork of Gazos Creek.	Near = Suddjian	Near=P	None
FR-7	Franklin Point	Gazos Creek-"C"		Gazos Creek	63.47	Yes	Middle Fork of Gazos Creek. Scattered residuals.	CDFG, Suddjian, part of SRL old-growth	OB	None
FR-8	Franklin Point	Gazos Creek-"F"		Gazos Creek	20.55	No	North Fork of Gazos Creek.	CDFG, Suddjian, part of SRL old-growth	OB	Only very small portion within a THP.
FR-9	Franklin Point	Gazos Creek-"G"		Gazos Creek	64.75	Yes	North Fork of Gazos Creek. Just outside of Butano State Park. Boundaries uncertain due to poor photo quality.	CDFG, Suddjian	OB	None
FR-10	Franklin Point	Gazos Creek-"H"		Gazos Creek	178.59	Yes	Gazos Tree Farm. About 170 acres in size. Boundary somewhat uncertain due to varying density of residuals and mediocre photo quality.	CDFG, Suddjian	P	THP 1-07-147 SMO
FR-12	Franklin Point	Gazos Creek-"J"		Gazos Creek	8.16	No	Upper end of Middle Fk of Gazos Creek. Touches stand "K".	CDFG	Unk	None
FR-13	Franklin Point	Gazos Creek-"K"		Gazos Creek	25.75	No	Near Sandy Point. Adjoins stand "J".	CDFG, part of SRL old-growth	Unk	None
DA-7	Felton	Laguna Creek-Cemex "A"		Laguna Creek	54.79	Yes	On former Cemex property which is now San Vicente Redwoods. Presence found on ARU survey in 2015.	None	P	None

Murrelet Inland Distribution And Detection Numbers in Zone 6 **Chapter 2**

Table 2-8. Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
DA-8	Felton	Laguna Creek-Cemex "B"		Laguna Creek	54.33	Yes	On former Cemex property which is now San Vicente Redwoods, owned by a land trust.	None	Unk	None
DA-19	Davenport	Little Creek-"A"		Scott Creek	35.31	No	On Cal Poly's Swanton-Pacific Ranch. Just outside Lockheed Fire perimeter.	CDFG	NP	2009: NTMP
FE-3	Felton	Majors Creek-"B"	2	Majors Creek	23.65	No	Two stands. One adjoins previously mapped old-growth (Singer, stand FELT-4).	part of SRL old-growth	Unk	1992: 1-92-170-SCR
BI-3	Big Basin	Mill Ck-Lockheed "A"		Scott Creek	5.41	No	On Lockheed property near buildings. This small stand drains toward Scott Creek but is very near the watershed divide with Mill Creek. Appears to be virgin old-growth.	None	Unk	None
BI-4	Big Basin	Mill Ck-Lockheed "B"		Scott Creek	16.64	No	On Lockheed property near buildings. Appears to be virgin old-growth.	None	Unk	None
BI-5	Big Basin	Mill Ck-Lockheed "C"		Scott Creek	15.54	No	On Lockheed property near buildings. Appears to be virgin old-growth.	None	Unk	None
BI-6	Big Basin	Mill Ck-Lockheed "D"		Scott Creek	68.30	Yes	On Lockheed property near buildings. Appears to be virgin old-growth.	None	Unk	None
DA-9	Davenport	Mill Creek-"A"		Scott Creek	44.87	Yes	Touches stand "B" in one small area. Inside Lockheed Fire perimeter but only minor damage.	CDFG	Unk	None
DA-10	Davenport	Mill Creek-"B"		Scott Creek	18.45	Yes	Touches stand "A" in one small area. Experienced significant damage from the Lockheed Fire.	CDFG	Unk	None
DA-11	Davenport	Mill Creek-"C"		Scott Creek	16.47	No	Stand is primarily younger growth but has many residuals. Located outside of the Lockheed Fire perimeter.	None	Unk	None

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-8. *Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range*

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
MI-1	Mindego Hill	Pescadero Ck-Bear Ck		Pescadero Creek	13.18	No	Borders Portola Redwoods State Park. Very near previously mapped old-growth (Singer, stand MIHI-4).	None	Unk	None
BI-7	Big Basin	Pescadero Ck-Highway 9		Pescadero Creek	8.75	No	Located on the west edge of Highway #9.	None	Unk	None
MI-2	Mindego Hill	Pescadero Ck-Portola		Pescadero Creek	115.78	Yes	Connects two previously mapped old-growth stands on Peters Creek in the area near Portola State Park (Singer, stands MIHI-3 and BIBA-1).	part of SRL old-growth	OB	None
FR-14 and LA-7	La Honda	Pescadero Ck-Spaulding Curve	2	Pescadero Creek	429.01	Yes	Consists of 2 stands. Together they contain 350-400 acres and are the largest older second-growth stand. One stand nearly surrounds the previously mapped old-growth area entitled "BCL-Pescadero"-mapped by Singer as LAHO-8. Both stands border the privately owned Pesky Ranch with OG Douglas-fir under protective easement with POST.		OB	None
BI-9	Big Basin	Pescadero Ck-Water Tank Creek		Pescadero Creek	40.33	No	Remote area, surrounded by second-growth timber lands. OB observed by John Bulger in 2007.	CDFW Database & THP Files, Jones & Stokes, 2007	OB	2007: 1-07-023-SMO
BI-8	Big Basin	Pescadero Ck-Waterman Gap		Pescadero Creek	7.09	No	Borders Hwy 236 and adjoins a parcel owned by the Semp. Fund. May be a publicly-owned easement for the Skyline-to-the-Sea trail.	CDFG	Unk	1984: 5-84-15-SMO
LA-2	La Honda	Pescadero Creek-"F"		Pescadero Creek	13.57	No	SF YMCA Camp. Adjoins previously mapped old-growth (Singer, stand LAHO-6).	CDFG	OB	2006: 1-06NTMP-14
LA-3	La Honda	Pescadero Creek-"G"		Pescadero Creek	9.84	No	SF YMCA Camp.	CDFG	Unk	2006: 1-06NTMP-14

Murrelet Inland Distribution And Detection Numbers in Zone 6 **Chapter 2**

Table 2-8. Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
LA-4	La Honda	Pescadero Creek-"H"		Pescadero Creek	5.73	No	On the edge of Pescadero Creek Road.	CDFG	Unk	2006: 1-06NTMP-14
LA-5	La Honda	Pescadero Creek-"L"		Pescadero Creek	56.19	No	Located in a canyon southeast of Loma Mar.	None	OB	1991: 1-91-281-SMO
LA-8	La Honda	Pescadero Creek-"M"		Pescadero Creek	23.33	No	Barely meets threshold for older second-growth. Stand includes some large tree redwood craters with merged crowns.	None	Unk	2003: 1-03-113-SMO
LA-9	La Honda	Pescadero Creek-"N"		Pescadero Creek	28.20	No	In north part of McCormick Creek Canyon. Barely meets the threshold for older second-growth.	CDFG	P	2006: 1-06NTMP-14
LA-6	La Honda	Pescadero Creek-"O"		Pescadero Creek	15.21	No	Southern end of McCormick Creek. Barely meets the threshold for older second-growth.	None	Unk	2006: 1-06NTMP-14
MI-3	Mindego Hill	Pescadero Creek-Oil Creek-"B"		Pescadero Creek	46.14	No	Remote area, surrounded by second-growth timber lands.	CDFW Database & THP Files,	Unk	Unk
BI-12	Big Basin	San Lorenzo Riv.-Boulder Creek "B"		San Lorenzo River	26.07	No	Holmes property on China Grade Road. Adjoins previously mapped old-growth (Singer BIBA-3).	CDFG	Unk	None
DA-13	Davenport	San Vicente-Cemex "H"		San Vicente	4.38	No	Very small stand of young-growth but with dense residuals. Within San Vicente Redwoods.	Portion mapped by CDFG	Unk	None
DA-15	Davenport	San Vicente-Cemex "Z"		San Vicente	76.19	Yes	This stand is about 75 acres in size and is the largest older second-growth stand in the San Vicente Redwoods and the watershed.	None	Unk	2001: 1-01-439-SCR
DA-12	Davenport	San Vicente Ck-Cemex "G"		San Vicente	57.41	Yes	This stand is about 70 acres in size. In San Vicentes Redwoods propety.	CDFG	Unk	1990: 1-90-498-SCR

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-8. *Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range*

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
DA-14	Davenport	San Vicente Ck-Cemex "I"		San Vicente	28.94	No	Possibly virgin old-growth. Located within San Vicente Redwoods.	None	Unk	None
DA-16	Davenport	San Vicente Creek-"L"		San Vicente	40.20	No	"Redwood Meadows" area outside of former Cemex property. A-V surveys for CDFG did not find marbled murrelets.	Small part mapped by CDFG	NP	None
DA-17	Davenport	Scott Creek-"D"		Scott Creek	25.40	No	On the main stem of Scott Creek and not far downstream of previously mapped old-growth called BCL-Scott Creek (Singer, DAVE-1).	None	Unk	2002: 1-02-101-SCR
DA-18	Davenport	Scott Creek-"E"		Scott Creek	22.23	No	Located on a tributary to Scott Creek.	Portion mapped by CDFG	Unk	None
PO-2	Año Nuevo	Scott Creek-"F"		Scott Creek	184.21	Yes	Lairs Gulch and environs. Owned by Big Creek Lumber. Moderate aged stand with old-growth residuals. Has supported nesting by murrelets. Contains about 200 acres and is one of only 7 older second-growth stands found within the CAPP area that is larger than 100 acres.	CDFG	NEST, OB	None
BI-10	Big Basin	Scott Creek-"H"		Scott Creek	17.75	No	Boundary touches stand "L" and adjoins previously mapped old-growth (Singer, BIBI-7).	part of SRL old-growth	Near = OB	1996: 1-96-239-SCR
BI-11	Big Basin	Scott Creek-"L"		Scott Creek	38.54	No	Boundary touches stand "H" and adjoins previously mapped old-growth (Singer BIBI-7).	near to CDFG, part of SRL old-growth	Near = OB	1996: 1-96-239-SCR
WO-1	Woodside	Tunitas Creek-"A"	2	Tunitas Creek	58.87	Yes	Privately owned.	CDFW Database and THP files	Unk	Unk
CA-1	Castle Rock Ridge	Upper San Lorenzo Riv.-Deer Creek "A"		San Lorenzo River	20.71	No	Adjoins previously mapped old-growth (Singer, stand CARO-5).	part of SRL old-growth	Unk	None

Murrelet Inland Distribution And Detection Numbers in Zone 6 **Chapter 2**

Table 2-8. Size and Characteristics of Older Second-growth Stands in the Murrelet Breeding Range

MAMU Activity Codes : NEST = nest or grounded fledgling/chick, OB = occupied behavior, P = presence, NP = not present, Unk = Unknown, not surveyed

Map ID	Quad	Stand Name	# sub-units	Watershed	Acres	>50 A?	Description	Secondary Sources	MAMU Activity	THPs or NTMPs?
CA-2	Castle Rock Ridge	Upper San Lorenzo Riv.- White Rock "A"		San Lorenzo River	21.61	No	Close to residences/rural ranchettes on Summit Road.	part of SRL old-growth	Unk	None
FR-16	Franklin Point	Waddell Creek- "A"		Waddell Creek	38.72	No	Very small stand. Boundaries uncertain due to poor quality photos.	CDFG, Suddjian	Near=P	None
PO-3	Año Nuevo	Waddell Creek- "B"		Waddell Creek	34.82	No	Boundaries uncertain due to mediocre quality photos. Large area between "B" and "C" and to east may soon qualify as older second-growth, but currently has smaller tree crown sizes than the "B" and "C" stands.	near CDFG larger area, part of SRL old-growth	Unk	None
PO-4	Año Nuevo	Waddell Creek- "C"		Waddell Creek	11.45	No		CDFG, Suddjian	OB	None
FR-11	Franklin Point	Whitehouse Creek- "A"		Whitehouse Creek	16.47	No	Located on the Santa Clara County Girl Scout camp.	SVF records	Unk	None
FR-15	Franklin Point	Whitehouse Creek- "B"		Whitehouse Creek	31.58	No	Owned by Art Lachenbruch. Stand contains many residuals and adjoins old-growth stands in Big Basin State Park. Grounded fledgling found in watershed in 2016.	CDFG, SVP records	OB	None
TOTAL		n = 67 stands			3117.89					

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-9. *Size and Characteristics of Old-growth Stands in the Murrelet Breeding Range*

MAMU Activity Codes: NEST = nest or grounded fledgling, chick, OB = occupied behavior, P = presence, NP = not present, UNK = unknown

Map ID	Stand Name	# sub-units	Watershed	Acres	Description	MAMU Activity
FRPO-8	BCL - Butano Falls	4	Butano Creek	67.3	Stands located on both sides of Canyon Road. Located near to Girl Scout Creek. Owned by Big Creek Lumber. Protected by easement.	O.B.
FRPO-7	BCL - Gazos Creek	2	Gazos Creek	41.4	Owned by Big Creek Lumber, north of Gazos Creek Road.	O.B.
LAHO-8	BCL - Pescadero	3	Pescadero Creek	107.2	Includes sub-areas known as Hidden Gulch and Dearborn Park. Owned by Big Creek Lumber	NEST
BIBA-5, DAVE-1	BCL - Scott Creek	2	Scott Creek	115.0	Adjoins Locatelli Old-growth and stands of Older 2G forest are nearby. Owned by Big Creek Lumber	NEST
FRPO-5, BIBA-2	Big Basin State Park	7	Waddell Creek	4405.5	Largest OG stand in Zone 6, containing more than 40% of total remaining OG. East of Middle Ridge, park is heavily visited with many campgrounds and picnic areas. West of Middle Ridge is a wilderness area with no improvements.	NEST
FELT-1	Big Trees	3	San Lorenzo River	63.2	Privately owned. On grounds of Roaring Camp Railroad	NP
FRPO-1	Bryan Grove	1	Gazos Creek	69.3	Part of Big Basin State Park, but not connected and listed separately here.	O.B.
BIBA-6	Butano Creek	4	Butano Creek	31.8	Four small stands, two at upper end of South Fork and 2 near upper end of the main stem, Butano Creek. Privately owned.	O.B.
FRPO-11	Butano Creek - Moore	1	Butano Creek	25.0	Privately owned.	UNK
FRPO-9	Butano State Park	3	Butano Creek, primarily Little Butano Creek subwatershed.	622.0	Large portion of park is unimproved. Includes North Slope OG stand which drains into the South Fork of Butano Creek. Park also has significant amounts of Older 2G forest.	NEST

*Table 2-9. Size and Characteristics of Old-growth Stands in the Murrelet Breeding Range**MAMU Activity Codes: NEST = nest or grounded fledgling, chick, OB = occupied behavior, P = presence, NP = not present, UNK = unknown*

Map ID	Stand Name	# sub-units	Watershed	Acres	Description	MAMU Activity
FRPO-2	Cascade Creek	1	Cascade Creek	260.3	Privately owned. An adjacent portion of this property with old-growth Douglas-firs was harvested in 1988, and may have been the last murrelet breeding location to have been logged in the Santa Cruz Mountains.	O.B.
BIBA-3	China Grade	2	San Lorenzo River	67.5	Privately owned.	UNK
FRPO-4	Croce-Williams	2	Butano Creek	4.8	Current ownership status is unknown. Formerly was privately owned.	UNK
LAHO-9	Dearborn Park (Michelsen)	1	Pescadero Creek	306.2	Privately owned but under conservation easement (no-cut) with POST. Appears to be a large stand of OG Douglas-fir.	UNK
LAHO-1	El Corte de Madera	1	El Corte de Madera Creek	72.9	Privately owned.	NP (based on 3 AV surveys in 1994)
FRPO-10	Gazos Mountain Camp	1	Gazos Creek	15.8	Part of Butano State Park. Some Older-2G forest with residuals and likely nesting is adjacent.	O.B.
FRPO-6	Girl Scout Creek	1	Butano Creek	54.5	Part of Butano State Park. Adjoining Butano Girl Scout Camp contains Older 2G forest and is under conservation easement (no-cut) with the Sempervirens Fund.	O.B.
FELT-4	Gray Whale 1	2	Majors Creek	16.6	Owned by Save the Redwoods League.	NP (based on 3 old AV surveys)

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-9. Size and Characteristics of Old-growth Stands in the Murrelet Breeding Range

MAMU Activity Codes: NEST = nest or grounded fledgling, chick, OB = occupied behavior, P = presence, NP = not present, UNK = unknown

Map ID	Stand Name	# sub-units	Watershed	Acres	Description	MAMU Activity
FELT-5	Henry Cowell State Park	1	San Lorenzo River	36.20	OG stand is adjacent to the Big Trees OG stand.	NP
MIHI-1	Heritage Grove	1	San Gregorio Creek	27.60	Part of San Mateo County Park system. Very close to Lower Mindego O.G. stand.	O.B.
CARO-1	Kings Creek	1	San Lorenzo River	11.70	Within Castle Rock State Park	UNK
BIBA-4	Last Chance Road	1	Waddell Creek	41.70	Outlier parcel of Big Basin State Park, at head of Last Chance Creek on east side of Pine Mountain.	UNK
LAHO-2	Lower Mindego	1	San Gregorio Creek	24.70	Part of Log Cabin Ranch - San Francisco's Juvenile Boys Camp. Located close to Heritage Grove.	O.B.
SACR-4, FELT-6	Majors Creek	2	Majors Creek	70.1	Outlying parcel of Wilder Ranch State Park.	UNK
LAHO-3	McDonald County Park	1	San Gregorio Creek	30.90	Part of San Mateo County Park system.	O.B.
LAHO-5	Memorial County Park	1	Pescadero Creek	203.00	Part of San Mateo County Park system. Heavily developed with campgrounds and picnic areas.	NESTING
MIHI-3	Middleton Tract	1	Pescadero Creek	148.90	A fairly recent addition to Portola State Park. Stand is located on Peters Creek.	O.B.
CARO-2	Miller Grove	2	San Lorenzo River	36.00	Part of Santa Cruz County Park system. Un-developed now, but formerly was a summer campground for the University of California staff and faculty with a few small building remains.	UNK

Murrelet Inland Distribution And Detection Numbers in Zone 6 **Chapter 2**

Table 2-9. Size and Characteristics of Old-growth Stands in the Murrelet Breeding Range

MAMU Activity Codes: NEST = nest or grounded fledgling, chick, OB = occupied behavior, P = presence, NP = not present, UNK = unknown

Map ID	Stand Name	# sub-units	Watershed	Acres	Description	MAMU Activity
LAHO-7, MIHI-5, and FRPO-3	Pescadero Creek County Park	8	Pescadero Creek	530.60	Part of the San Mateo County Parks system. Located intermediate between Memorial County Park and Portola State Park.	NESTING, grounded juvenile found 1984.
MIHI-4	Portola State Park	5	Pescadero Creek	974.30	Is the third-largest remaining stand of OG forest in the Santa Cruz Mountains.	NESTING
FELT-2	Powder Mill Creek	1	San Lorenzo River	25.00	Mixed ownership - part is Henry Cowell State Park and part is private residential community.	UNK
WOOD-1	Purisima O.S. Preserve - A	2	Purisima Creek	19.60	Part of Mid-peninsula Regional Open Space District. Mapped by H.T. Harvey and Associate (2007) in Purisima Creek Open Space Preserve.	NESTING somewhere in Preserve.
WOOD-5	Purisima O.S. Preserve - B	2	Purisima Creek	22.00	Part of Mid-peninsula Regional Open Space District. Mapped by H.T. Harvey and Associate (2007) in Purisima Creek Open Space Preserve.	NESTING somewhere in Preserve.
WOOD-6	Purisima O.S. Preserve - C	2	Purisima Creek	18.70	Part of Mid-peninsula Regional Open Space District. Mapped by H.T. Harvey and Associate (2007) in Purisima Creek Open Space Preserve.	NESTING somewhere in Preserve.
LAHO-12	Redwood Terrace	1	San Gregorio Creek	18.30	Privately owned. Current status of this stand is unknown and needs field check.	UNK
FELT-3	San Lorenzo River	2	San Lorenzo River	122.40	Located within Henry Cowell Redwoods State Park.	NP
BIBA-7	Scott Creek - Locatelli	1	Scott Creek	37.80	Privately owned.	NESTING
WOOD-4	Tunitas Creek	2	Tunitas Creek	12.5	Privately owned.	UNK

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-9. Size and Characteristics of Old-growth Stands in the Murrelet Breeding Range

MAMU Activity Codes: NEST = nest or grounded fledgling, chick, OB = occupied behavior, P = presence, NP = not present, UNK = unknown

Map ID	Stand Name	# sub-units	Watershed	Acres	Description	MAMU Activity
MOMO-1	Upper Pilarcitos Creek	2	Pilarcitos Creek	1135.50	Owned by San Francisco Public Utilities District and managed as water supply watershed. Very limited public use.	O.B.
LAHO-6	Valley of the Giants	1	Pescadero Creek	38.60	Owned by the San Francisco YMCA, and operated as Camp Jones Gulch.	O.B.
LAHO-10	Woodhaven Camp	1	San Gregorio Creek	35.60	Part of the Midpeninsula Regional Open Space District. Site needs field verification of current status.	UNK
LAHO-4, WOOD-2	Young	3	El Corte de Madera Creek	65.50	Privately owned.	UNK
TOTAL	number of stands = 42			10033.50		

Table 2-10 Watersheds with the Most Remaining Habitat

<u>Watershed Unit</u>	<u>Remaining Potential Habitat (acres)</u>	<u>Flyway Identi-fied?</u>	<u>Most Important Breeding Sites, Their Status¹ and Size</u>	<u>Research & Monitoring Needs</u>
Waddell	4500	Yes	(1) Big Basin State Park - 4500 A., nesting confirmed, Occupied Behavior (OB) seen.	New surveys needed in western half of park, which has not been adequately monitored. Important to continue annual surveys at Redwood Meadow.
Middle Pescadero (upstream of Memorial Co. Park, ending after Portola St. Park.)	2000 ²	Yes	(1) Portola State Park - 1115 A., nesting confirmed, OB seen. (2) Pescadero Creek Co. Park - est. 720 A., nesting confirmed, OB seen.	Continue surveys at Portola and Pescadero Creek Co. Park.
Lower Pescadero (Memorial Co. Park & further downstream)	1200	Yes	(1) Memorial Co. Park - 240 A., nesting confirmed, OB seen. (2) Dearborn Valley - Big Creek Lumber (BCL) - 45 A., nesting confirmed, OB seen. (3) Hidden gulch-BCL- 72 A., nesting confirmed, OB seen	Initial surveys needed in P.O.S.T.'s Michelson Property easement parcel. Important to do new surveys in Dearborn Valley & Hidden Gulch which were last surveyed in 2001.
Pilarcitos	870	No	(1) Upper Pilarcitos Creek - 870 A., OB seen.	Continue annual surveys.
Little Butano	650	No	(1) Little Butano Creek watershed inside the state park - 650 A., nesting confirmed, OB seen.	Continue annual surveys.

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-10 Watersheds with the Most Remaining Habitat

<u>Watershed Unit</u>	<u>Remaining Potential Habitat (acres)</u>	<u>Flyway Identified?</u>	<u>Most Important Breeding Sites, Their Status¹ and Size</u>	<u>Research & Monitoring Needs</u>
Butano (excluding Little Butano)	600	Yes	(1) North Slope stand in state park - 260 A., nesting confirmed, OB seen. (2) Girl Scout Creek - 53 A., OB seen.	Important to do new surveys at North Slope stand; last ones were 2001. Re-surveys needed for BCL's conservation easement on Canyon Rd as well.
Scott Creek, above Swanton Road	500	No	(1) Lair Gulch - 184 A., confirmed nesting, OB seen. (2) Upper Scott Creek - BCL - 100 A., OB seen. (3) BCL old-growth stand - 120 A., OB seen. (4) Locatelli old-growth stand - 66 A., confirmed nesting, OB seen.	New Surveys needed. It is very important to determine the current status of this site.
Gazos	450	Yes	(1) Gazos Mountain Camp - 10 A., plus surrounding older second-growth small stands, OB seen. (2) Redwood Empire Middle Gazos - 65 A., OB seen.	Important to continue annual surveys.

¹Confirmed nesting requires one of these: physical nest, chick, egg, eggshell fragment or grounded fledgling

²Plus an undetermined amount of older second-growth potential habitat.

Table 2-11. **Characteristics of Important Murrelet Areas.** Important Murrelet Areas are clusters of suitable nesting habitat with buffers that either have relatively high murrelet activity levels or have a high potential for successful nesting by murrelets due to their isolation and lack of most adverse human influences.

Area No	Area Name	Acres	OG & Older 2G (Acres)	Description	Habitat Conditions	Murrelet Activity Level
Total:		29,983	10730			
1	Lower Pescadero	2606	1113	Portion of the Pescadero Ck Watershed from near Pesky Ranch upstream to and including Memorial County Park. Incorporates 3 old-growth (OG) stands and 4 older second-growth (2G) stands. Ownership is private except for the County park. Largest stand is 410 acres owned by Big Creek Lumber.	Area contains many human land uses and a high degree of habitat fragmentation. The density of ravens is probably large due to the large number of anthropogenic food sources available.	High with much evidence of nesting. Associated with one of the four known murrelet flyways.
2	Butano - Gazos	6394	1430	All of the Gazos Creek Watershed and lower part of the Butano Creek Watershed up to and including Butano State Park. Incorporates 7 OG stands and 9 mostly smaller older 2G stands. A mix of public and private owners. Largest stand is 612 acres of old-growth in Butano State Park. Not included in the total habitat acreage is a likely significant area of older second-growth forest in the state park that has not been delineated.	Human activities within this Area include logging, one state park, one youth camp, and one residential community.	High with many occupied behaviors regularly detected, and some stronger evidence of nesting. Two murrelet flyways are known for this Area. One goes up Butano Creek, the other goes up Gazos Creek. A peregrine falcon nest is known to exist on or near the Butano Flyway and take of murrelets by peregrines has been observed.

Chapter 2 Murrelet Inland Distribution And Detection Numbers in Zone 6

Table 2-11. **Characteristics of Important Murrelet Areas.** Important Murrelet Areas are clusters of suitable nesting habitat with buffers that either have relatively high murrelet activity levels or have a high potential for successful nesting by murrelets due to their isolation and lack of most adverse human influences.

Area No	Area Name	Acres	OG & Older 2G (Acres)	Description	Habitat Conditions	Murrelet Activity Level
3	Scott Creek	1739	483	Scott Creek Watershed above Scott Creek Road and below the Lockheed property. Incorporates 4 small old growth stands, 4 small older 2G stands, and one stand of 184 acres that is owned by BCL. Ownership is almost entirely private.	Few human land uses other than logging. Public access is restricted.	Moderate. Two nests have been found within this Area, but there has been very little monitoring of inland murrelet activity.
4	Mill Creek - Big Creek	1747	268	Upper part of Mill Creek Watershed below Lockheed and middle part of the Big Creek Watershed. Incorporates no OG stands and 8 small older 2G stands. Largest stand is privately owned, 126 acres.	Only land use is logging. Public land use is restricted.	Unknown. Few surveys done.
5	Middle Pescadero - Portola State Park	7214	1861	Pescadero Creek Watershed upstream of Memorial County Park and includes Pescadero Creek County Park and Portola State Park. Incorporates 6 O.G. stands and 4 older 2G stands. Ownership is all public. Also included is an unknown quantity of older 2G in Pescadero Creek County Park and Portola State Park. Several stands in Portola, taken together, provide over 1000 acres of old-growth habitat.	Human activities within this Area include two parks, several youth camps, and some human settlements.	High. Located along one of four known murrelet flyways.

Table 2-11. **Characteristics of Important Murrelet Areas.** Important Murrelet Areas are clusters of suitable nesting habitat with buffers that either have relatively high murrelet activity levels or have a high potential for successful nesting by murrelets due to their isolation and lack of most adverse human influences.

Area No	Area Name	Acres	OG & Older 2G (Acres)	Description	Habitat Conditions	Murrelet Activity Level
6	Big Basin	8640	4437	Big Basin Redwoods State Park and one small stand in Whitehouse Canyon owned by the Sempervirens Fund. Contains the largest remaining stand of old-growth in the Santa Cruz Mountains with a size of over 4,000 acres. Associated with one of the four murrelet flyways, this one along the Waddell Creek Watershed.	High human use in the developed portion of the State Park has produced unusually high numbers of resident Steller's jays and Common ravens.	Currently low to moderate, being low in the developed portion of the park, which once, many years ago, had the highest murrelet activity levels in the Santa Cruz Mountains. Located along one of the four known murrelet flyways, which also contains an active peregrine falcon nest, where some take of "commuting" adult murrelets must occur.
7	Upper Pilarcitos	1642	1138	A large stand of old-growth Douglas-fir on the San Francisco Watershed lands.	No human uses occur in this area and no habitat fragmentation. Major threat is probably the risk of wildfire.	Low to moderate, but seems to have a high potential for successful nesting and for expansion of the number of nests.

CHAPTER 3 CORVID PREDATION OF MURRELET NESTS IN ZONE 6

Elena H. West, PhD candidate, Department of Zoology at the University of Wisconsin-Madison, Introduction to Combined Chapter on Corvid Predation; William C. Webb, PhD, Management of Crows and Ravens to Reduce the Risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains, and Elena H. West, Management of Steller's Jays to Reduce the risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains

INTRODUCTION

The purpose of this chapter is to review the threat posed to nesting murrelets in the Santa Cruz Mountains by increasing numbers of ravens, crows, and jays (corvids) and suggest management strategies for reducing the negative impact of these species on murrelet productivity. Reviewed for each species are distribution, trends in abundance, diet, foraging behavior and sociality. Nest predatory behavior of ravens, crows, and jays and the documented instances of murrelet nest predation by these species are also reviewed. Finally, potential management approaches and future research suggestions for reducing negative impacts of corvids on murrelet productivity are considered. Greater emphasis in this report overall is focused on ravens and jays, since their numbers are greater in murrelet nesting habitat in the Santa Cruz Mountains, and because they are both documented murrelet nest predators and crows are considered potential murrelet nest predators.

BACKGROUND INFORMATION

The Corvidae (corvids) is a large family of passerines (songbirds) with 113 species and 25 genera described worldwide (Madge and Burn 1994). In forests of the Santa Cruz Mountains of California, three resident corvids are common. These are common ravens (*Corvus corax*), hereafter “ravens”, American crows (*Corvus brachyrhynchos*), hereafter “crows” and Steller’s jays (*Cyanocitta stelleri*), hereafter “jays”.

Another corvid species that occurs in the Santa Cruz Mountains but is not generally found in conifer forests is the western scrub jay (*Aphelocoma californica*).

Like many species in the corvid family, the common raven, American crow, and Steller’s jay are conspicuous members of the native avifauna of many ecosystems in western North America and, until recently, are believed to have existed at relatively low densities. As generalists, they obtain food in a number of ways, including depredating the nests of other species, and are capable of exploiting a wide range of anthropogenic resource subsidies, and their abundance has grown in concert with increasing human populations overall and increasing human presence in wildlands. As a result, their numbers are growing across large portions of western North America in concert with a growing human presence (Marzluff et al. 1994, Sauer et al. 2014).

Each of these species has been implicated as predators of a number of species of concern, including the federally threatened marbled murrelet (*Brachyramphus marmoratus*). Therefore, growing corvid populations subsidized by anthropogenic resources add yet another problem to an increasing list of conservation concerns for sensitive species already impacted by human-mediated factors including habitat loss.

Ravens and jays have been documented depredating murrelet nests, and crows are considered potential murrelet nest predators in the future. Much of the evidence of nest predation on murrelets by corvids is attributed to predation on simulated murrelet eggs and chicks. Although both native species, the abundance of ravens and crows over the last few decades has increased significantly across most of western North America, including California and locally in the Santa Cruz Mountains. A dramatic increase in regional raven and crow abundance since the 1980's in the Santa Cruz Mountains has coincided with extremely low murrelet productivity as measured by at-sea ratios of juveniles to adults and a significant decrease in the number of murrelets attending Big Basin, which was once the most important breeding area in the Santa Cruz Mountains.

The risk of predation on murrelet nests from predator abundance is not well understood due in large part to a small sample size. Researchers have attempted to detect habitat factors associated with nest predation of murrelet nests, but such efforts are limited by the difficulties in locating their nests. Some studies suggest that nest proximity to forest stand edges appears related to a greater risk of nest predation for murrelets. Results from nest predation studies, including those of murrelet nests, and studies of corvid abundance suggest that corvids in forested regions occur more frequently near human settlement and recreation, in fragmented landscapes, and along forest edges. Marzluff and Neatherlin (2006), conducting research in the Olympic Peninsula of Washington, suggested that the positive relationship between corvid abundance and nest predation was driven primarily by increased crow abundance and nest predation at sites < 1 km from human settlement and recreation. Crows were the least abundant corvid > 5 km from settlement and recreation

but their abundance increased dramatically within 1 km of settlement and recreation. Ravens were moderately abundant both within 1 km and > 5 km from settlement and recreation and Steller's jays were equally abundant both within 1 km and > 5km from settlement and recreation. Steller's jays were the most abundant corvid on the Olympic Peninsula, approximately four times more abundant than ravens, and three times more abundant than crows.

In the Santa Cruz Mountains, Suddjian (2010a) found Steller's jays nine times more numerous in campgrounds than control areas, picnic areas, or residential areas. Jay density was positively correlated with the number of occupied campsites. In Redwood National and State Parks, picnic areas and campgrounds hosted twice as many and five times as many Steller's jays, respectively, compared to control areas (Benson 2008). On the Olympic Peninsula, Marzluff et al. (2004) radio-tagged 25 Steller's jays and determined resources use within their home ranges. Jays used young forest, human settlements, and agriculture more than clearcuts and mature forest. Although ravens were generally less common, Suddjian (2010) found that raven numbers at campgrounds in the Santa Cruz Mountains exceeded those in control areas by 28 times.

Scarpignato and George (2013) radio-tagged and followed eight adult ravens during the spring and summer of 2009 and 2010 in the old-growth forests of Redwood National and State Parks. The old growth forests protected within these parks supports some of the largest amounts of remaining nesting habitat for murrelets. Ravens used areas near paved roads and areas closer to old growth edge, but their use of old-growth was less than prairie, mixed hardwood and bare ground.

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

Webb et al. (2011) found that resource use by adult ravens in the Olympic Peninsula was positively associated with logging roads and paved roads, but nonbreeders avoided roads. Anthropogenic food subsidies was also one of the resources used most by breeding ravens, but not by nonbreeding ravens. Anthropogenic land uses on the sparsely populated Olympic Peninsula includes low density residential (rural and exurban housing), waste facilities, and fish hatcheries which all presented supplemental food for ravens.

Unlike crows and ravens, Steller's jay abundance does not necessarily increase with high-density human settlement (Marzluff et al. 1994, Luginbuhl et al. 2001, Vigallon and Marzluff 2005a), likely because of their close association with coniferous and mixed-coniferous forests and the loss of important vegetative elements with increases in development. However, Steller's jay abundance appears to be increasing in rural areas of the mountain west which have experienced unprecedented exurban development over the last several decades (Radeloff et al. 2012, Wood et al. 2014). In California, common raven and Steller's jay abundance has increased over the last several decades in the Santa Cruz Mountains (Peery and Henry 2010).. Steller's jays occur at significantly greater densities in and around recreation areas and campgrounds than in surrounding forests, presumably because of the greater prevalence of anthropogenic food in these areas (Suddjian 2009, Peery and Henry 2010). High jay densities in and around state parks in central California pose a serious threat to marbled murrelets because approximately half of known murrelet nests in the Santa Cruz Mountains occur within 1 km of campgrounds in state and county parks (Baker et al. 2006).

Although experiments conducted with simulated murrelet nests contribute substantially to our

understanding, the ongoing challenge of locating and monitoring active murrelet nests continues to limit our ability to understand factors contributing to nest predation and overall low productivity for murrelets. Since the first murrelet nest was located in 1974, only 19 additional nests have been found (Chapter 2, this Plan) and only a few of those were monitored while the nests were active. Peery et al. (2004a) discussed the fate of 19 of the known murrelet nests in Zone 6. Only three nests were successful. Seven of the 16 failed nests were known to be depredated, four by corvids (three by raven, one by jay). Of the remaining nine failed nests, predation was a possibility but there was no conclusive evidence. Predator identity was ascribed by direct evidence of the event (observations, photos or videos) or circumstantial evidence such as the condition of the nest and eggshell remains (e.g. Manley 1999).

Since murrelets will often re-use the same nest site, corvids may pose a special threat to them. Corvids are reported to have excellent spatial memories and "show evidence of episodic memory whereby they recall past events to influence present activities" (Burger et al. 2009 and Clayton et al. 2003, cited therein). The hooded crow (*Corvus corone cornix*) has been shown to remember and revisit the nests it had preyed upon in the previous year (Sonerud and Fjeld 1987). If the common raven and Steller's jay share this ability, which seems likely given their ability to hide and later relocate food caches, then the high nest site fidelity exhibited by marbled murrelets may have become a maladaptive trait for a habitat with a high density of ravens and jays.

MANAGEMENT OF CROWS AND RAVENS TO REDUCE THE RISK OF NEST PREDATION ON MARBLED MURRELETS IN THE SANTA CRUZ MOUNTAINS*William C. Webb***SUMMARY**

This report summarizes the threats posed by two hyper-abundant native corvids, American crows (*Corvus brachyrhynchos*) and common ravens (*Corvus corax*) on the productivity of nesting marbled murrelets (*Brachyramphus marmoratus*) in the Santa Cruz Mountains. Populations of American crows and common ravens in the Santa Cruz Mountains are continuous with, and part of their continental distributions. The earliest reports from the mid-nineteenth century state that common raven and American crows were originally widespread in Central California. However, historical accounts from the Santa Cruz Mountains (1883 -1942) report common ravens and American crows as rare or absent from this region.

Over the last several decades, common raven and American crow numbers have increased in many parts of western North America, which has raised concern about their negative effects on sensitive species. Breeding Bird Surveys from the Santa Cruz Mountains recorded few ravens until the mid-1980's but increased significantly beginning in the early 2000's when large numbers of common ravens began to be observed. American crows were rarely observed on Breeding Bird Survey routes in the Santa Cruz Mountains until 2007 until their numbers began increasing. During Christmas Bird Count surveys in the Santa Cruz Mountains, the number of common ravens began sharply increasing in the late 1980's, and peaked between 2003-2009. The number of American crows increased sharply at the Crystal Springs and Santa Cruz County count circles beginning in the late 1990's and continued through 2014.

Breeding ravens exclude conspecific from their territories and remain on their territories year-round, except when a mate dies. In species such as the common raven, territorial behavior creates space shortages, resulting in large populations of "floating" individuals unable to obtain breeding territories. Large numbers of ravens often gather at concentrated food resources, such as animal carcasses, which become "food bonanzas" for ravens. Resident pairs of ravens or single birds that encounter food bonanzas are unable to monopolize these large subsidies from conspecifics. American crows exhibit wider flexibility in their territorial behavior compared to common ravens. Breeding American crows in some populations in western North America may not defend "traditional" territories. Flexibility in territoriality may allow American crows to respond to local ecological conditions and occur in much higher density than common ravens.

Both American crows and common ravens exhibit omnivorous diets and employ a variety of foraging strategies. Results from a raven diet meta-analysis show that ravens consume a broad range of food items. Diet analyses both within and across studies suggest that food items consumed by ravens vary both temporally and spatially. However, the single most important food items for ravens are small mammals. Insects, birds, vegetation and large mammals are also important food categories for ravens.

Numerous reports exist of nest predation by ravens for a wide variety of species, some of them threatened and/or endangered. Many of the documented cases of nest predation by ravens are of waterbirds, including shorebirds and seabirds, and landbirds, including corvids,

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

grouse, eagles and California Condors. Factors associated with nest predation by ravens include increased raven abundance, the presence of food bonanzas and reduced vegetative structure. Forested landscapes disturbed by human activities such as agriculture, urbanization and recreation favor synanthropic, generalist species like corvids that are capable of exploiting novel resources associated with fragmentation as well anthropogenic subsidies. Corvids in forested regions occur more frequently near human settlement and recreation sites, in fragmented landscapes, and along forest edges. Since corvids are habitat generalists with large home ranges, the increased abundance of subsidized corvid populations may result in spill-over predation across wide areas.

In forested habitats, several predator species have been observed taking adult murrelets, their eggs and/or their nestlings. A total of nineteen murrelet nests have been located and monitored in the Santa Cruz Mountains, excluding the original nest found in 1974. Only three of these nests fledged young, and the cause of failure was reasonably determined for nine nests. Nest predation caused six of the nest failures and the predators included: ravens (3 nests), jays (1 nest), a red-shouldered Hawk (1 nest) and an unknown raptor (1 nest). A metanalysis of published and unpublished records of nest predation of real and simulated murrelet nests by corvids revealed 52 predation events where predation was assigned at the species level. A total of 21, 13 and 18 events were assigned to Steller's jays, gray jays and common ravens, respectively. Ravens and Steller's jays were no more likely to depredate nests in California when compared to Alaska, British Columbian, Washington and Oregon combined.

Because corvids present a risk of nest predation for murrelets, corvid populations in the Santa Cruz Mountains require intensive management

to aid in the recovery of the murrelet population. Lethal control of native predators is an important tool with a long history in conservation for increasing breeding performance and the density of prey species. Results from the scientific literature show that lethal removal is not universally successful in either reducing numbers of corvids nor improving productivity in prey species. In continental populations, when territorial corvids are lethally removed, non-breeding birds quickly reoccupy vacancies if the resource base remains unchanged. Indeed, the available evidence suggests that efforts to lethally remove ravens at parks in the Santa Cruz Mountains have failed to reduce raven numbers, therefore it is important to evaluate the efficiency of this approach and allocate limited resources towards methods most likely to achieve management goals.

Alternative short-term corvid management approaches include behavioral modification such as conditioned taste aversion (CTA), which been shown to reduce nest predation by ravens and jays in some cases. Conditioned taste aversion may hold promise for reducing the nest predation risk to murrelets by corvids, however it is incumbent upon managers to establish robust monitoring programs to evaluate the effectiveness of efforts like CTA, regardless of which management approaches are chosen.

Ultimately, access to anthropogenic resource subsidies is the ultimate cause of increased American crow and common raven abundance and associated increased risk of nest predation. Therefore, the primary long-term management goal should be the reduction of anthropogenic resource subsidies. Reducing subsidies will promote a lower density of corvids through larger home ranges of resident birds and reduce the presence of nonresident, territorial birds. Coordinated efforts among land managers should be made to reduce anthropogenic food

subsidizing regional populations of crows and ravens. If visitor management measures continue to prove unsatisfactory, managers may consider closing picnic areas and campgrounds during nesting season and/or relocating these facilities away from murrelet nesting habitat.

THE COMMON RAVEN AND THE AMERICAN CROW

Species Descriptions and Overview

The common raven (*Corvus corax*) (hereafter, “raven”) is a large black corvid and is North America’s largest passerine (Madge and Burn 1994). Ravens are the largest member of the corvid family, and like other corvids, are generalists whose populations respond positively to anthropogenic resources (Webb et al. 2004, Webb et al. 2011). Ravens are the most widespread of all corvids, with a natural range that includes almost the entire Northern Hemisphere, with the exception of regions where their range has retracted due to human persecution and habitat modifications. Ravens exhibit a wide ecological tolerance that enables them to survive environments ranging from scorching deserts to the frigid Arctic. In North America, ravens occur throughout most of Alaska, east across Canada to Newfoundland.

Ravens are residents throughout most of California, including the Santa Cruz Mountains, but are absent in some parts of the Central Valley (Small 1994). Ravens in the Santa Cruz Mountains are part of the continental population that extends north to the Arctic Circle and south through most of western Mexico reaching as far south as Guatemala and Nicaragua.

The American crow (*Corvus brachyrhynchos*) (hereafter “crow”) is a medium-sized, all black corvid found throughout most of North America. crows are widespread across North America, ranging from eastern British Columbia in the

extreme northwest to Newfoundland in the northeast and south to the Gulf of Mexico. In California, crows are present throughout much of the state, but they are absent from California deserts, southern San Diego County and dry parts of the San Joaquin Valley (Small 1994). Crows breeding at higher elevations, such as found in the Sierra Nevada, migrate to lower elevations in the winter (Small 1994). Crows are found in a wide variety of natural and anthropogenic habitats, generally avoiding areas of dense forest or extreme aridity. They can be found in riparian woodlands (Richards 1971, Knopf and Knopf 1983), croplands, wetlands, roadsides, beaches, lake shores (Good 1952, Chamberlain-Augur et al. 1990) and urban/suburban areas (Chamberlain-Augur et al. 1990, Caffrey 1992). They are absent from deserts and other dry, treeless areas. Crows favor open landscapes with scattered trees including agriculture and urban areas.

Raven and Crow Population Trends in the Santa Cruz Mountains

Historical accounts from the Santa Cruz Mountains (1883-1942) report ravens and crows as rare or absent. A number of unpublished sources, including observations by local experts, strongly support the conclusion that ravens were absent from Big Basin and San Mateo County Memorial Park (Singer and Suddjian 1995). McGregor (1901) compiled a species list of 188 species from five trips conducted by three different collectors between 1883-1898 in the Santa Cruz Mountains. Ravens were described as rare in the Santa Cruz Mountains but habitat associations were not described. Bird collectors working near Pescadero provided two specimens obtained in 1896 and 1898 to the California Academy of Sciences. McGregor (1901) reported that crows were locally abundant along riparian areas in Santa Cruz.

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

Population trends for crows and ravens are reported from the Breeding Bird Survey (BBS) over the period 1972-2013. A summary of population trends for crows and ravens from the Christmas Bird Count (CBC) database (National Audubon Society 2016) over the period 1960-2014 is also reported. Results from BBS survey data (1972-2013) indicates a substantial increase over the last several decades in raven populations across broad areas of the U.S and Canada (Figure 3-1). A regional trend analysis generated for ravens estimated 4.78% increase in raven abundance across California over the time period between 1966-2013. Across the U.S. and Canada, the trend for crows is uneven, with some regions showing decreasing number of crows, but an increasing number of crows in many western locations (Figure 3-2 page 75).

For California, regional trend analyses estimate 1.51% increase in the abundance of crows between 1966–2013. The Waterman Gap and Pescadero Routes are the only BBS survey routes situated in the Santa Cruz Mountains. Few ravens were detected on these routes when they initiated. The number of ravens observed on these routes peaked between 2002 and 2007 and have generally declined since then. Few ravens were recorded on the Waterman Gap route until the mid-1980's, continuing until the mid-1990's until a large gap in surveys. A large increase in the number of ravens occurred when the route resumed in 2002, peaking in 2008. Fewer ravens have been observed recently, but

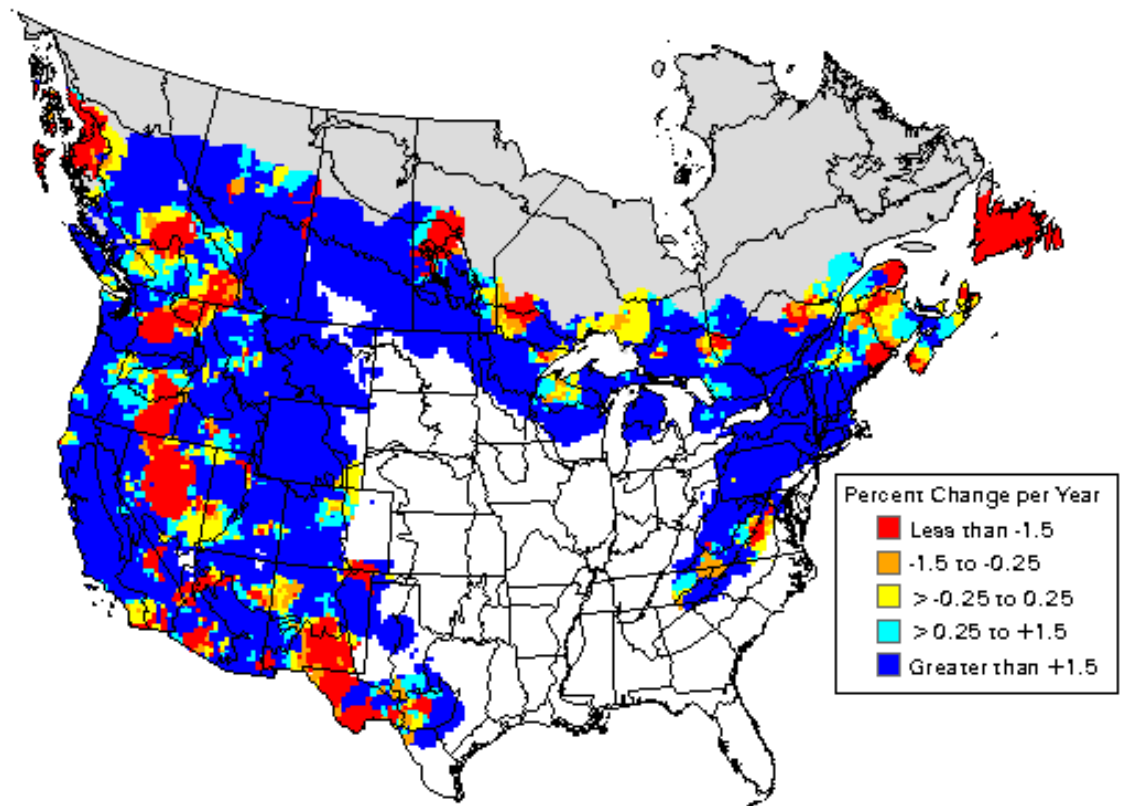


Figure 3-1. Trend map for ravens generated from BBS survey data from the time period 1966–2013.

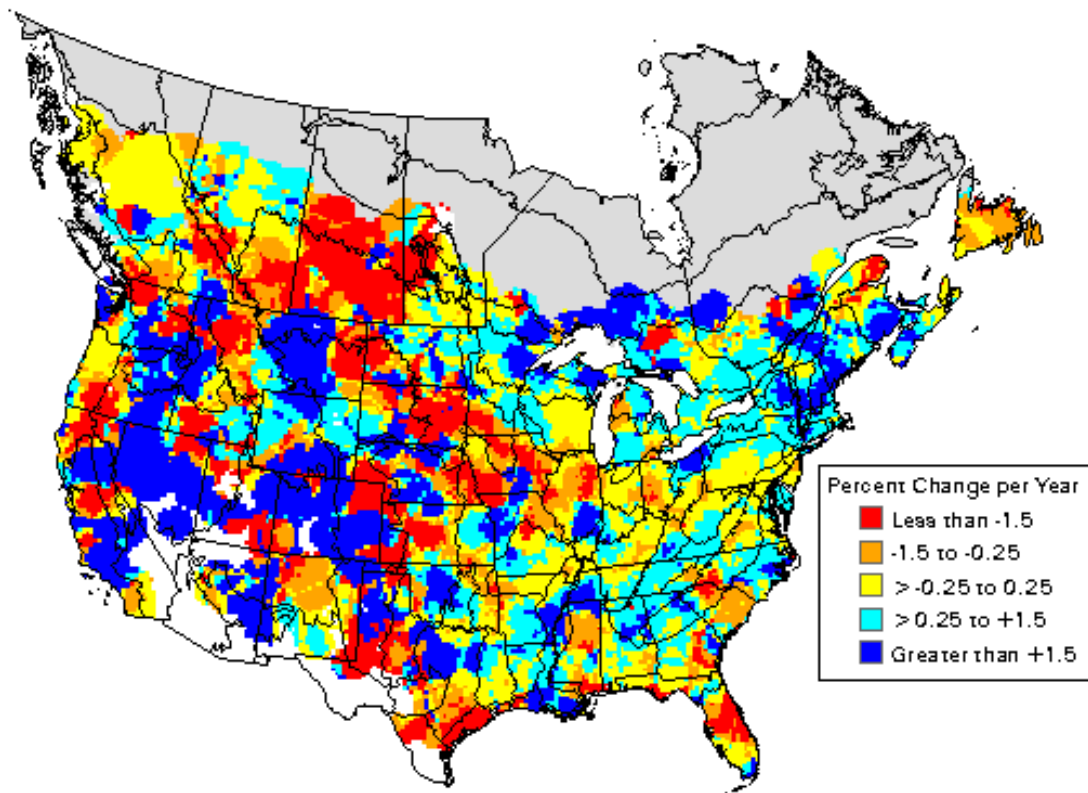


Figure 3-2. Trend map for crows generated from BBS survey data from the time period 1966–2013.

they are still more abundant on this route compared to when surveys began. Five ravens were recorded on the Pescadero route when it was initiated in 1992. Excluding a three-year gap in surveys on this route, the fewest ravens observed was 13 and the most was 63. Ravens numbers have declined on the Pescadero route since 2007 when 50 were observed, however numbers are still higher than when the route was initiated (Figure 3-4 page 77). Except for one individual in 1972 and 1978, crows were not recorded on the Waterman Gap route until 2007. They have been recorded every year since and relatively large numbers were observed in 2009 and 2013. On the Pescadero route, crows were first observed in 2006 and have been seen every year since 2008 (Figure 3-3 page 76)

Christmas Bird Count (CBC) surveys near the Santa Cruz Mountains (and their initial survey years) include Crystal Springs (1949), Santa

Cruz County (1957) and Año Nuevo (1971). The Crystal Springs circle was first surveyed in 1949, not again until 1956, but has been surveyed every year since. Ravens were first observed in 1960, 1973 and 1979 on the Crystal Springs, Año Nuevo and Santa Cruz County circles, respectively. Ravens have been detected annually for all three count circles since 1979. Across all three circles, the number of raven observations began sharply increasing in the late 1980s, but peaked between 2003-2009. Although fewer ravens have been observed recently, their numbers are still considerably higher than the initial survey years. These trends mirror the pattern observed for ravens across all count circles statewide, which showed an approximately six-fold increase in ravens counted between 1961 and 2014 (Figure 3-5 page 78).

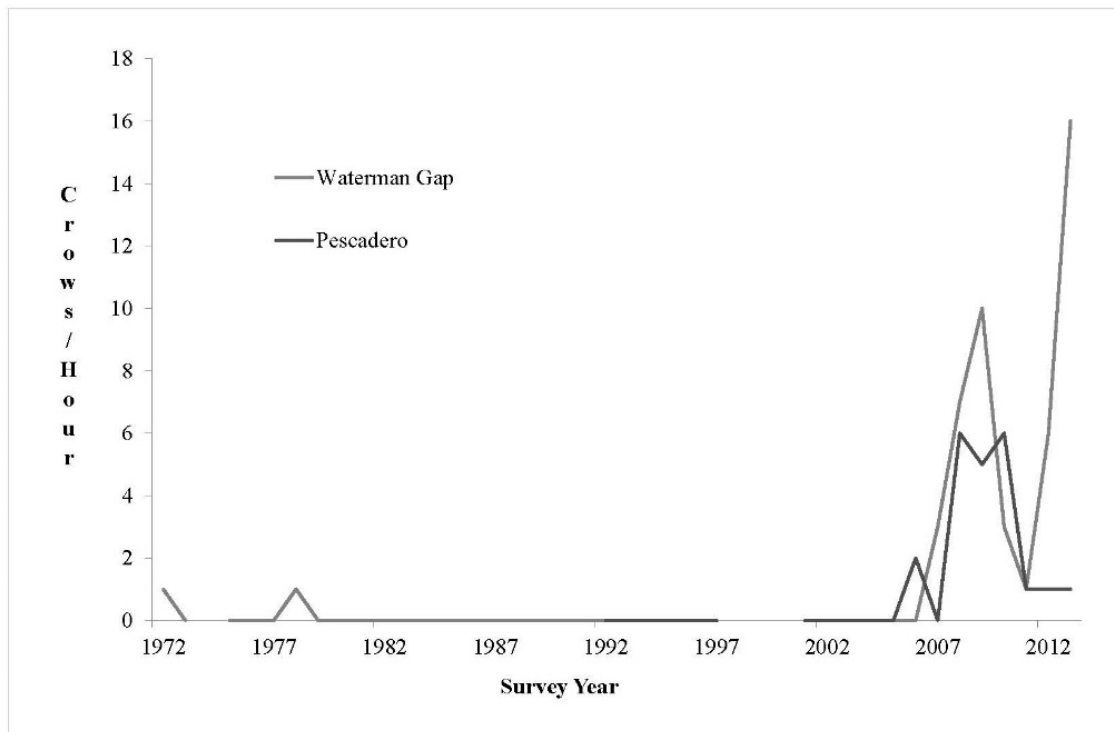


Figure 3-3. Number of crows observed on the two Breeding Bird Survey routes in the Santa Cruz Mountains between 1972 -2014. Gaps in the lines represent years in which surveys did not occur.

Crows were first observed in 1959, 1961 and 1974 on the Crystal Springs, Santa Cruz County and Año Nuevo circles, respectively. Few crows were observed in all three circles until the 1990s. The number of crows observed statewide in CBC circles has gradually increased since the late 1970s. Compared to the CBC statewide averages, fewer crows were observed overall in the Santa Cruz Mountains. However, the number of crows observed since the late 1990s is increasing in the Santa Cruz Mountains compared to the statewide trend (Figure 3-6 page 79).

The most fine-scaled and detailed data available on corvid population trends in the Santa Cruz Mountains comes from surveys conducted from 2002-2012 (Suddjian 2010, Halbert 2012). Beginning in 2002, Suddjian established a corvid monitoring program in each of four parks known or suspected to support nesting

murrelets: Big Basin Redwoods State Park, Portola Redwoods State Park, Butano State Park and San Mateo County Memorial County Park. Within each park, this study paired surveys of corvid abundance in treatment areas - high visitor use areas (campgrounds) with controls located in low visitor use areas. The method used to census birds was the area search method (Ralph et al. 1993).

Halbert (2012) provided raw survey data for survey years 2003-8 and 2012. Graphical inspection of the data shows ravens substantially more numerous in campgrounds compared to controls (Figure 3-7 page 80, Figure 3-9 page 81). Crows were first detected in these survey efforts in 2008 at Big Basin and Memorial Parks, and again at these parks in 2009 in addition to Portola (Suddjian 2010, Halbert 2012). On each occasion, one to four crows were observed and it was likely these were

nonbreeding floaters rather than territorial breeding individuals.

Diet and Foraging Behavior

Results from diet analyses, behavioral studies and anecdotal observations indicate ravens have an omnivorous diet and consume a wide range of food items (Figure 3-8 page 80). Ravens employ a variety of tactics to acquire food, including hunting, scavenging, gleaning and stealing food from conspecifics (Bugnyar and Kotrschal 2002) and other species (Careau et al. 2007). Vegetation often forms a substantial part of their diet, including seeds, nuts and berries (Salmon et al 1986). Scavenged food items include animal carcasses from the kills of predators such as wolves (Stahler et al. 2002), fish (Matley et al. 2012), roadkill (Webb et al. 2011) and other anthropogenic foods including refuse obtained at landfills (Webb et al. 2009).

Ravens also hunt arthropods (Engel 1989) small mammals (Temple 1974), adult birds (Marr and Knight 1982), and depredate the contents of bird

nests (Coates and Delehanty 2010). In a study by Webb (2010), raven abundance and the presence of experimental food bonanzas were associated with an increased risk of passerine nest predation by ravens at multiple scales of analysis.

Numerous reports exist of nest predation by ravens on a variety of species, some of them threatened and/or endangered. Many documented cases of nest predation by ravens are of waterbirds including shorebirds and seabirds. Shorebirds affected by nest predation by ravens include herons (Hothem and Hatch 2004), egrets (Kelly et al. 2005), snowy plovers (Colwell et al. 2009), and ardeid colonies in (Great Blue Heron, Great Egret, Snowy Egret and Black-crowned Night Herons; Kelly et al. 2005). The U.S. Fish and Wildlife Service (2007) identified nest predation by ravens and crows as one of the primary contributors to low productivity of the federally-threatened Western Snowy Plover (*Charadrius alexandrinus*

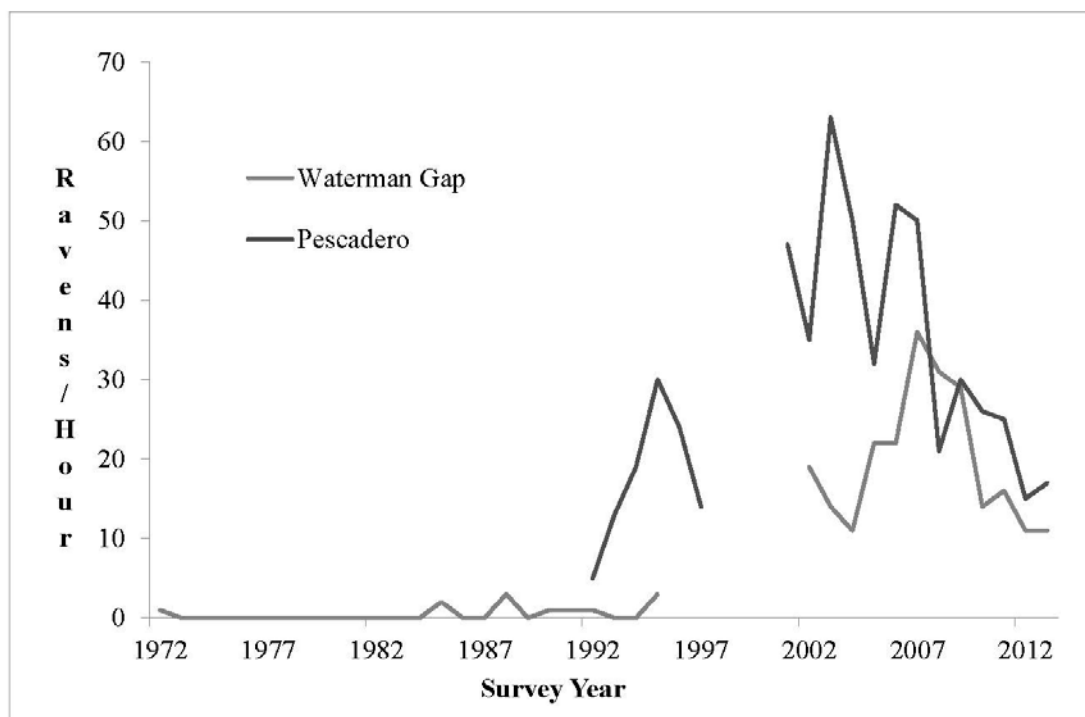


Figure 3-4. Number of ravens observed on the two Breeding Bird Survey routes in the Santa Cruz Mountains between 1972 -2014.

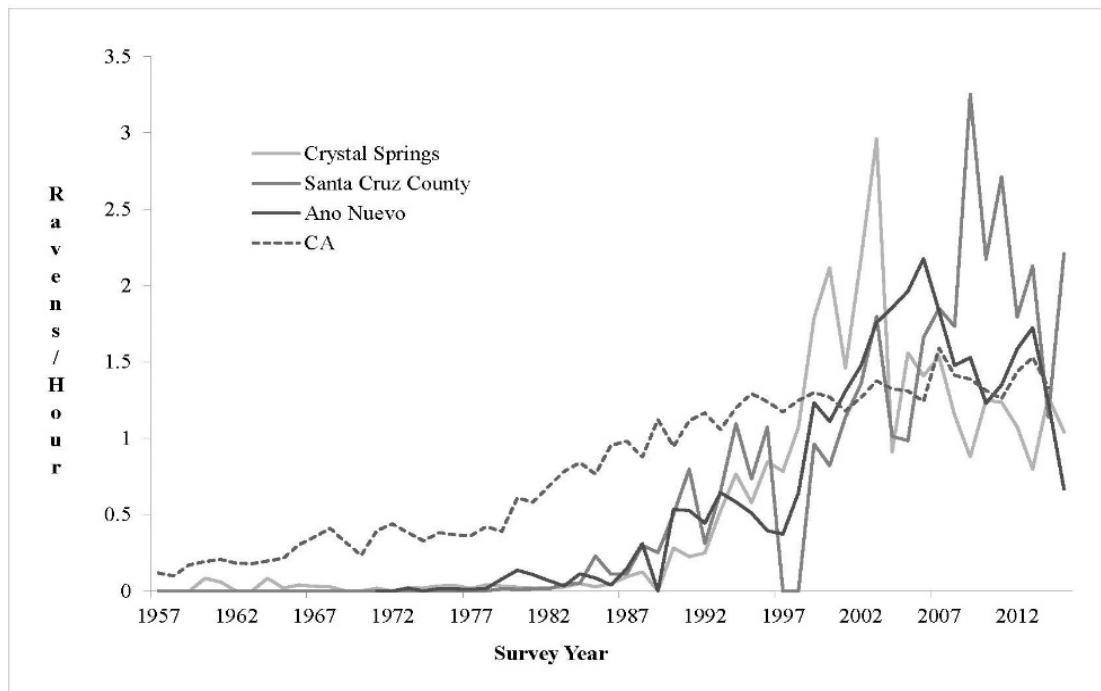


Figure 3-5. Number ravens observed per party hour from Audubon Society's Christmas Bird Counts, 1956-2015 Data are from statewide averages and the three closest census sites to the forested portions of the Santa Cruz Mountains: Crystal Springs, Santa Cruz County and Ano Nuevo.

nivosus). Nest predation by ravens of colonial-nesting seabirds has been reported and includes predation on Black-legged Kittiwakes (*Rissa tridactyla*; Montevecchi 1979), California least tern (*Sternula antillarum browni*; Marschalek 2011), Brunnich's Guillemots (*Uria lomvia*; Gaston and Elliot 1996), and Rhinoceros Auklets (*Cerorhinca monocerata*; Hayward et al. 2015).

Studies show ravens also depredate nests from a range of landbird taxa across ecoregions, including the pinyon jay (*Gymnorhinus cyanocephalus*; Marzluff 1988), Greater Sage-Grouse (*Centrocercus urophasianus*; Coates et al. 2008). Ravens in British Columbia were responsible for the only recorded instance of egg predation of a Golden Eagle (*Aquila chrysaetos*) (Morton and Pereyra 2008). Synder et al. (1986) reported a minimum of two confirmed instances

of nest predation by ravens of California Condors (*Gymnogyps californianus*) and circumstantial evidence of several more. Moreover, risk of nest predation by ravens was one of the factors leading to the original decision to move all remaining wild California Condors into a captive breeding program.

Crows have an omnivorous diet including a wide array of invertebrates including insects, earthworms, snails and millipedes (Hendricks 1980, Quiring and Timmons 1988, Solem 1997). Crows also consume vegetation in the form of seeds, fruits, nuts and grain crops (Hering 1934, Cristol 2001). Vertebrates in the crow diet include amphibians, reptiles, mammals, small birds, bird eggs and nestlings (Prescott 1965, George and Kimmel 1977). Their diet also includes carrion and human refuse (Knight et al. 1991, Marzluff and Neatherlin 2006). Crows

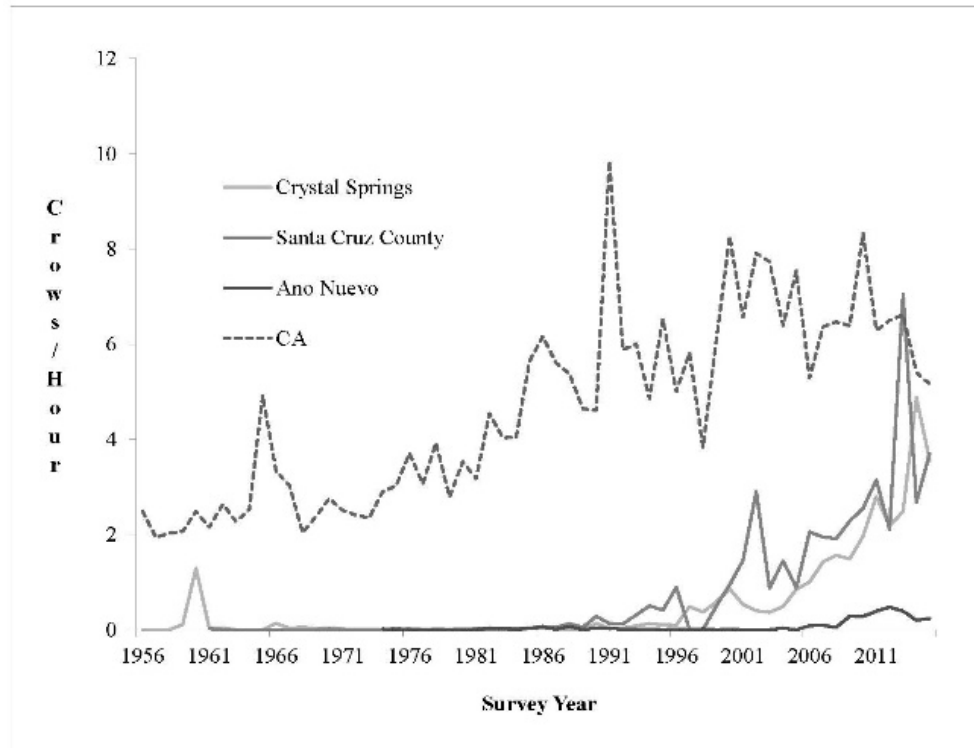


Figure 3-6. Number of crows per party hours observed during Audubon Society's Christmas Bird Counts, 1956-2015 Data include statewide averages and from the three closest census sites to the forested portions of the Santa Cruz Mountains: Crystal Springs, Santa Cruz County and Ano Nuevo.

obtain food by hunting, gleaning and scavenging from both terrestrial and intertidal habitats.

Crows forage primarily on the ground but they will also hunt and/or glean from shrubs and trees (George and Kimmel 1977, Phillips 1978, Bayer 1984). Crows often feed along the edges of fresh and salt water and sometime wade into shallow water while feeding. They will sometimes drop objects, such as bivalves, from heights onto hard surfaces in order to break them open (Bayer 1984).

Crows are also important nest predators, and have been recorded predated the eggs of waterfowl (Klambach 1937, Sugden and Beyersbergen 1986) and are a threat to the eggs and young of endangered species, including the Western Snowy Plover (Castelein et al. 2000a, b) and the California Least Tern (Caffrey 1993, 1994, 1995a, 1998, Keane 1999).

Sociality of Ravens and Crows

Ravens reach sexual maturity in their second year (Jollie 1976), but most likely do not breed until later. Only two published records of raven natal dispersal exist. In the Mojave a male raven first bred in its fifth year 2.6 km from its natal nest (Webb et al. 2012). On the Olympic Peninsula of Washington State bred unsuccessfully in his fourth year but fledged two young in his fifth year in a territory 4.9 km from his natal territory where his father still resided (Webb et al. 2012). Ravens mate for life and defend a territory year-round from conspecifics (Webb et al. 2011, 2012). Ravens display a preemptive or despotic (dominance) distribution (Carpenter 1971). Breeding ravens exclude conspecific from their territories and remain on their territories year-round, except when a mate dies (Webb et al. 2012) or in extreme climates where territorial behavior may vary between

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

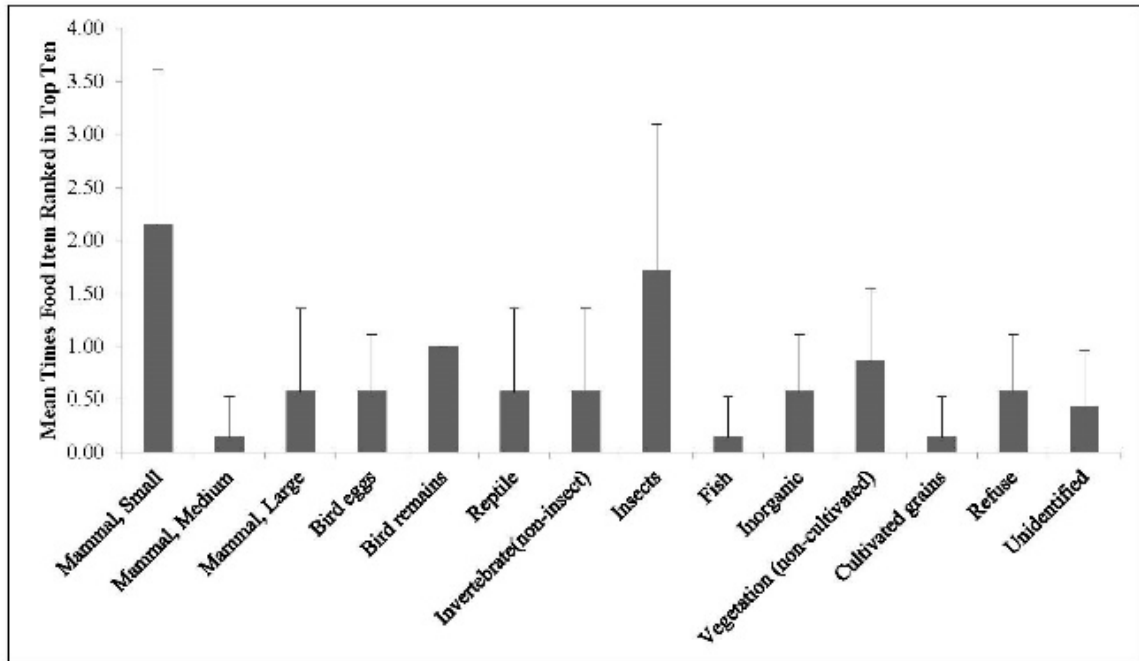


Figure 3-8. Results of a diet metanalysis from seven studies of raven pellets or stomach contents. Displayed are the mean number of times a food item (from the top ten most frequently consumed in each study) fell into a particular dietary category. Plotted are the mean and standard deviation (error bars).

seasons (Boarman and Heinrich 1999). Young ravens fledge from their nests 4-5 weeks after hatching, and remain in their natal territory from 1–8 weeks (Webb et al 2004, 2012). Over time, juvenile ravens accompany adults on increasingly longer foraging trips away from the nest (Stiehl 1985, Webb et al. 2012). By 8 weeks after fledging, all surviving juvenile ravens permanently depart from their natal territory (Webb et al. 2004, 2012).

In species such as the common raven, territorial behavior creates space shortages, resulting in large populations of “floating” individuals unable to obtain breeding territories (Newton 1992, Sutherland 1996). These floaters are often young, inexperienced individuals (Zack and Stutchbury 1992). Juvenile and older nonbreeding ravens behave similarly to other strongly territorial species with delayed breeding by forming floater flocks. Since ravens do not reach sexual maturity until their second year, floating might be preferable to delayed dispersal

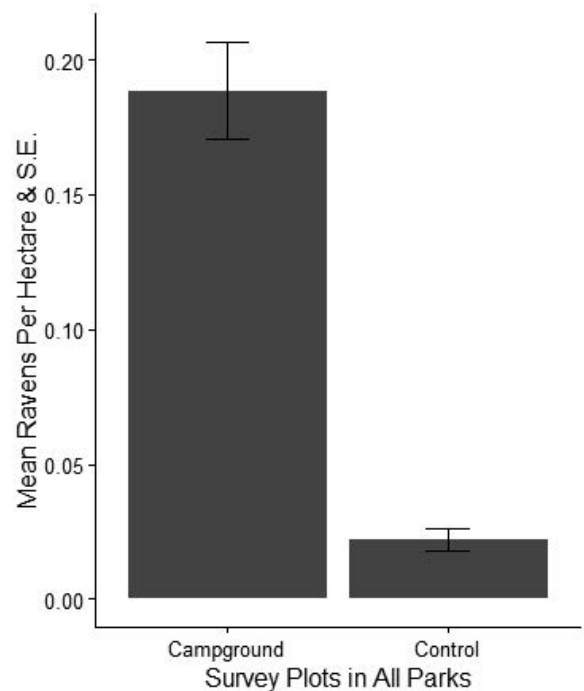


Figure 3-7. Raven density in campgrounds compared to control sites observed during corvid surveys. Data are from (Halbert 2012) , which includes surveys conducted 2003-2008 and 2012.

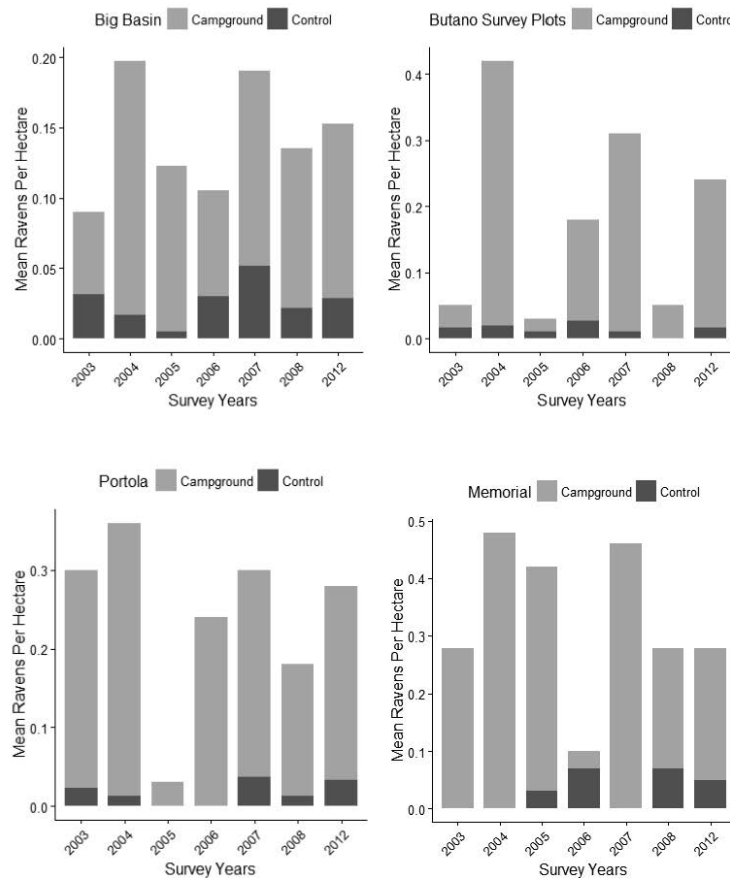


Figure 3-9. Raven density in campgrounds and control sites at all four parks. Data are from (Halbert 2012), which includes surveys conducted 2003-2008 and 2012. Note: Light gray bars are not stacked but intended to extend beneath the dark gray bars.

because it avoids kin competition (Lambdin and et al. 2000) and increases foraging efficiency through communal food sharing (Stacey 1987). Joining the nonbreeding flock might also be the quickest route to acquiring a mate (Woolfenden and Fitzpatrick 1978) and scouting widely for potential breeding territories. It is also possible that floaters may increase their fitness by obtaining extra-pair copulations or by intraspecific brood parasitism.

Marzluff and Heinrich (1991) showed that raven floaters use their numerical advantage to gain access to ephemeral resources such as animal carcasses and other food bonanzas by overwhelming the defensive ability of resident ravens. Nonbreeding floaters feeding in large

groups at super-abundant food sources will also roost in large groups. Communal raven roosts of floaters serve as information centers that enable floaters with knowledge of food bonanzas to recruit conspecifics in order to overwhelm resident ravens (Marzluff et al. 1996, Wright et al. 2003).

Large numbers of ravens often gather at concentrated food resources, such as animal carcasses, which become "food bonanzas" for ravens (Marzluff and Heinrich 1991). Resident pairs of ravens or single birds that encounter food bonanzas are unable to monopolize these large subsidies from conspecifics (Marzluff and Heinrich 1991). Consequently, food bonanzas can attract dozens or hundreds of ravens that

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

will congregate in the vicinity for days or weeks until the resource is depleted (Heinrich 1988, Webb et al. 2011, 2012).

Raven foraging behavior increases the risk of incidental, spillover predation in the vicinity of food bonanzas. Raven foraging behavior in response to bonanzas contributes to increased abundance of ravens in the immediate vicinity and within several hectares surrounding bonanzas (Marzluff et al. 1996, Webb 2010). Bonanzas elevate raven abundance over a wide area because not all ravens attending bonanzas feed simultaneously, in part due to dominance hierarchies which allow priority access to bonanzas for dominants and restrict access for subordinates (Marzluff and Heinrich 1991). Raven abundance is also elevated in the surroundings near bonanzas due to frequent caching (Heinrich and Pepper 1998). However, large numbers of ravens typically do not aggregate in anthropogenic land cover unless a food bonanza becomes temporarily available (Webb et al. 2011). Thus, spillover nest predation may not be associated with anthropogenic land cover and land use except in the proximity of food bonanzas.

FACTORS ASSOCIATED WITH NEST PREDATION OF MURRELETS

The risk of predation on murrelet nests from predator abundance and landscape configuration is not well understood. Researchers have attempted to detect habitat factors associated with nest predation of murrelet nests, but such efforts are limited by the difficulties in locating their nests. Some studies suggest that nest proximity to forest stand edges appears related to a greater risk of nest predation for murrelets (Nelson and Hamer 1995, Manley et al. 1999). Results from experimental studies suggests that the risk to artificial murrelet nests varies depending on attributes of forest structure and configuration of landscape elements. In general,

landscape factors associated with elevated nest predation include hard edges, forest fragmentation and forest complexity.

Anthropogenic landscape alterations may influence murrelet predator distributions and patterns of nest predation. In some landscapes, increased abundance of corvids is associated with the amount of forest edge, habitat complexity and areas of low forest cover (Andren 1992, Robinson et al. 1995, Hannon and Cotterill 1998). On the Olympic Peninsula, nonbreeding ravens avoided edges and breeding ravens did not significantly use edge habitats (Webb et al. 2011). However, both breeding and nonbreeding ravens preferentially used areas of complex landscape configurations with diverse and patchy patterns of landcover types (Webb et al. 2011). Complex landscaped configurations in this mostly forested region are typified by disturbed habitats with anthropogenic land uses and anthropogenic resource subsidies utilized by ravens, jays and crows.

In forested landscapes, increased risk of nest predation has frequently been observed with loss of forest cover (Robinson et al. 1995), which has led some to assume that these effects hold universally true. While a number studies have reported elevated rates of nest predation for birds nesting near edges in forest habitats, other have not detected edge effects (Marzluff and Restani 1999, Marzluff and Neatherlin 2006). In their review of the literature on edge effects for nesting birds, Marzluff and Restani (1999) suggested that failure to account for variation in the land cover surrounding forest plots was a major contributor to seemingly inconsistent results from edge effect studies. Studies taking place in landscapes with forests fragmented by urban and agricultural landscapes were more likely to detect edge effects than studies in landscapes fragmented by mainly by commercial forestry.

Variation in resource subsidies available to potential nest predators is an important difference between landscapes fragmented by forestry compared to those fragmented by agriculture or urbanization. Forested landscapes disturbed by human activities such as agriculture, urbanization and recreation favor synanthropic, generalist species like corvids that are capable of exploiting novel resources associated with fragmentation as well anthropogenic subsidies. The abundance of anthropogenic subsidies improves corvid survival and reproduction (Webb et al. 2004, Marzluff and Neatherlin 2006, Kristan and Boarman 2007, Webb et al. 2011) which leads to increased corvid abundance. Since corvids are habitat generalists with large home ranges, the increased abundance of subsidized corvid populations may result in spill-over predation across wide areas (Holt 1984, Schneider 2001, Kristan and Boarman 2003).

ROLE OF CORVIDS AS MURRELET NEST PREDATORS

Results from nest predation studies, including those of murrelet nests, and studies of corvid abundance suggest that corvids in forested regions occur more frequently near human settlement and recreation, in fragmented landscapes, and along forest edges. Marzluff and Neatherlin (2006) found that the positive relationship between corvid abundance and nest predation was driven primarily by increased crow abundance and nest predation at sites < 1 km from human settlement and recreation. Crows were the least abundant corvid > 5 km from settlement and recreation but their abundance increased dramatically within 1 km of settlement and recreation. Ravens were moderately abundant both within 1 km and > 5 km from settlement and recreation and Steller's jays were equally abundant both within 1 km and > 5km from settlement and recreation.

Steller's jays were the most abundant corvid on the Olympic Peninsula, approximately four times more abundant than ravens, and three times more abundant than crows.

Neatherlin and Marzluff (2004) observed the habitat use and foraging behavior of radio-tagged crows near murrelet nesting habitat on the Olympic Peninsula. For 39 crows with campgrounds in their home ranges, campgrounds and exurban areas were used more frequently relative to their occurrence than other land-cover types such as mature forest. They concluded that reducing the numbers of crows would have little effect on nest predation rates since less than 1% of 817 foraging observations involved nest predation by crows. However, they also suggested that reducing the suitability and accessibility of campgrounds to crows also may reduce other nest predators, including jays and rodents, that benefit from anthropogenic foods.

Although ravens were generally uncommon, corvid surveys in the Santa Cruz Mountains (Suddjian 2010, Halbert 2012) found that raven numbers at campgrounds far exceeded those in control areas (Figure 3-7 page 80). Scarpignato and George (2013) radio-tagged and followed eight adult ravens in Northern California during the spring and summer of 2009 and 2010 and found that ravens used areas near paved roads and areas closer to old growth edge. Resource use on the Olympic Peninsula by adult ravens was positively associated with anthropogenic areas, logging roads and paved roads, but nonbreeders avoided roads (Webb et al. 2011).

A metanalysis of published and unpublished records of nest predation of real and simulated murrelet nests by corvids revealed ten sources and 24 observations of one or more predation events totaling 52 predation events where predation was assigned at the species level.

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

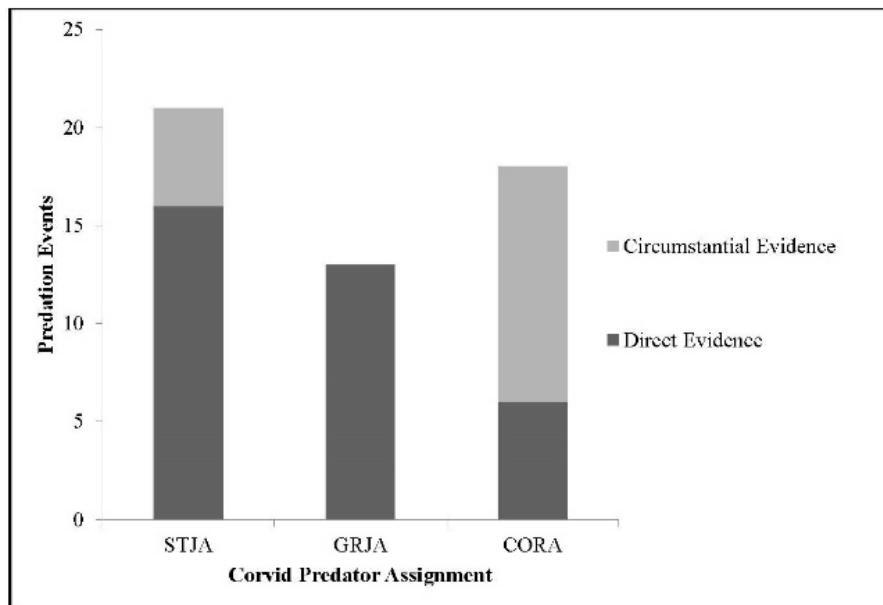


Figure 3-10. The number of predation events attributed to steller's jays (STJA), Gray Jays (GRJA) and ravens (CORA) from the 52 predation events of real or simulated murrelet nests assigned to corvids. Assignments determined by circumstantial evidence are colored light grey, and assignments observed directly or through video or photos are colored dark grey.

Predator identity was ascribed by direct evidence of the event (observations, photos or videos) or circumstantial evidence such as the condition of the nest and eggshell remains (e.g. Manley 1999). One or more predation events have been reported from each of the major political jurisdictions within the murrelet's range: Alaska, British Columbia, Washington, Oregon and California. Corvid predators of real murrelet nests included ravens and Steller's jays, which also depredated simulated nests, although gray jays and various small mammals depredated simulated nests. Each corvid species documented as a murrelet nest predator was assigned at least one event in every jurisdiction, except that ravens have not been documented depredating nests in Washington and gray jays have not been documented depredating nests in California.

Although crows occur in most regions where murrelets nest, few data exist regarding the potential they pose as murrelet nest predators. Crows have never been documented depredating

a real murrelet nest but were identified by photograph depredating an egg from one simulated nest from the subset of 48 that Luginbuhl et al. (2001) outfitted with cameras. Because most of the 948 simulated nests did not have cameras, Luginbuhl et al. (2001) were unable to distinguish between crows or ravens as nest predators. However, large corvids were rare nest predators overall, leaving evidence at nine nests with nestlings (2%) and 28 nests with eggs (6.2%). Further refinement of methods employed by potential future nest predation studies may elucidate the risk posed by crows as potential murrelet nest predators.

The sample size of failed murrelet nests with assigned corvid predators is small and not all predator identification was supported by direct evidence. However, patterns in predator identity in this small, imperfect dataset do emerge. A total of 21, 13 and 18 events were assigned to Steller's jays, gray jays and ravens, respectively (Figure 3-10 page 84). Although gray jays are suspected predators of real murrelet nests, all 13

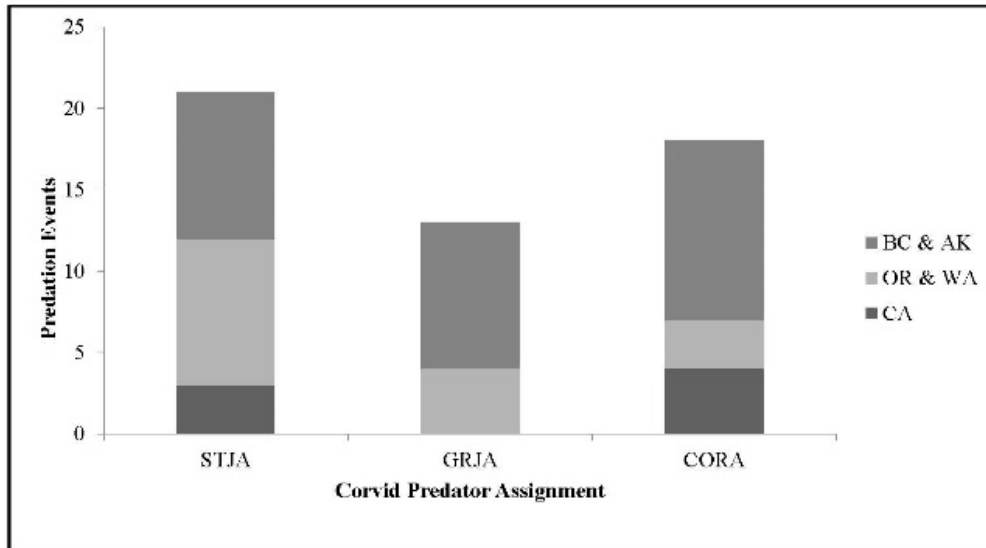


Figure 3-11. The number of predation events attributed to steller's jays (STJA), Gray Jays (GRJA) and ravens (CORA) from the 52 predation events of real or simulated murrelet nests assigned to corvids. Predation events for each predator are divided by political jurisdictions: California (CA); dark grey; Oregon and Washington State (OR & WA); light grey; and British Columbia and Alaska (BC & AK); medium grey.

predation events were of simulated nests either recorded in Washington on camera (Luginbuhl et al. 2001) or in British Columbia on video (Malt and Lank 2007). Predation of both real and simulated nests was attributed to both Steller's jays and ravens.

Chi-square tests of goodness-of-fit were performed to determine if predator assignment differed between Steller's jays and ravens in relation to the type of nest, the type of evidence used and political jurisdiction. Most (94%) of events assigned to ravens involved real nests (Figure 3-11 page 85) and predation on real nests was less likely to be attributed to Steller's jays than ravens ($X^2 (1, N = 52) = 13.37, p < .01$). However, a majority of events attributed to ravens were based on circumstantial evidence (67%), Figure 3-12 page 86) and ravens were more likely to be implicated based on circumstantial evidence compared to Steller's jays (24%) ($X^2 (1, N = 52) = 7.23, p < .01$). This result was largely influenced by Manley (1999) who assigned 8/12 events to ravens based on the state of eggshell remains. Even though four of

five events in the Santa Cruz Mountains were assigned to ravens with direct evidence, the pattern of predator assignment was similar in California compared to elsewhere.

CORVID MANAGEMENT TO REDUCE THE RISK OF NEST PREDATION OF MURRELETS

In the Santa Cruz Mountains, murrelet productivity is exceptionally low (Peery et al. 2004), corvid numbers are exceptionally high (Sauer et al. 2014, National Audubon Society 2016), and much of the remaining murrelet nesting habitat occurs in close proximity to public campgrounds and picnic areas with high densities of corvids (Peery and Henry 2010). Because corvids present a significant risk of nest predation for murrelets, corvid populations in the Santa Cruz Mountains require intensive management to aid in the recovery of the Zone 6 murrelet population. Corvid management options are given in Table 3-1 page 92.

Lethal Control of Crows and Ravens

Lethal control of native predators is an important tool with a long history in both game

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

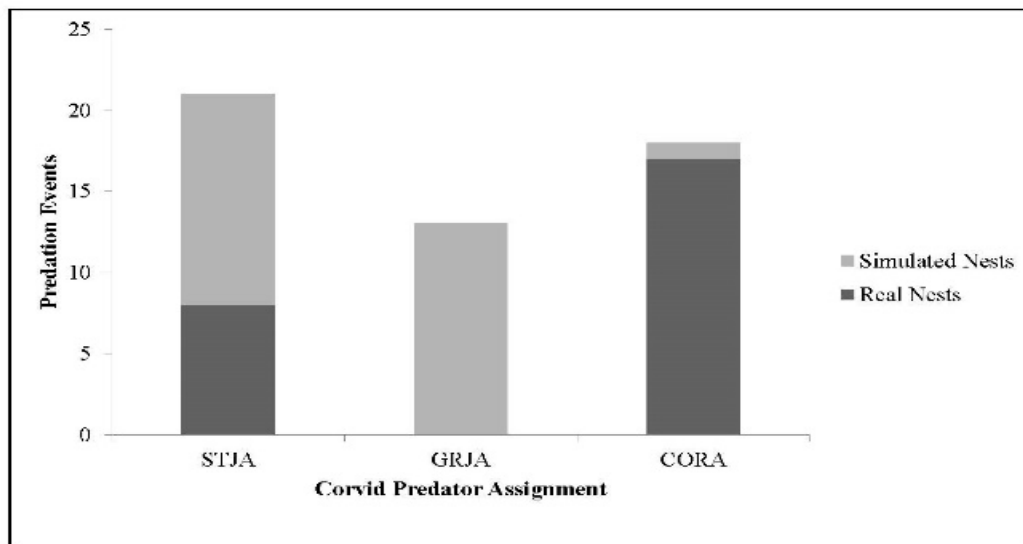


Figure 3-12. The number of predation events for simulated (light grey) and real nests (dark grey) attributed to steller's jays (STJA), Gray Jays (GRJA) and ravens (CORA) from the 52 predation events of real or simulated murrelet nests assigned to corvids.

management and conservation for increasing breeding performance and density of prey species

(Potts 1986, Butchko and Small 1992, Reynolds and Tapper 1996, Meckstroth and Miles 2005). Numerous studies have employed shooting to reduce numbers of ravens and/or crows (Chesness et al. 1968, Parker 1984, Butchko 1990, Littlefield 2003, Struthers and Ryan 2005, Bodey et al. 2009, Steen and Haugvold 2009). Corvids' ability to quickly adapt to human behavioral patterns and recognize individual humans rapidly reduces the efficiency of shooting over time (Cornell et al. 2011). The most commonly used poison to kill corvids is DRC-1339 (3-chloro-4-methylbenzenamine HCL) (Schafer 1984, Butchko 1990, Rado 1993, Coates and Delehanty 2004).

Results from the scientific literature show that lethal removal is not universally successful in either reducing numbers of crows and ravens nor improving productivity in target species. In Norway, corvid control has been traditionally practiced by game managers and hunters, and

often promoted by bounties (Parker 1984). Working on Karlsoy Island off the coast of Norway, Parker et al. (1984) removed ravens and hooded crows by shooting and lacing bait eggs with alpha-chloralose. They found no differences in brood success of willow ptarmigan (*Lagopus lagopus*) and black grouse (*Lyrurus tetrix*) between the experimental area where corvids were removed and a control area. From 1976 until at least 1990, wide scale, government-sponsored lethal control of ravens by shooting and poisoning was practiced in Iceland (Skarphedinsson et al. 1990). Despite indiscriminate killing of ravens resulting in an estimated 4,116 ravens killed annually, occupancy rates of territories and nonbreeding flock sizes remained constant.

Given the reputation of corvids as major nest predators, variation in the success of lethal corvid control may seem surprising. However, published meta-analyses show that mixed results for lethal control is a common pattern regardless of which predator species is targeted. For example, Cote and Sutherland (1997) reviewed 20 studies employing mammalian and/or avian

predator removal to improve avian productivity. They found a large positive effect of lethal control on hatching success and post-breeding population sizes, but lethal control did not usually improve breeding population sizes. As such, they concluded that predator removal was a better tool for game managers than conservation biologists.

Multiple explanations exist why many studies removing just corvids did not detect increased prey productivity nor increased prey abundance. These include overestimating the effects of predation, trophic interactions between predator species, compensatory predation, and overestimating the role of corvids. In many cases, immigration of new individuals of the predator species occurs after lethal removal and negates any benefits of predator removal. Populations that are spatially saturated by territory holders are typified by large numbers of surplus individuals, and when territorial birds perish, non-breeding birds quickly reoccupy vacancies as long as the resource base remains unchanged (Webb et al. 2012).

Like most efforts to control mainland populations of corvids, efforts to lethally remove ravens at parks in the Santa Cruz Mountains have failed to reduce raven numbers. Despite shooting ravens in parks beginning as early as 2005, the most recently-available survey data shows no difference in raven numbers over time (Fig. 11; (Suddjian 2010, Halbert 2012). This result is consistent with previous studies of raven demography and with control efforts conducted on mainland study sites where the local raven population was continuous with a larger continental population. Regions such as the Santa Cruz Mountains with robust raven populations contain large numbers of surplus individuals which readily fill territory vacancies. On the Olympic Peninsula of Washington State, illegal shooting was the most frequent source of

mortality for territorial ravens (Webb et al. 2011, 2012). However, territorial ravens killed by shooting or other means were rapidly replaced by immigrants (Webb et al. 2012).

Concern about the possibility of ravens to remember and return to murrelet nests is cited as justification for lethal control of ravens (Halbert 2016). Although the ability to remember the location of artificial ground nests was demonstrated in an experiment using a single captive hooded crow (*Corvus corone*) (Sonerud and Fjeld 1987), it has never been documented in wild birds. However, most corvids (including ravens) are believed to have exceptional spatial memory (de Kort and Clayton 2006). For example, the caching behavior of ravens has been well-studied in captive birds (Bugnyar et al. 2007) also incidentally observed in the wild (Howe and Coates 2014). Collectively, the results of Sonerud and Fjeld (1987) and studies of raven spatial memory provide compelling rationale to speculate regarding the potential ability of ravens to recall and revisit nest locations.

Despite widespread concern for ravens as nest predators, most aspects of raven nest predatory behavior, including the spatial aspect, remain unstudied. Currently no data exist to objectively evaluate the specific hypothesis that individual ravens remember and return to bird nest they have depredated in previous nesting seasons. Moreover, if ravens do display this behavior, it is also not known how frequent the behavior is, or what its potential impacts are to prey species. Strictly speaking, this aspect of raven behavior remains an untested hypothesis. It is not surprising that such data do not exist given the high level of effort that would be required to embark on such a study. Obtaining this type of data would likely require a long-term, detailed behavioral study of individually-marked ravens combined with videography.

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

Given the limitations of lethal control, it is important to evaluate its efficiency in each case and allocate limited resources towards methods most likely to achieve management goals (O’Conner 1991). Biologists involved in the conservation of rare species should use lethal control only as a last resort, such as when an abundant native vertebrate species poses an immediate threat to the survival of an endangered species (Goodrich and Buskirk 1995). In such cases, lethal control should serve as a short-term solution while long-term solutions are implemented.

Behavioral Modification

In addition to lethal control, other short-term approaches to predator control include behavioral modification and reproductive control. One approach to behavioral modification for reducing predation involves conditioning predators to avoid certain foods or frightening them away from potential prey. Conditioned taste aversion (CTA) trains potential predators to avoid foods that mimic prey with the use of toxins. CTA is usually employed by lacing baits that resemble prey species’ eggs and/or nestlings with a non-lethal, but illness-causing substance.

CTA has been successfully tested in different predator species, including corvids. Crows that consumed chicken eggs painted green containing nonlethal Carbachol (carbamylcholine chloride) subsequently avoided green eggs at different locations, whether or not they contained the toxin (Nicolaus et al. 1983). Cox et al. (2004) trained wild-caught carrion crows to avoid non-toxic colored eggs after conditioning with Carbachol. In Redwood National and State Park, depredation of Carbachol-laced simulated murrelet eggs by Steller’s jays was reduced 37-72% subsequent to conditioning. Application of a similar approach achieved comparable

reduction in predation by Steller’s jays in the Santa Cruz Mountains (Gabriel et al. 2013).

CTA has been used successfully to reduce raven predation of sensitive species. At Malheur National Wildlife Refuge, predation of surrogate Sandhill Crane eggs (*i.e* turkey eggs) decreased at experimental sites where they were laced with Landrin compared to controls (Nicolaus 1987). Survival of treated surrogate eggs was also higher within raven breeding territories, suggesting that territory holders not only learned to avoid the eggs, but exclude nonbreeding ravens from depredating them as well. Avery et al. (1995) placed Japanese Quail (*Coturnix japonica*) eggs treated with the methiocarb near raven nests at the U. S. Marine Corps Base, Camp Pendleton, CA. All raven pairs learned to avoid the treated eggs within five days.

CTA targeted at territorial corvids in murrelet nesting habitat could reduce predation risk for both murrelets eggs and nestlings by ravens. Once a resident pair has been conditioned, they will not only stop preying on the target species but will exclude untrained conspecifics from entering their territory and potentially depredating the target species. In contrast to CTA, lethal removal of territorial corvids initiates intrusions by new conspecifics (Webb et al. 2012) which could lead to greater density if new immigrants are unable to establish a defended territory. Similar to lethal control, CTA shares the disadvantage of being labor intensive. However, CTA uses important aspects of raven biology as an advantage. CTA uses ravens’ ability to learn and their territorial behavior as an advantage. In contrast, ravens’ ability to adapt quickly to lethal control methods is a significant challenge to implementing lethal control, especially when repeated application is required. Compared to lethal control, CTA holds more consistent, long-term promise for reducing predation in mainland settings by adaptable

species like ravens and crows that maintain stable territories.

Another behavioral approach to reducing the risk of predation involves frightening predators away from potential prey using corvid effigies alone or in combination with other tactics. Effigies have been used with some success to repel corvids, including crows and ravens. Naef-Daenzer (1983) found that playbacks of distress calls at regular intervals were more effective in limiting damage by carrion crows to sprouting corn crops when compared to fields with effigies alone or compared to controls. Crows were completely repelled and predation was prevented by placing dismembered crow heads on the perimeter of a fenced-off breeding colony of California Least Terns in Venice Beach (Caffrey 1994). In Lancaster, Pennsylvania, Avery et al. (2008a) successfully dispersed roosts of as many as 40,000 crows using a combination of laser harassment, distress calls and effigies of crows, ravens and fish crows (*Corvus ossifragus*). The mounting of raven effigies reduced corvid abundance 27-70% and corvid incidence 55-100% along a northern California Beach (Peterson and Colwell 2014). In Washington State, Swift and Marzluff (2015) discovered that crows became more reluctant to approach food after observing humans or hawks with crow effigies.

Reproductive Control

For most avian species, reproduction is the most energetically-demanding part of their annual cycle (Sibly et al. 2012). In order to meet the energetic requirements of raising a brood, adult birds significantly increase the amount of time spent foraging (Ettinger and King 1980). It follows that predation risk to prey species increases in concert with the foraging effort of their predators. In their study of raven predatory behavior at heronries in the San Francisco Bay region, Kelly et al. (2005) found that nest

predation of Great Egrets (*Area alba*) and raven interactions with ardeids increased with increased raven productivity. At Big Basin, Suddjian (2003) observed a raven depredating a murrelet nest while being trailed by three begging juveniles.

Reproductive control is a common approach to managing nuisance wildlife and has been used to manage avian pest species such as Canada Goose (*Branta canadensis*) and Ring-billed Gulls (Rodger 2003). Reproductive control also holds promise for reducing the predatory behavior and abundance of crows and ravens. The primary techniques employed in avian reproductive control include egg addling, nest removal and sterilants. Various approaches towards egg addling exist, including shaking, freezing, removal, and destruction have been used in wildlife management (Pochop et al. 1998), but egg oiling is most commonly-employed. Although no data exists specifically for ravens, but in general, dipping eggs in mineral oil or corn oil prevents hatching and causes incubating birds to continue incubating past the normal hatching time which prevents renesting (Christens and Blokpoel 1991, Pochop et al. 1998).

Oiling the eggs of ravens nesting in murrelet habitat presents logistical challenges. In order to employ egg oiling, raven nests must be located and accessed during the 21-day incubation period (Boarman and Heinrich 1999). Previous studies conducted in murrelet habitat successfully located and monitored raven nests, but these researchers benefitted from the ability to track radio-tagged ravens to their nests (Marzluff and Neatherlin 2006, Webb et al. 2011). In addition, ravens nesting in murrelet habitat typically build nests in the crowns of tall conifers (Webb et al. 2012) which requires specialized tree climbing techniques for accessing the nests. Tree climbing is regularly

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

used for canopy studies including murrelet studies (Luginbuhl et al. 2001, others). Although oiling presents significant logistical challenges, the techniques necessary to accomplish it for ravens nesting in murrelet habitat are well-established.

The use of sterilants through injection or ingestion have been used to cause long-term or temporary infertility in nuisance bird species. Sterilants have been used to control: Red-winged Blackbirds (*Agelaius phoeniceus*) using thiotepa and diazacon (20,25 diazacholesterol) (Cyr and LaCombe 1992), feral pigeons (*Columbia livia*) using diazacon; (Avery et al. 2008b), and Monk Parakeets (*Myiopsitta monachus*) using diazacon; (Avery et al. 2008b). The use of nicarbazin also represents a promising approach as an avian contraceptive (Bynum et al. 2005). Nicarbazin is a compound traditionally used on broiler chickens to prevent the disease coccidiosis, but decreased egg production and hatching rates occur as side effects. An avian oral contraceptive using nicarbazin was recently developed by the U.S. Department of Agriculture's Wildlife Services' National Wildlife Research Center and by Innolytics, LLC primarily to control populations of Canada Goose and feral pigeons (Wildlife Services 2001). The contraceptive is contained in bird feed and is sold commercially as OvoControl. However, the effectiveness of sterilants is variable and none have been tested on corvids.

REDUCING ANTHROPOGENIC FOOD SUBSIDIES FOR CORVIDS

Over the last several decades, numbers of crows and ravens have increased over large parts of western North America (Marzluff et al. 1994, Sauer et al. 2014). Although changes in the level of persecution have played a role, the underlying cause of increased numbers of crows and raven is increased human activities. Most corvid

species are human commensals, otherwise known as synanthropic species and thrive in habitats disturbed by humans (Marzluff et al. 1994). The list of anthropogenic food subsidies utilized by crows and ravens is long and includes garbage at landfills, dumpsters, and along roads (Boarman 2003), agricultural grains (Stiehl 1978b, Engel 1989), fruits (Simpson 1972), ranching by-products (Larsen and Dietrich 1970), feed at dairy farms (Roth et al. 2004, Webb et al. 2004), road kill (Boarman and Heinrich 1999) and hunter-killed animal carcasses (Webb et al. 2011). Ultimately, access to anthropogenic resources subsidies is the ultimate cause of increased crow and raven abundance and associated increased risk of nest predation.

Since increased access to, and use of, anthropogenic resources results in greater abundance, reproduction and survival of crows and ravens, the reverse should also be true. In the forested, relatively moist Santa Cruz Mountains, crows and ravens are not limited by access to water and nest sites as they are in arid ecoregions (Boarman 2003, Kristan and Boarman 2007). Since access to supplemental food is the primary anthropogenic subsidy for crows and ravens in the Santa Cruz Mountains, reducing this subsidy will decrease the carrying capacity, resulting in reduced abundance and immigration of new individuals. Reducing food subsidies will promote lower density of corvids through larger home ranges of resident birds and reduce the presence of nonresident, territorial birds. Management should prioritize reducing food subsidies in proximity to potential murrelet nesting habitat. Managers face a significant challenge reducing food subsidies for corvids in the Santa Cruz Mountains since most of the remaining murrelet nesting habitat exists within parks that have a high density of heavily-used campground and picnic areas (Peery and Henry

2010). Since crows and ravens have a broad diet and use a variety of foraging strategies, reducing food subsidies necessitates multiple approaches. Reducing corvid access to refuse and table scraps can be accomplished in a variety of ways including self-closing garbage receptacles, improved visitor education, increased policing of visitors and more resources dedicated for cleaning and maintenance. If visitor management measures continue to prove unsatisfactory, managers may consider closing picnic areas and campgrounds during nesting season and/or relocating these facilities them away from murrelet nesting habitat (Peery and Henry 2010).

The increase in crows and ravens is a regional, if not continental phenomenon. Regardless of the effectiveness of individual land managers in reducing anthropogenic subsidies, immigration pressure will exist due to the presence of surplus non-breeding individuals in the region. Land managers with restricted jurisdictions should coordinate with regional public and private land managers to reduce anthropogenic food subsidizing regional populations of crows and ravens. Land managers should prioritize coordination with adjacent land holders to reduce the attractiveness of the surrounding landscape to corvids, since adjacent land uses may subsidize corvids that also use murrelet habitat. Anthropogenic land uses such as ranches, hobby farms, agricultural fields and landfills are known as anthropogenic point subsidies (Webb et al. 2004) because they provide permanent, reliable sources of food for corvids. In addition to potentially attracting large numbers of nonbreeders (Webb et al. 2009, Webb et al. 2011), use of point subsidies has been shown to increase survival and reproduction of both nonbreeding and territorial ravens (Webb et al. 2004, Webb et al. 2011).

MONITORING PROGRAM

It is incumbent upon managers to establish robust monitoring programs to evaluate the effectiveness of corvid management efforts, regardless of which management approaches are chosen (Peery and Henry 2010). Ecological systems are complex, variable and unpredictable in their response to management actions (Lyons et al. 2008). When monitoring is included as part of decision-making, sources of uncertainty are addressed and new knowledge is generated about how systems respond to specific management actions (Lancia et al. 1996, Kendall 2001, Lyons et al. 2008). For example, monitoring programs can include “triggers” which serve as benchmarks for changing management practices (Colwell et al. 2009). Triggers and other ways to incorporate new knowledge into future management decisions embrace the general framework of adaptive management. It is especially important for predator management programs to incorporate monitoring programs, whether lethal or non-lethal methods are employed, since these programs are subject to substantial controversy (Goodrich and Buskirk 1995). Without monitoring programs, predator control programs are potentially vulnerable to criticism, especially from critics of lethal control (Colwell et al. 2009, Warburton and Nelson 2009).

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

Table 3-1. Comparison of alternative management strategies with the greatest potential for immediate effects on raven, crow and murrelet populations. The strategies included fall under the "Active Raven and Crow Management" and "Human Behavioral Modification" categories described in the text.

Category	#	Strategy	Effect on Ravens	Effect on Crows	Murrelet Productivity	Murrelet Population
Education	1	Continue Crumb Clean Campaign	Localized decrease in raven activity	Localized decrease in crow activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
Education	2	Consider a PSA or similar broad education efforts	Unknown	Unknown	Unknown	Unknown
Education	3	Use social media to educate and/or enlist citizen scientists	Unknown	Unknown	Unknown	Unknown
Human Behavioral Modification -Direct Subsidy Reduction	4	Reduce human food subsidies in campgrounds	Localized decrease in raven activity	Localized decrease in crow activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
Human Behavioral Modification -Direct Subsidy Reduction	5	Restrict visitor activities during nesting season	Localized decrease in raven activity	Localized decrease in crow activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
Human Behavioral Modification -Direct Subsidy Reduction	6	Reduce food subsidies on neighboring properties	Regional decrease in raven activity	Regional decrease in crow activity	Regional increase in nest survival	Increased number of juveniles regionally; population increases

Table 3-1. Comparison of alternative management strategies with the greatest potential for immediate effects on raven, crow and murrelet populations. The strategies included fall under the "Active Raven and Crow Management" and "Human Behavioral Modification" categories described in the text.

Category	#	Strategy	Effect on Ravens	Effect on Crows	Murrelet Productivity	Murrelet Population
Human Behavioral Modification -Direct Subsidy Reduction	7	Limit raven and crow access to point subsidies such as landfills	Regional decrease in raven activity	Regional decrease in crow activity	Regional increase in nest survival	Increased number of juveniles regionally; population increases
Active Raven and Crow Management	8	Aversively condition ravens to not eat eggs	Potential decrease in egg predation by conditioned ravens	NA	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
Active Raven and Crow Management	9	Use effigies and/or haze ravens and crows near areas of high murrelet breeding density	Localized decrease in raven activity	Localized decrease in crow activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
Active Raven and Crow Management	10	Locate raven nests and study raven diet and nesting behavior; use to implement egg oiling or other controls	Reduced predatory behavior by ravens	NA	Localized increase in nest survival	Increased numbers of juveniles in nearshore waters; population increases if management efforts are sustained for years
Active Raven and Crow Management	11	Analyze prey remains in pellets or install nest cameras; use to implement control	Potential Reduced predatory behavior by ravens	NA	Localized increase in nest survival	Increased numbers of juveniles in nearshore waters; population increases if management efforts are sustained for years

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

Table 3-1. Comparison of alternative management strategies with the greatest potential for immediate effects on raven, crow and murrelet populations. The strategies included fall under the "Active Raven and Crow Management" and "Human Behavioral Modification" categories described in the text.

Category	#	Strategy	Effect on Ravens	Effect on Crows	Murrelet Productivity	Murrelet Population
Active Raven and Crow Management	12	Use a sterilant to reduce raven productivity	Localized decrease in raven activity	NA	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
Active Raven and Crow Management	13	Translocate individual ravens responsible for nest predation	Temporary, localized decrease in raven density; absence of offending individuals; altered social system	NA	Localized increase in nest survival	Increased numbers of juveniles in nearshore waters; population increases if management efforts are sustained for years
Active Raven and Crow Management	14	Kill individual ravens responsible for nest predation	Small, localized and temporary decrease in raven density; altered social system	NA	Localized increase in nest survival	Increased numbers of juveniles in nearshore waters; population increases if management efforts are sustained for years
Active Raven and Crow Management	15	Kill large numbers of ravens and crows across broad areas of old-growth forest	Reduction in raven density; increased wariness of individuals	Reduction in crow densities; increased wariness of individuals	Widespread increase in survival	Increased numbers of juveniles in nearshore waters; population increases if management efforts are sustained for years

MANAGEMENT OF STELLER’S JAYS TO REDUCE THE RISK OF NEST PREDATION ON MARBLED MURRELETS IN THE SANTA CRUZ MOUNTAINS*Elena H. West***SUMMARY**

This report is a summary of the ecology and behavior of Steller’s jays (*Cyanocitta stelleri*), with particular emphasis on the factors that have facilitated their role as important nest predators of marbled murrelets (*Brachyramphus marmoratus*) in the Santa Cruz Mountains, California. Steller’s jays are small corvids that occupy a wide range of forested habitats throughout western North America. While Breeding Bird Survey (BBS) and Christmas Bird Count (CBC) data have documented substantial increases in the populations of other corvid species—namely, common ravens (*Corvus corax*) and American crows (*Corvus brachyrhynchos*) in California over the last 30 years, populations of Steller’s jays have generally remained stable over this period. BBS data indicates that Steller’s jay populations have increased significantly in the Santa Cruz Mountains, which may be due to the expansion of exurban development, and increases in human activities and associated food resources within parks and recreation areas in this region. Recent research also shows that Steller’s jay densities remain very high in state park campgrounds.

Steller’s jays are non-migratory and can be found on their territories throughout the year, although territorial boundaries are weaker during the non-breeding season when jays are more mobile. Steller’s jays exhibit site-related dominance, a social system where monogamous pairs defend the area close to their nest but territoriality weakens with increasing distance from the nest. Behavioral plasticity with regard to nest defense can result in extensively overlapping home ranges and high densities.

Steller’s jays are dietary generalists and exhibit a variety of foraging strategies, often concentrating foraging behaviors along habitat edges. Steller’s jays subsist on a diet of insects, seeds, nuts, berries, and anthropogenic food, where their ranges overlap with areas of heavy human use. Steller’s jays are highly responsive to human activity, and their use of parks and recreational areas is positively associated with the number of human visitors in Oregon, Washington and California, likely due to their attraction to anthropogenic food and garbage from park visitors. Recent diet analyses suggest that Steller’s jays in state park campgrounds along the central coast of California (Big Basin Redwoods and Butano state parks) and in northern California (Jedediah Smith Redwoods and Redwood State and National parks) consume a significant proportion of anthropogenic foods compared to jays outside of campgrounds. This research also indicates that subsidized jays in campgrounds are in better body condition and have higher reproductive success than jays outside of campgrounds. These areas also appear to act as “source” habitats that produce large numbers of juvenile jays with high survival rates.

Corvids have been documented preying on the nests or young of a number of species, some of them threatened or endangered. Like other corvids, Steller’s jays will opportunistically depredate the eggs and young of open-nesting birds incidentally encountered during foraging and pose a significant risk of nest predation to marbled murrelets throughout the redwood region. Both published and unpublished accounts of nest predation of real and simulated

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

murrelet nests by corvids revealed that Steller's jays accounted for 40% of predation events. In the Santa Cruz Mountains, marbled murrelets experience a high rate of nest failure due primarily to predation by corvids (Peery and Henry 2010). Steller's jays may account for as much as 20% of predation events on Murrelet eggs and young, and are therefore considered a major limiting factor for Murrelet reproduction.

Factors that are associated with nest predation by Steller's jays include increased jay abundance, the presence of anthropogenic food subsidies, and forest edges. While some corvids in forested regions occur more frequently near human settlements (American crows and common ravens), Steller's jay abundance does not necessarily increase with housing development, which may be due to the loss of nesting sites and reductions in important food sources (insects, berries, and mast) as settlement increases. In the Santa Cruz Mountains, populations of Steller's jays and other corvids have increased in parks and recreation areas due to point sources of human food subsidies within these habitats. Increased abundance of subsidized corvids in these habitats may result in impacts to other species through spillover predation. As a result, the conservation benefit of protected areas may be compromised as human activity increases within and around these areas.

Given the risk that abundant Steller's jay populations pose to nesting murrelets, jay populations in the Santa Cruz Mountains require targeted management in order to reduce predation and recover murrelet populations over the long-term. Techniques that have been employed to reduce predation by corvids include lethal removal, behavioral modification, and control of features in the environment that affect predator populations (control of anthropogenic resources). Many of these techniques have been

applied to crow and raven populations where they co-occur with threatened and endangered species. Management efforts targeted at Steller's jays have primarily been limited to behavioral modification and efforts to limit access to anthropogenic foods. While lethal removal can result in an immediate reduction in corvid population size and has been effective in reducing nest predation by corvids on colonies of nesting seabirds, reductions are generally temporary and must be continued on a long-term basis in order to have any impact on prey recovery. In the Santa Cruz Mountains, efforts to lethally reduce crow and raven populations from state parks for murrelet recovery has been unsuccessful. While targeted lethal removal of Steller's jays would result in an immediate reduction in population size and reduce predation pressure in the short-term, the abundance of Steller's jay populations in these areas suggests that lethal removal would need to continue on an on-going basis in order to maintain any reduction in predation pressure for murrelets.

Approaches that involve behavioral modification of a target species for a specific purpose include Conditioned Taste Aversion (CTA), repellants, and effigies. CTA has shown some potential for reducing corvid predation on mimic murrelet eggs, and may have applicability to real murrelet eggs in some cases. Repellants and effigies generally have only very short-term effects and do not appear to be an effective means of deterring corvid predation.

Given the availability of anthropogenic food in state parks and recreation areas in the Santa Cruz Mountains, control of features in the environment that affect predator populations may be more successful at reducing predation pressure than direct predator control. Controlling access to anthropogenic food in these areas should reduce local Steller's jay population

growth rates by reducing reproduction and survivorship and causing jays to disperse to other areas. Eliminating or significantly reducing food subsidies will also result in lower densities of jays in state park campgrounds, as birds will need to increase their use of space for foraging. Ultimately, a significant reduction in the abundance of Steller's jays inside state park campgrounds is the only way to directly reduce predation pressure on nesting murrelets, given the overlap in where these species occur in the Santa Cruz Mountains.

Reducing food subsidies could require stronger enforcement of park rules and greater outreach and education to increase awareness and change visitor behavior. While reducing food subsidies in areas receiving high levels of visitors and camping traffic is challenging, changing human behavior for the purposes of species conservation through education and other means has been successful in some instances and involves the combination of stricter enforcement policies with extensive park visitor outreach. Ultimately, moving campgrounds and associated anthropogenic food resources out of marbled murrelet nesting habitat during the breeding season may be an effective long-term management strategy for reducing subsidies to jays in these areas.

Finally, ongoing marbled murrelet conservation efforts must include rigorous monitoring programs in order to evaluate the effectiveness of Steller's jay (and other corvid) management actions. Ideally, any monitoring effort would incorporate a robust control-treatment design, such that the treatment of interest (i.e. specific predator management action) can be determined to be the cause of any observed changes in the parameter of interest. Without rigorous monitoring, predator control programs are subject to bias in the interpretation of results, therefore reducing their overall applicability and

effectiveness, which ultimately is a disservice to species of concern

THE STELLER'S JAY

Species Description and Overview

The Steller's jay is a common, crested jay found in coniferous and mixed-coniferous forests in western North America. Sixteen subspecies are currently recognized, many of which exhibit considerable geographic variation in body size and plumage color. Steller's jays are gregarious members of avian communities throughout their range. They are associated with forest-edge habitat and often habituate readily to rural and exurban areas where low-density housing and roads are interspersed among forested habitat. They are opportunistic omnivores whose diet includes a wide variety of animal and plant food. Steller's jays are conspicuous at bird feeders, picnic areas, and campgrounds and can be relatively tame or even bold in locations where they have become habituated to humans.

Like many members of the Corvid family, Steller's jays are highly social, and engage in group foraging and predator mobbing. Steller's jay social interactions involve a complex array of postures, crest displays, and vocalizations. While many basic vocalizations have been described, a number of Steller's jay calls are highly variable and their social context is not well understood. Steller's jays reach sexual maturity in their second year, but most likely do not breed until their third year. Adults appear to be socially monogamous and form long-term pair bonds. Pairs generally remain together on their nesting territory year-round. Steller's jays exhibit site-related dominance, a social system where individuals are socially dominant in parts of their territory but significant overlap occurs among territories, depending on hierarchy, population density, and food availability (Brown 1963). Dominance areas are approximately 120

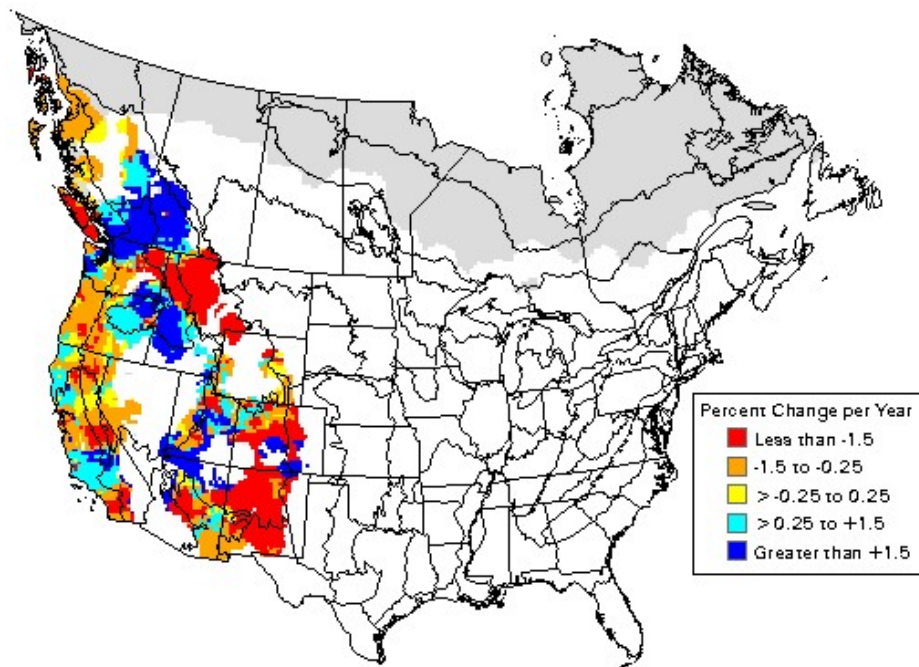


Figure 3-13. Trend map for Steller's jays generated from BBS survey data from the time period 1966–2015 showing percent change per year.

m in diameter (Brown 1963). With increasing distance from the nest, both male and female jays become less dominant.

Distribution and Seasonal Movement

Steller's jays occur throughout western coniferous and mixed-coniferous forests of North America, and breed from Alaska, western Canada, and the United States south through western Mexico and Nicaragua. Steller's jays are resident throughout most of California at elevations of 3,000–10,000 feet, and at lower elevations along the Pacific coast. They inhabit the northern Coast Ranges and Klamath Mountains from the Oregon border south to Morro Bay, San Luis Obispo County, the Warner Mountains of northeastern California, and the northern Cascades south through the Sierra Nevada and Greenhorn Mountains, Kern and Tulare Counties (Small 1994). They occur less frequently in the mountain ranges of southern California and rare vagrants have been reported in the Central Valley, eastern interior

valleys, and southern coast regions (Small 1994). Steller's jays are considered nonmigratory and resident where breeding populations occur, although seasonal movements have been recorded, particularly during severe winters (Small 1994). Large, irruptive post-breeding movements have also been reported in some areas (Greene et al. 1998). Post-breeding movements by Steller's jays are generally characterized as dispersal movements by first-year birds (Brown 1963, Greene et al. 1998).

Steller's jay Population Trends in the Santa Cruz Mountains

Population trends are reported for Steller's jays from the Breeding Bird Survey (BBS) over the period 1972–2015. A summary of population trends for Steller's jays from the Christmas Bird Count (CBC) database (National Audubon Society 2016) over the period 1961–2015 is also reported. Results from BBS survey data for the period 1972–2015 indicates relatively stable trends over the last several decades in Steller's

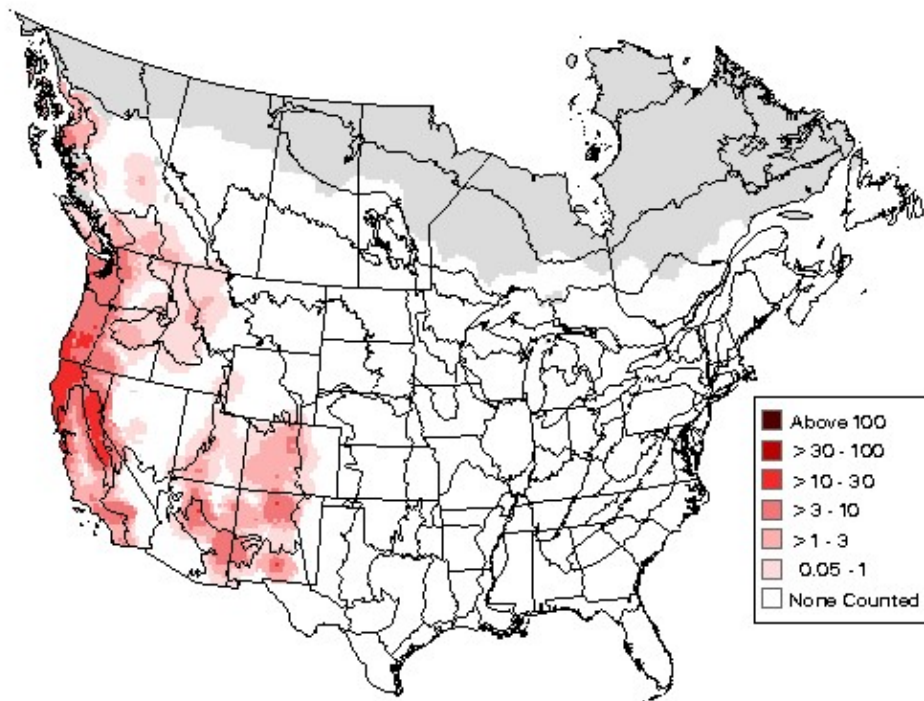


Figure 3-14. Trend map for Steller's jays generated from BBS survey data showing relative abundance during summer, estimated over the interval 2011-2015.

jay populations across broad areas of the U.S and Canada (Figure 3-13 page 98). Regional trend analysis generated for Steller's jays estimated a 0.25% increase in abundance across California over the time period between 1966–2015. BBS survey data for the period 2011–2015 indicate that Steller's jay relative abundance ranges from 3–30 individuals per route (data are based on average counts for each route; Figure 3-14 page 99).

Data from the two BBS routes in the Santa Cruz Mountains (Waterman Gap and Pescadero) indicate an upward trend in Steller's jay observations per party hour from 1972–1991, followed by a decline in 2003 (Figure 3-17 page 100). Christmas Bird Count (CBC) surveys near the Santa Cruz Mountains (and their initial survey years) include Crystal Springs (1961), Santa Cruz County (1961) and Año Nuevo (1972). Steller's jays were recorded on nearly all

survey in all years, although data are highly variable (Fig. 4). Overall, trends for each survey indicate that Steller's jay observations are considerably higher for counts in the Santa Cruz Mountains (1.22 jays per party hour) relative to statewide counts (0.44 jays per party hour), showing a threefold increase in Steller's jay counts between 1961–2015. Santa Cruz County and Año Nuevo had the highest number of jays counted per party hour (1.5 and 1.3, respectively).

As part of an effort to understand corvid population trends in state parks that harbor remnant murrelet habitat in Santa Cruz and San Mateo counties, Suddjian (2010) conducted surveys for common ravens, American crows, and Steller's jays during each breeding season from 2003–2009. Surveys compared corvid populations in murrelet nesting habitat within campgrounds (treatment areas) to corvid

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

populations in areas located >300 meters from campgrounds (control areas). Webb (this chapter) presents survey results for raven and

crows. Overall, adult Steller's jay abundance showed a significant decrease across all parks over the study period in both treatment and

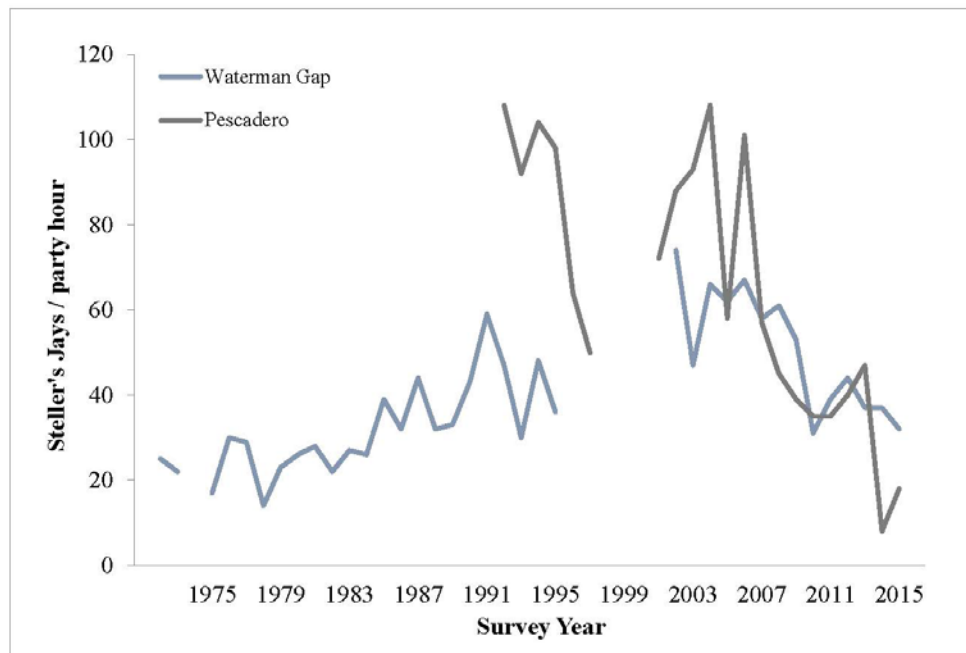


Figure 3-17. Number of steller's jays observed on the two Breeding Bird Survey routes in the Santa Cruz Mountains between 1972–2015. Gaps in the lines represent years in which surveys did not occur.

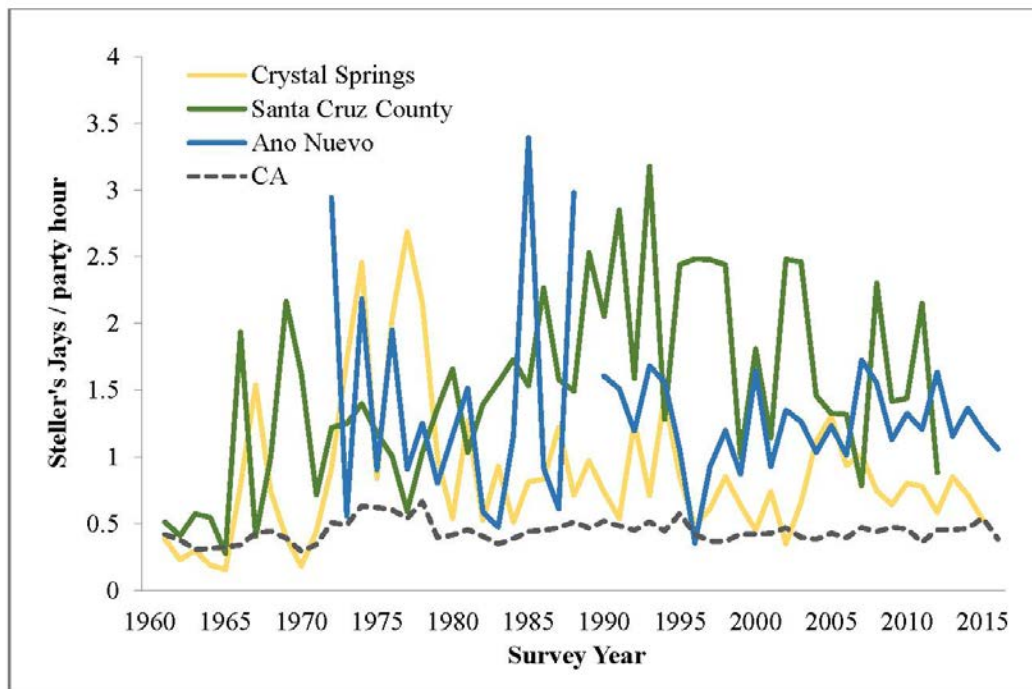


Figure 3-15. Number of Steller's jays observed per party hour from Audubon Society's Christmas Bird Counts, 1961-2015. Data are from statewide averages and the three closest census sites to the forested portions of the Santa Cruz Mountains: Crystal Springs, Santa Cruz County and Año Nuevo.

control areas. The decrease in adult jay abundance may have been a result of management actions to reduce access to anthropogenic food subsidies by jays and other corvids (Suddjian 2010). Results indicate that the average jay abundance was 2.0 jays/ha in Big Basin state park campgrounds and 0.2 jays/ha at control sites (2009 surveys).

West and Peery (*in press*) used point counts and distance-sampling techniques to compare population density of Steller's jays at

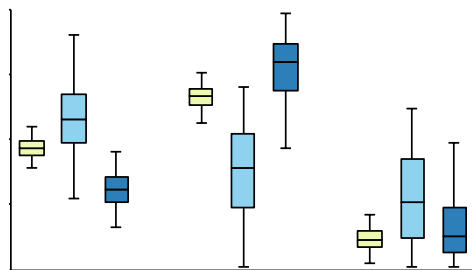


Figure 3-18. Stable isotope model results for Steller's jays in (a) Jedediah Smith Redwoods and Prairie Creek Redwoods State Parks, 2011, which were merged due to small sample sizes ($n = 45$), (b) Big Basin Redwoods State Park, 2011–2013 ($n = 197$) and (c) Butano State Park, 2012–2013 ($n = 53$). Boxes show 25th and 75th percentiles, whiskers depict the 95% credible interval, and solid lines in the boxes show the median. Figure reproduced with permission from Wiley and Sons Publishing

campground (high human use) and forest sites (areas within interior forests > 1km from human settlement) in Big Basin Redwoods State Park from 2011–2013. Results indicate that adult Steller's jay abundance was significantly greater in campgrounds ($4.33 \text{ jays/ha} \pm 0.91$) compared to forest sites ($0.70 \text{ jays/ha} \pm 0.22$) based on June point counts ($F_{1,17} = 855.58$, $P < 0.01$), presumably because of the presence of abundant anthropogenic food subsidies in these areas. Densities of juvenile jays were also significantly greater in campgrounds ($3.30 \text{ jays/ha} \pm 0.82$) in August than at forest sites ($0.18 \text{ jays/ha} \pm 0.08$). In Redwood National and State parks in California, Steller's jays are the most commonly observed corvid and abundance was significantly greater in picnic and camping areas compared to areas with backcountry trails and areas with low use (Wallen et al. 1998, 1999).

Diet and Foraging Behavior

Steller's jays are opportunistic omnivores whose diet includes a wide variety of animal and plant food, including arthropods, berries, fruits, nuts, seeds, small vertebrates, and the eggs and young of other birds. Mast seeds, such as acorns and pine seeds, are important food sources during fall and winter, which they will push into crevices on the ground or under the bark of trees. Steller's jays that are habituated to humans will consume a wide variety of anthropogenic foods. They have also been observed attacking and eating small adult passerines, including dark-eyed juncos, American robins, and pygmy nuthatches (Greene et al. 1998). Results from an analysis of 93 Steller's jay stomachs collected in California contained 28% animal material (largely made up of beetles, wasps, and bees), and 72% plant material (mostly acorns).

West et al. (2016) combined stable isotope analyses and radio-telemetry information to characterize space use and dietary patterns in Steller's jays sampled at campground and forest

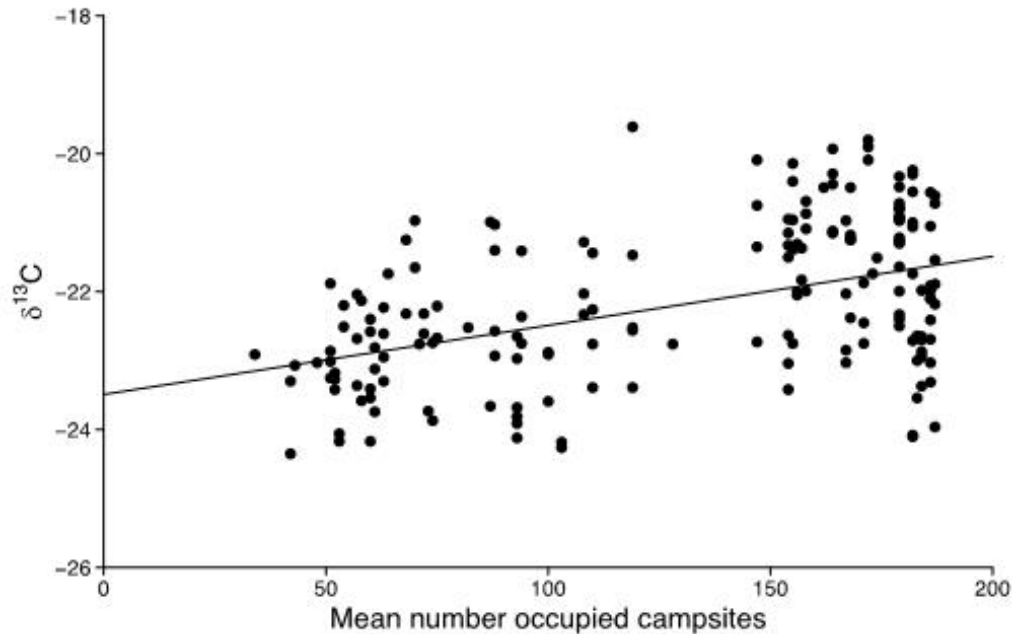


Figure 3-19. Relationship between carbon-isotope ratios ($\delta^{13}\text{C}$) of blood samples obtained from Steller's jays in campgrounds during the breeding period (April–August) 2011–2013 ($n = 179$) and human presence (mean number occupied campsites) in Big Basin Redwoods State Park. The solid line represents the least-square regression.

sites in California state parks that also harbor remnant murrelet nesting habitat. The authors used raw isotope values from blood as a proxy for jay diet, with increased enrichment in $\delta^{13}\text{C}$ indicating greater consumption of human-derived foods (Phillips et al. 2005, Newsome et al. 2010). Stable isotopes are a useful tool for reconstructing consumer diets (Hobson and Clark 1992, Caut et al. 2008, Ben-David and Flaherty 2012) as the isotopic ratios of nitrogen ($^{15}\text{N}/^{14}\text{N}$, noted $\delta^{15}\text{N}$) and carbon ($^{13}\text{C}/^{12}\text{C}$, noted $\delta^{13}\text{C}$) in consumer tissues predictably reflect those in their diets (DeNiro and Epstein 1978). Human foods are often derived from or processed using corn and cane sugar, which are enriched in $\delta^{13}\text{C}$ (Jahren et al. 2006). This $\delta^{13}\text{C}$ signal is traceable in the wildlife that consume anthropogenic foods (Newsome et al. 2010) and is thus useful for determining Steller's jays' reliance on anthropogenic food subsidies.

In this study, jays were classified into four groups based on patterns of space use: (i)

campground (jays captured in campgrounds that predominantly used these areas); (ii) periphery (jays captured in campgrounds that commonly used adjacent forests); (iii) intermediate (jays captured at forest sites that made long-distance movements between forests and campgrounds); and (iv) forest (jays captured and only detected in forests). Results showed that anthropogenic food comprised a large portion of the diet of campground jays across all parks studied, and more than half of the diet of campground jays in the most heavily visited park, Big Basin Redwoods State Park (Figure 3-18 page 101). Results also indicated that campground jays consumed a greater proportion of human foods than periphery or intermediate jays, which both consumed more anthropogenic foods than forest jays in all parks studied. Campground jays appeared to exhibit a functional response to anthropogenic foods as park visitation increased (Figure 3-19 page 102), and breeding individuals preferentially provisioned their young with human-derived foods (Figure 3-20 page 103).

Habitat Use

Steller's jays breed in a variety of coniferous and mixed coniferous-deciduous forest, as well as oak woodland, eucalyptus groves, orchards, and gardens in northwest North America. Populations that breed at lower elevations typically remain near their breeding territories during winter, while those that breed at high elevations will often move to lower elevations during severe winters. When nesting in forested habitats, Steller's jays typically build their nests on coniferous tree branches close to trunks and in berry bushes. When nesting near human settlement, Steller's jays build nests on building ledges and near windows. Several authors have reported higher Steller's jay densities close to forest edges, particularly near anthropogenic environments (Brand and George 2001, Marzluff et al. 2004, Vigallon and Marzluff 2005b).

Observed movement and diet patterns by West et al. (2016) may help explain observations of

high Steller's jay densities in areas of parks frequented by humans in both central California and other regions (Suddjian 2009, Walker and Marzluff 2015). Results of this study showed that individual jays with home ranges mostly in campgrounds tended to rely more on anthropogenic food and had relatively small home ranges, compared to individuals occupying areas outside of campgrounds, suggesting that anthropogenic foods allowed individuals in campgrounds to meet their dietary needs within relatively small areas (Figure 3-21 page 104). This finding mirrors a general tendency in birds, where individuals reduce their foraging areas when food is abundant and allows more individuals to occupy a given area (Boutin 1990, Shochat et al. 2004). Tolerance of conspecifics (home range overlap) also appeared to be high in males in campgrounds, despite the fact that this species is generally considered to hold distinct breeding territories (Oberski and Wilson 1991). However, territoriality in birds

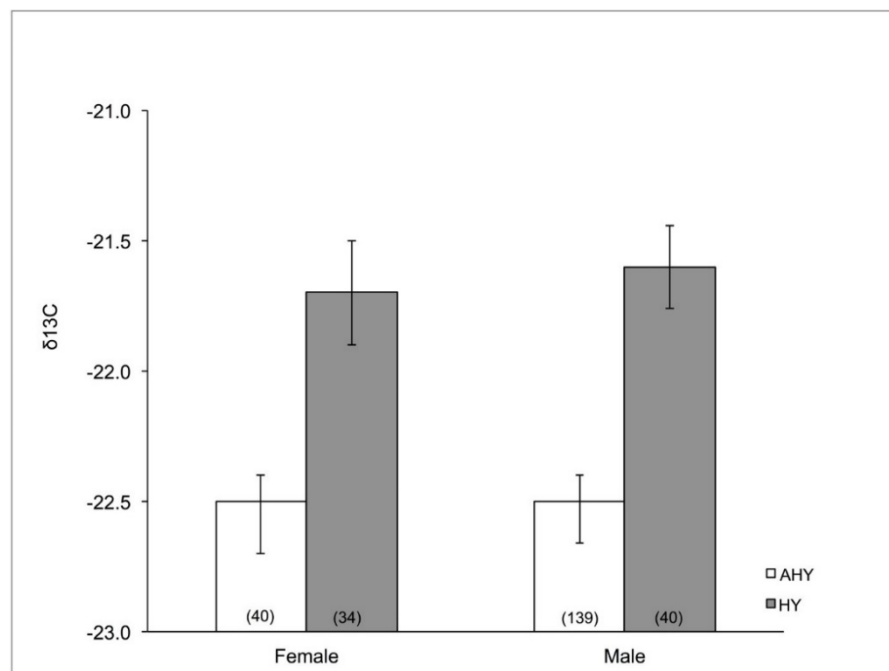


Figure 3-20. Mean carbon-isotope ratios ($\delta^{13}C$) of blood samples obtained from Steller's jays during the breeding period (April–August) 2011–2013 in Big Basin Redwoods and Butano state parks grouped by age and sex classes. Data are means $\pm$ SE for $\delta^{13}C$. Sample

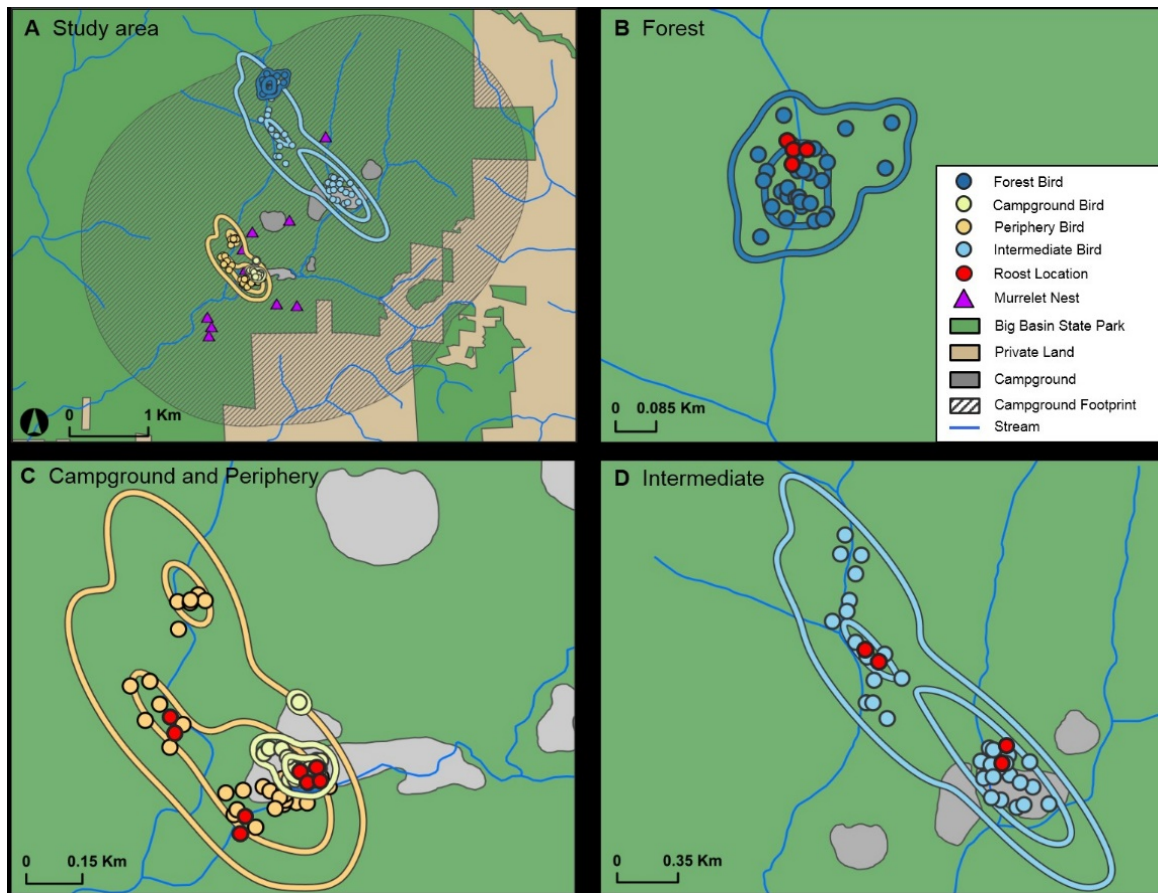


Figure 3-21. Representative core areas and home ranges (50% and 95% utilization distributions, respectively) for male forest, campground, periphery, and intermediate Steller's jays radio-marked in Big Basin Redwoods State Park in 2011. Also shown in (a) is the estimated 2 km "ecological footprint" of campgrounds and its overlap with 11 of the 17 known Marbled Murrelet nests in central California. Figure reproduced with permission from Wiley and Sons Publishing

often weakens when food is abundant and the incentive to exclude conspecifics from resources decreases (Ewald and Carpenter 1978, Hixon 1980, Schoener 1983). Increased abundance and density of Steller's jays in campgrounds may also result from the movement of individuals outside campground boundaries (Goldenberg 2013, West et al. 2016).

FACTORS ASSOCIATED WITH NEST PREDATION OF MURRELETS

Factors that are associated with nest predation by Steller's jays include increased forest edges and fragmentation, the presence of anthropogenic food subsidies, and increased jay abundance. While some corvids in forested regions occur more frequently near human

settlements (American crows and common ravens), Steller's jay abundance during the breeding season does not necessarily increase with housing development (Vigallon and Marzluff 2005a), which may be due to the loss of nesting sites and reductions in vegetation associated with important food sources (insects, berries, and mast) as settlement increases. Research has shown that jays are more abundant in forested landscapes that are fragmented and that they prefer areas with high-contrast edges such as clear cuts (Malt and Lank 2007), and small human settlements like campgrounds (Marzluff et al. 2004). Steller's jays, like many corvid species, are highly responsive to human activity (Liebezeit and George 2002) and a major factor in why they are successful in areas

used by humans is because they are generalist foragers, readily eating food provided or discarded by humans. Thus, a key factor in corvid population increases is thought to be the availability of anthropogenic food sources that subsidize their populations (Marzluff et al. 2001, Boarman 2003, West et al. 2016).

Anthropogenic food subsidies available to jays and other corvids in areas of heavy human use include garbage near homes, businesses, and landfills, agricultural grains, farm and ranch by-products, road kills, bird/wildlife feeders, and food provisioned or discarded by visitors to parks and recreation areas.

In addition to increases in corvid abundance as a result of the availability of abundant anthropogenic food resources on the landscape (Wallen et al. 1998, 1999, Vigallon and Marzluff 2005a, Webb et al. 2011, Goldenberg 2013, Walker and Marzluff 2015), studies have also shown that subsidized corvids have improved survival and reproduction compared with corvids that do not have access to subsidies (Webb et al. 2004, Marzluff and Neatherlin 2006, Kristan and Boarman 2007, Webb et al. 2011, West and Peery *in press*). In the Santa Cruz Mountains, populations of Steller's jays and other corvids have increased in parks and recreation areas, likely due to the widespread availability of anthropogenic food subsidies in campgrounds and picnic areas. Recent work by West and Peery (*in press*) suggests that Steller's jays in campgrounds were enriched in $\delta^{13}\text{C}$ (a proxy for anthropogenic food subsidies), indicating that these sites provided a source of food from the approximately 100,000 visitors per year that camp and consume food in Big Basin and Butano campgrounds (California State Parks, *unpubl. data*). Jays that were subsidized by anthropogenic food in campgrounds in these parks were also in better body condition, as indicated by both lipid stores and feather growth

bars, presumably as a result of resource subsidies. Improved body condition, in turn, appeared to promote higher reproductive output compared to putatively unsubsidized jays at nearby forest sites. Annual survival rates for juvenile and adult jays (HY and AHY, respectively) in campgrounds were high based on radio-telemetry ($S_{HY} = 0.75$, $n = 50$ and $S_{AHY} = 0.92$, $n = 30$; EHW, *unpubl. data*), although the authors were unable to compare survival rates between campground and forest habitats given that forest jays were not habituated to humans, resulting in a modest sample size of individuals radio-marked in this habitat ($n = 12$). Collectively, the results of this study suggest that jay total fitness was greater in campgrounds than forests and support the hypothesis that campgrounds provide higher quality habitat for jays than surrounding forests. Steller's jays, like other corvid species are likely to return to rewarding feeding sites such as bird feeders, masting trees, berry patches, or campgrounds. These sites may then serve as point sources of food subsidies and become "source" habitats for corvids on the landscape, which may result in impacts to other species through spillover predation.

ROLE OF STELLER'S JAYS AS MURRELET NEST PREDATORS

Corvids have been documented preying on the eggs and young of a number of bird species, from small passerines to large birds throughout North America and Europe (reviewed in Liebezeit and George 2002). A review of nest predation in fragmented forest habitats in North America and Europe found that 22 of 47 published studies implicated corvids as important nest predators (Marzluff and Restani 1999). Although nest predation by corvids is well documented in some cases, in others, corvids have been implicated as important predators with little evidence. Identification of

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

corvids preying on nests or young is challenged by locating and monitoring active murrelet nests and continues to limit our ability to fully understand the factors that contribute to nest predation and overall low nest productivity for murrelets. Of the few studies that have documented predation on active murrelet nests, very little is based on direct observation such that it is conclusive. Circumstantial and conjectural evidence may be reliable in some cases, for example, tracks leading to a recently depredated nest or predator attack marks in egg remnants, however, identifying predators based on nest evidence like eggs and nestling remnants is often unreliable (Larivière 1999). A number of studies that implicate corvids as important nest predators have been conducted with artificial nests, which provide information on nest predator communities, comparisons between habitats (i.e. edge vs. interior) and allow for inference about predation on species like murrelets whose nests are difficult to find.

Like other corvids, Steller's jays will opportunistically depredate the eggs and young of open-nesting birds incidentally encountered during foraging but do not rely on bird eggs as a major source of food. Although Steller's jays do not use specialized search strategies for nests (Vigallon and Marzluff 2005b), they are regular food cachers, and may return to previously discovered nests (Gabriel and Golightly 2014). Returning to rewarding food sites may be particularly damaging to marbled murrelets, as evidence suggests that they return to the same nesting tree over multiple years (Nelson and Peck 1995). Although Steller's jays occur in most regions where murrelets nest, few data exist regarding the potential they pose as murrelet nest predators. Both published and unpublished accounts of nest predation of real and simulated murrelet nests by corvids revealed that Steller's jays accounted for 40% of

predation events (data from Luginbuhl et al. 2001, Malt and Lank 2007; reviewed by Webb, this chapter).

In the Santa Cruz Mountains, marbled murrelets experience a high rate of nest failure due primarily to predation by corvids. Steller's jays may account for as much as 20% of predation events on Murrelet eggs and young (Peery et al. 2004), and are therefore considered a major limiting factor for Murrelet reproduction in the Santa Cruz Mountains. In addition, Steller's jays have been observed preying repeatedly on a regularly re-used murrelet nest site in Redwood National and State Park (Hébert and Golightly 2006). A review by Liebezeit and George (2002) found 33 sources that implicated common ravens, American crows, and Steller's jays as nest predators. Nine of these studies provided direct evidence of corvid predation at real nests for all three species, while 11 studies documented direct evidence of corvid predation at artificial nests by all three species. It is important to note that the sample size of failed murrelet nests with assigned corvid predators is small and not all predator identification is supported by direct evidence. This, along with very limited information on the actual number of murrelet nests in the Santa Cruz Mountains results in a large amount of uncertainty in our ability to estimate nest predation rates on murrelets by jays and other corvids. Indeed, given the diversity of potential nest predators and the difficulty identifying which are the most important for murrelets, the authors advise that managers use local jay abundance at a given site as the baseline nest predation risk for nesting birds, a finding from work by Marzluff and Neatherlin (2006b) on the Olympic Peninsula, WA.

CORVID MANAGEMENT TO REDUCE THE RISK OF NEST PREDATION OF MURRELETS

Given the risk that abundant Steller's jay populations pose to nesting murrelets, jay populations in the Santa Cruz Mountains require targeted management in order to reduce predation and recover murrelet populations over the long-term. Techniques that have been employed to reduce predation by corvids include lethal removal, behavioral modification, and control of features in the environment that affect predator populations (control of anthropogenic resources). Many of these techniques have been applied to crow and raven populations where they co-occur with threatened and endangered species. Management efforts targeted at Steller's jays have primarily been limited to behavioral modification and efforts to limit access to anthropogenic foods. While lethal removal can result in an immediate reduction in corvid population size and has been effective in reducing nest predation by corvids on colonies of nesting seabirds, reductions are generally temporary and must be continued on a long-term basis in order to have any impact on prey recovery. In the Santa Cruz Mountains, efforts to lethally reduce crow and raven populations from state parks for murrelet recovery began in 2005. Since then, 192 ravens and 13 crows have been lethally removed from Big Basin, Butano, Portola, and Memorial County Parks combined. While targeted lethal removal of Steller's jays would result in an immediate reduction in population size and reduce predation pressure in the short-term, the abundance of Steller's jay populations in these areas suggests that lethal removal would need to continue on an on-going basis in order to maintain any reduction in predation pressure for murrelets.

Recently, controlled taste aversion (CTA) has been proposed as a strategy to reduce Steller's jay predation on marbled murrelets in many

regional parks, which involves deploying noxious eggs that mimic murrelet eggs in appearance at landscape scales (Gabriel and Golightly 2014). Trial runs indicate that CTA is effective at reducing predation by jays that consume mimic eggs; however, results from work by West et al. (2016) and West and Peery (*in press*) suggest that such a strategy should consider dense deployments of mimic eggs in campgrounds given that jays appear to aggregate in these areas in high densities due to the prevalence of anthropogenic foods. Moreover, a CTA program would likely need to be coupled with effective trash management and visitor education to lessen the benefits that food subsidies provide to Steller's jay populations.

Results from recent work by West et al. (2016) and West and Peery (*in press*) have several implications for marbled murrelet conservation and management. All four sampled state parks in this study have long-standing visitor education and trash management programs designed to reduce food subsidies to Steller's jays, and ultimately to reduce nest predation on marbled murrelets. The finding that a high proportion of the diet of Steller's jays breeding in and around park campgrounds was comprised of anthropogenic foods indicates that these programs have not yet fully achieved their intended effect. The authors suggest that this is particularly true in Big Basin Redwoods State Park, which formerly harbored the largest remaining breeding population of marbled murrelets in central California. In addition, adult jays in campgrounds were 6 times more abundant than at forest sites, and individuals that were subsidized by anthropogenic food were also in better body condition, presumably as a result of resource subsidies in campgrounds. Improved body condition, in turn, appeared to promote higher reproductive output compared to putatively unsubsidized jays at nearby forest

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

sites. Annual survival rates for HY and AHY jays in campgrounds were also higher than expected based on previous findings of corvid survival rates. In a separate study, 60% of radio-marked juvenile jays ($n = 40$) produced in campgrounds dispersed into murrelet nesting habitat during their hatch year (EHW, *unpubl. data*). Collectively, these findings suggest that campgrounds in Big Basin Redwoods State Park serve as “source” habitats for Steller’s jays on the landscape, which ultimately impacts murrelets and may result in negative impacts to other species through spillover predation.

Reducing food subsidies will require stronger enforcement of park rules and greater outreach and education to increase awareness and change visitor behavior. Reducing the quality of high-quality habitats—i.e., campgrounds with heavy anthropogenic food subsidies—has the potential to be an effective approach for reducing jay population size and growth rates within marbled murrelet nesting habitat. Presumably, doing so could reduce not just locally high jay densities in campgrounds, but potentially the number of offspring produced in campgrounds that ultimately disperse to establish breeding territories in other forested areas used by murrelets. While reducing food subsidies in areas receiving high levels of camping traffic is challenging, changing human behavior for the purposes of species conservation through education and other means has been successful in some instances. Notable management achievements in Yosemite and Yellowstone

National Parks are examples in which managers were able to significantly reduce anthropogenic food subsidies to American black bears (*Ursus americanus*). Although these examples also involve safety concerns over human-bear conflict, they provide evidence that combining stricter enforcement policies and extensive park visitor outreach can reduce anthropogenic food subsidies to synanthropic predators.

Alternatively, removal of Steller’s jays from campgrounds could be an effective means to reduce jay densities in marbled murrelet habitat, but would likely need to be continued on a regular basis to account for jays likely to disperse into murrelet habitat from surrounding forests. Ultimately, moving campgrounds and associated anthropogenic food resources out of marbled murrelet nesting habitat may be the most effective long-term strategy for reducing subsidies to jays in these areas. Without concomitant reductions in food subsidies at relocated campgrounds, these sites may still act as source habitats that produce large numbers of young jays that disperse into murrelet nesting habitat within parks (Restani et al. 2001, Marzluff and Neatherlin 2006a). Managers working on murrelet conservation must weigh the potential effectiveness of various management actions. Toward that goal, a list of hypothesized outcomes of various management strategies aimed at decreasing negative effects of Steller’s jays on marbled murrelet productivity are listed in Table 3-2 page 109. .

Table 3-2. Comparison of alternative management strategies aimed at decreasing negative effects of Steller's jays on Marbled Murrelet productivity.

Strategy	Effect on Steller's jays	Murrelet Productivity	Murrelet Population
1. Continue Crumb Clean Campaign	Localized decrease in jay activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
2. Expand Crumb Clean Campaign	Localized decrease in jay activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
3. Improve enforcement of park policies	Localized decrease in jay activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
4. Partner with local organizations for visitor education campaign	Unknown	Unknown	Unknown
5. Reduce human food subsidies in campgrounds	Localized decrease in jay activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases
6. Restrict visitor activities during nesting season	Localized decrease in jay activity	Localized increase in nest survival	Increased number of juveniles in nearshore waters adjacent to managed areas; population increases

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

Table 3-2. Comparison of alternative management strategies aimed at decreasing negative effects of Steller's jays on Marbled Murrelet productivity.

Strategy	Effect on Steller's jays	Murrelet Productivity	Murrelet Population
7. CTA deployments	Potential decrease in egg predation by conditioned jays	Potential localized increase in nest survival	Potential increased number of juveniles in nearshore waters adjacent to managed areas; population increases
8. Use effigies and/or haze jays near areas of high murrelet breeding density	Potential localized decrease in jay activity	Potential localized increase in nest survival	Potential increased number of juveniles in nearshore waters adjacent to managed areas; population increases
9. Locate jay nests in murrelet nesting habitat and oil/addle eggs	Localized decrease in jay activity/reduced reproduction	Potential localized increase in nest survival	Increased numbers of juveniles in nearshore waters; population increases if management efforts are sustained for years
10. Translocate banded Steller's jays from campgrounds	Temporary, localized decrease in jay density; absence of offending individuals; altered social system	Potential localized increase in nest survival	Increased numbers of juveniles in nearshore waters; population increases if management efforts are sustained for years
11. Euthanize large numbers of jays in park campgrounds	Reduction in jay density; increased wariness of individuals; altered social system	Potential localized increase in nest survival	Unknown

MANAGEMENT PLAN RECOMMENDATIONS

Recommendations to Monitor Corvid Numbers in State Parks

1. Re-initiate corvid population surveys in Big Basin State Park that were last done in 2012. Survey both high-visitor use areas and control areas, as a way to determine if the Crumb Clean Campaign is working.

Recommendations to Reduce Availability of Anthropogenic Food Sources for Corvids

1. Continue the Crumb Clean Campaign and other BMPs for control of corvid food sources in parks (see also Chapter 6—this Plan).
2. Explore the formation of a partnership with local Resource Conservation Districts to instigate a private landowner murrelet education program on private land that borders parks with occupied habitat. The program would seek to educate nearby land owners of land use management techniques that minimize the availability of food subsidies for ravens and jays, such as proper garbage management. A murrelet “ranger” would be hired to: (1) identify sites that provide food subsidies for corvids, (2) develop suitable alternative land use practices for those sites (murrelet habitat BMPs), and (3) meet with land owners to encourage and assist with their implementation. Outreach efforts would focus on youth camps, ranchettes, horse stables, farms, vineyards, recreation sites, and residential areas.
3. Protect publicly-owned occupied nesting stands from new disturbances or new activities that bolster corvid populations by prudent placement of recreational improvements and new developments. Require mitigation measures that protect nesting murrelets from increased levels of nest depredation.

Recommendations to Learn More About Raven Distribution and Density in or Near Parks, and Raven Foraging Behavior and Diet.

1. Initiate a citizen-scientist program using volunteers to collect raven information in parks or open space preserves, especially Big Basin State Park. Information would include foraging observations and the location of nests, juvenile roosts, and food bonanzas.
2. Investigate feasibility of and a funding source for monitoring raven nests in Big Basin State Park. Project would require locating raven nests in the park and monitoring nest activity via webcams or volunteer observers. Nests would be climbed to collect prey remains. The diet of park ravens would be determined.

Recommendations to Reduce Corvid Numbers in Occupied Stands in State Parks

1. Consider continuation of the Conditioned Taste Aversion program where carbaccol-treated mimic murrelet eggs are placed in the forest. Jays eat the eggs, get sick, and then avoid real murrelet eggs in the future (See Chapter 6).
2. Consider continuation of lethal control of ravens in state parks.
3. Explore the feasibility and effectiveness of oiling or addling raven eggs.
4. Explore the feasibility and effectiveness of a program that attracts corvids to eat bait dosed with a chemical that causes sterilization. This could reduce the number of young ravens and jays needing to be fed.

Chapter 3 Corvid Predation of Murrelet Nests in Zone 6

Recommendations to Evaluate Effectiveness of All Implemented Projects

1. Perform effectiveness monitoring of implemented corvid control techniques through scientific collection of “before” and “after” data or “treated area” and “control area” data. Analyze collected data to determine how effective the implemented measure was in achieving its goal.

ACKNOWLEDGMENTS

Management of Crows and Ravens to Reduce the Risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains

William C. Webb

I thank California State Parks for providing funding and the opportunity to produce this report. I thank Portia Halbert for helping to guide the contents of the report and useful discussions on corvid and murrelet biology and management. I am also very grateful for guidance from Steven Singer, who has been an invaluable contributor to my knowledge and appreciation of murrelets and the ecology Santa Cruz Mountains. Steve has pointed me towards a number of useful resources used in this report and we have had many productive discussions about the challenges faced with managing corvids and murrelet biology in general.

Management of Steller’s Jays to Reduce the risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains

Elena H. West

I thank California State Parks for providing the funding and the opportunity to produce this report. I thank Portia Halbert and Steve Singer for helping to guide the contents of the report and useful discussions on corvid biology and management. I am also very grateful for guidance from my Doctoral thesis advisor, Dr. Zach Peery, who has been an invaluable contributor to my knowledge and appreciation of murrelets and the ecology of the Santa Cruz Mountains. My goal in writing this report is to provide wildlife managers with relevant information on Steller’s jay ecology as it relates to impacts on marbled murrelets and their conservation. My sincere hope is that this work will stimulate further research that is needed in order to develop the most effective management strategies for those of us working to conserve marbled murrelets in California and throughout their range

CHAPTER 4 PEREGRINE FALCON PREDATION OF MARBLED MURRELETS IN THE SANTA CRUZ MOUNTAINS

by Craig Himmelwright, DVM, Biologist and Consultant

Concerns have been raised that the impacts of peregrine falcon (*Falco peregrinus*) predation on nesting marbled murrelets in Zone 6 may be a significant yet poorly understood threat to murrelet population viability. Indeed, peregrines are efficient and skillful predators of birds, including many members of the family Alcidae. Further, breeding falcon pairs have the ability to take large numbers of birds close to their nesting sites. However, recent or reliable historic data is not available to assess the extent to which peregrines are a real or potential threat to local murrelet recovery. There is confirmed peregrine nesting at two locations in the Santa Cruz Mountains adjacent to murrelet flyways or nesting areas, and a suspected nest at a third significant location in near the Portola flyway. Peregrines were documented killing marbled murrelets at one of these locations.

HISTORIC EVIDENCE OF PEREGRINE FALCON PREDATION ON MARBLED MURRELETS IN THE SANTA CRUZ MOUNTAINS:

On May 12, 1994 David Suddjian observed a nesting peregrine falcon chase and capture a marbled murrelet on the south fork of Butano Creek. This is the first documented local predation of a marbled murrelet, and follows the recovery and expansion of California peregrine populations during the last two decades of the 20th century. Between 1994 and 2001, five falcon predations, and eight foraging attempts on murrelets with unknown outcomes, were documented in the Butano Creek drainage

(Suddjian 2003). During this period, a sixth murrelet was observed killed by a peregrine in the Butano Creek area (Jeff Davis, personal communication). It is noteworthy that these were merely incidental sightings made during murrelet surveys, and not observations collected directly for the purpose of investigating peregrine foraging. Additionally, in the period from 1997 to 2003, 117 marbled murrelets were captured off the coast of Santa Cruz and San Mateo counties, and fitted with radio transmitters (Peery 2006). The recovered remains of two of these radioed murrelets were most likely attributable to peregrine falcon predation.

The Butano Creek peregrine nesting territory was first observed occupied in 1993 (Figure 4-1 page 5). A second nearby peregrine nesting territory, on the east fork of Waddell Creek, was also documented in the 1990's. This nesting territory is located on a murrelet flyway to Big Basin nesting sites, but the area has not been observed specifically to determine the extent to which resident peregrine foraging on murrelets.

However, no marbled murrelets were identified in prey remains collected from the nest and cliff at this site in 1992, 1993, and 1994 (John Schmitt, personal communication). Finally, there are no known or documented predations by peregrine falcons on murrelets in Santa Cruz County between 2003 and 2016. It is important to note that since 2003 no murrelet surveys have been performed in areas where peregrine foraging is likely to occur (Steve Singer, personal communication).

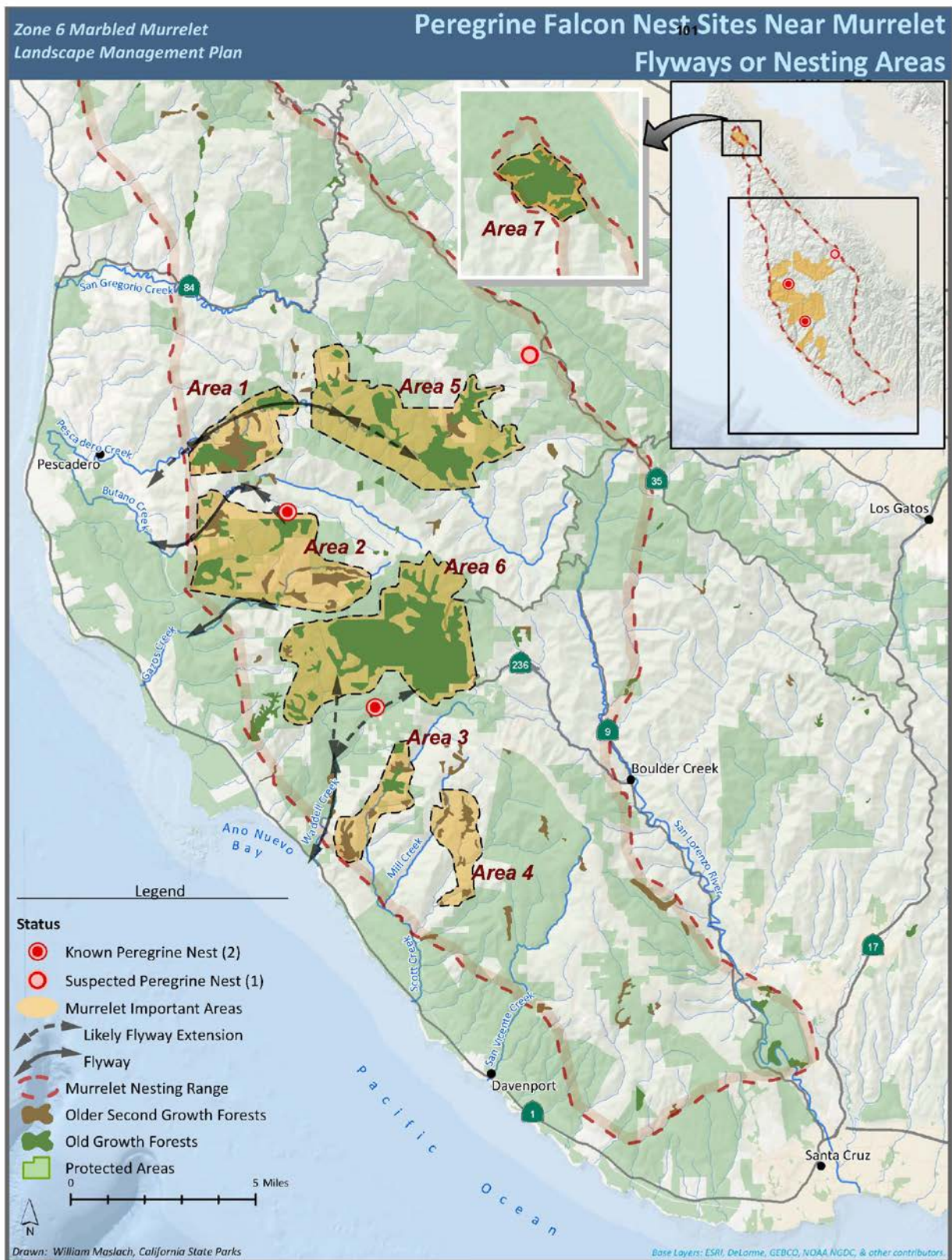


Figure 4-1. Peregrine Falcon Nest Sites Near Murrelet Flyways or Nesting Areas

Multiple observations of predation events, despite the difficulties in observing them and non-targeted surveys suggest that impacts could be significant. Overall, they are relatively few in number, spread over a long time period, and impossible to quantify in any reliable manner. Therefore, it is difficult to assess or accurately determine the current impact of peregrine falcons on local murrelet populations and demographics (USFWS 2009, Peery et al. 2010).

RECENT EVIDENCE OF PEREGRINE FALCON PREDATION ON MARBLED MURRELETS IN NORTHERN CALIFORNIA AND OREGON:

Overall, there is limited knowledge and documentation of recent peregrine predation on marbled murrelets, and no compelling evidence of peregrine predation impacts in areas of northern California and southern Oregon. This is despite the fact there are multiple peregrine nesting territories located near murrelet nesting areas or along their flyways. In the Siskiyou National Forest in Oregon there are at least three peregrine nests located near inland areas of murrelet detections (Dillingham 1995, Joel Pagel personal communication). During multiple climbs of these nests through the 1980's, 1990's, and early 2000's, the only alcid prey remains recovered were of a single ancient murrelet. Peregrines also nest along sections of the Eel River utilized by murrelets as they fly to nesting areas (Bigger et al. 2006), and at Prairie Creek Redwoods State Park, close to murrelet nesting areas (Elizabeth Morata, personal communication). No confirmed peregrine kills or foraging attempts have been documented. Unfortunately, there have been no recent collections of prey remains from peregrine sites, or systematic observations to determine if murrelets are

being hunted. There is only one reported murrelet fatality from peregrines in northern California and Oregon in recent years. Of 105 marbled murrelets captured and fitted with radio transmitters from 2001 to 2003 in Redwood National and State Parks, a single murrelet death was attributed to peregrine predation based on remains (Hebert 2006, Richard Golightly, personal communication).

PEREGRINE PREDATION ON OTHER SPECIES OF ALCIDAE:

While there is currently limited information to assess the impact of peregrine predation on marbled murrelets in the Santa Cruz Mountains specifically, there is abundant and reliable documentation of peregrine predation on other species in the family Alcidae. The most illuminating cases in conservation history and ecological studies that may relate to the marbled murrelet are found with Scripps's murrelets, Cassin's auklets, and pigeon guillemots on the California Channel Islands, and Ancient and Kittlitz's murrelets in Canada and Alaska. There is also abundant literature detailing colonial seabird colonies' support of high nesting densities of peregrines (Hunt 1988, Hunt 1998), including on the Channel Islands, where Cassin's auklets and pigeon guillemots are a primary food source for peregrines (Kiff 1980, Hunt 1994, Latta 2012, Sharpe 2015). Peregrine studies cited, beginning with Hunt (1994), were well-funded, and included thorough foraging and reproductive ecology studies of peregrine falcons, supported by the Montrose Chemical Corporation DDT lawsuit and restoration fund. The studies involved foraging behavior observations of telemetered peregrines, and prey remains analysis from numerous nesting territories.

Chapter 4 Peregrine Falcon Predation of Marbled Murrelets in the Santa Cruz Mountains

The data related to Scripps's murrelets collected in these studies is illustrative of a perceived threat to Scripps's murrelet recovery from an increase in peregrine numbers, but the perceived threat never materialized. During reviews of the listing petition for then-named Xantus's murrelet, there were concerns that the peregrine falcon was potentially an "emerging threat", but at the time the Service found no information to indicate peregrines are an "imminent or significant threat" to murrelets. The peregrine studies cited above demonstrated Scripps's murrelet remains in numerous peregrine nests. However, Newton (2016) reports evidence of murrelet population growth on Anacapa Island, expansion of the breeding areas, and steadily increasing nest occupancy since the eradication of rats. This is during the same time period that Anacapa went from two occupied peregrine nesting territories to four. In addition, Cassin's auklets have returned to former breeding sites on Anacapa, despite the increase in peregrine presence and predation pressure.

In their 1976 article in *Condor* on the decline of peregrines and seabirds at Langara Island, Nelson and Myers make an impressive statement regarding falcon predation on ancient murrelets, another alcid species: "In a calendar year a family of falcons will kill ca. 1000 murrelets. Therefore, in 1968-73 the number of ancient murrelets on the ocean around Langara Island was adequate to support, for a few years, the estimated 20+ pairs of breeding falcons that were documented on the island in the early 1950s." If a "family" is two adults and four juveniles, and 20 falcon pairs are present, this represents 5% of the estimated breeding ancient murrelets (Bertram 1994).

In an abstract from the 2013 Pacific Seabird Group's annual meeting, Lewis et al. assess raptor predation on Kittlitz's murrelets in de-glaciated coastal fjords in Alaska. They stated that bald eagle and peregrine falcon predation exceeded murrelet reproductive output in the study, and peregrines were the most "common" predator. The authors note that habitat change due to melting tidewater glaciers may be a key factor resulting in higher levels of predation on Kittlitz's murrelets.

Peregrine predation on alcids is certainly common, often dramatic, and mostly associated with large seabird breeding colony size, high falcon nesting densities, or open hunting habitats. However, the unique reproductive ecology and terrestrial habitats of the marbled murrelet make comparisons problematic, and as such should be investigated directly to determine if peregrines take a potentially significant number of murrelets locally.

IMPACTS OF PEREGRINE PREDATION ON MURRELETS

Peregrine falcons have the potential to adversely impact the local marbled murrelet population due to low total murrelet numbers, low annual reproductive output, and the fact that only a segment of the adult population makes a nesting attempt in a given year. These nesting adults are likely more vulnerable with frequent flights to and from the ocean to nest in order to feed their young. In addition, peregrines frequently hunt in low light conditions prior to dawn, which is the same time that murrelets are typically moving inland. The historical record of murrelet kills at the Butano Creek peregrine nesting territory is compelling, but difficult to quantify or assess without

additional foraging data, and more reliable murrelet demographic information. Therefore only a rough estimate of possible impacts can be made at this time, and additional data and demographic information is required for a thorough analysis and assessment of murrelet kills by peregrines.

A conservative estimate of predation for a breeding pair of peregrine falcons, over a four-month breeding season from March 15 to July 15, would be 50 bird kills per month. If only 5% of the kills were murrelets, that would be 10 birds, a high number of potential breeding adults. Peregrines tend to hunt close to or from their nest cliffs, and perhaps up to 3 kilometers from the nest site. Thus this predation pressure would focus on a specific area of murrelet movement, and may affect a sub-population specific to a particular drainage, flyway, or nesting area. Further, the number of kills by a peregrine pair typically increases early in the nestling phase, when the adult female no longer needs to brood large nestlings during the day, starting typically when chicks are 14 days into a 38-42 day nestling phase. The female peregrine begins hunting again, often

cooperatively with the male, thus increasing the number of daily kills, to feed what is most frequently a brood of two to four chicks. A conservative estimate of kills would be 80 birds per month from May 15 to July 15, and, if 5% were murrelets, that would include 16 murrelet kills.

Further, peregrine fledglings are dependent on adults for food while they develop hunting skills, a period lasting 4-6 weeks, or more. This may prolong the peregrine presence into late July, delaying post-breeding dispersal from the site. This is a typical breeding timeline for our area, but many factors can alter this, including earlier nesting, first clutch failure and re-nesting, death of nestlings or fledglings, and early dispersal of a family group to a “nursery area”, often well away from the nest cliff, that is more suited to fledgling activity or closer to hunting areas utilized by the adults. Overall, taking into account a peregrine’s capacity to take alcids, and murrelet potential for avoidance behaviors, an estimate of 5-15 murrelet kills during a breeding season is reasonable, for each murrelet flyway with an active falcon nest.

MANAGEMENT PLAN RECOMMENDATIONS

Recommendations to Learn More about Predation by Peregrine Falcons and its Impact on Murrelet Population Demographics

1. Locate active peregrine nests, plucking sites, and prey caches located on the Waddell Creek and South Fork Butano Creek murrelet flyways and monitor for 1–3 years. Observe early morning foraging activities.
2. Climb these sites to collect prey remains.

Recommendations to Control Predation on Adult Murrelets by Peregrine Falcons

1. If studies of active peregrine nests in murrelet flyways find significant take of murrelets, take action to reduce the number of peregrines and shorten their breeding season. Remove peregrine nestlings when young and release them through hacking at a distant location. This results immediately in lower predation pressure and can shorten the time period that the adult peregrines stay in the nesting area.
2. Alternatively, a peregrine nest could be climbed during the incubation phase, eggs removed and hybrid or falconry bred chicks placed in the nest for 12 – 14 days, then removed. This shortens the breeding season even more dramatically, and insures that the female will not lay a second set of eggs. This approach saves the expensive of having to hack the young. However, a take permit will be required for the eggs, and two climbs will be necessary.
3. Simple egg set removal or addling is not recommended because pairs would likely re-nest and might move to a new nest site in the same watershed.

CHAPTER 5 EVALUATION OF NOISE IMPACTS ON MURRELETS IN ZONE 6

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INTRODUCTION

Anthropogenic disturbance of wildlife can have significant effects on individuals and populations. Anthropogenic activities that cause wildlife to change behavior, disrupt their normal behaviors, or cause them to flee, have potential to directly injure individuals and indirectly compromise energy acquisition, survival, or reproduction (Knight and Gutzwiller 1995, Kight and Swaddle 2011). For mammals and birds, a disturbance event is typically perceived by the animal from a combination of visual and auditory stimuli, or either stimulus by itself.

These two stimuli are often linked in discussions of disturbance as a general phenomenon. However, for managers and researchers of wildlife it is also important to distinguish between these two stimuli when considering the sources of disturbance, the natural history of the species of concern, and for developing measures to avoid or minimize the impact of disturbance (see Francis et al. 2009).

When considering mammals or birds that are threatened or endangered, understanding and avoiding disturbing events is especially important. The marbled murrelet is a species identified under the federal Endangered Species Act (ESA) as “threatened”. It is also classified as “endangered” in California under the California Endangered Species Act (CESA). Marbled murrelets nest high in old growth trees where there are few ground predators and visual cues of a predator approach are limited; consequently sound is

likely the major stimulus causing disturbance at the nest (with the possible exception of corvids which could produce both an auditory and visual stimulus as they approached a nest).

Noise has been described as undesirable sound (Crocker 1998) and an ongoing terrestrial threat to marbled murrelets (McShane et al. 2004). Effective management of this species requires consideration of noise as a source of disturbance during nesting. Further, noise can be considered to be a component of the animal’s habitat because noise can compromise communication and reproduction, as well as influence the potential for predation. Noise can cause a decrease in the assessment of habitat quality, especially if noise is persistent in that environment.

Although there is not extensive information available about how noise affects marbled murrelets, other avian species have been studied in detail. Birds can be influenced by anthropogenic noise, either to individuals (Habib et al. 2007, Blickley and Patrircelli 2010, Blickley et al. 2012, Kight et al. 2012) or to the structure of the avian community (Francis et al. 2009). Noise can compromise avian productivity through a variety of mechanisms (Kight et al. 2012). Noise that causes disturbance can result in injury to birds when it causes individuals to fail to reproduce, or when eggs or chicks are lost as direct or indirect consequences of the disturbance. The additional energy required

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

when responding to noise can be a significant factor in the health of the bird. For many avian species, the masking effects of noise (noise so loud that relevant sound can not be heard or distinguished by the bird) can also change patterns of predation (Patricelli and Blickley 2006, Barber et al. 2010) leading to differential mortality among species (Francis et al. 2009), or impact mating systems.

Conservation and management of murrelets requires an understanding of anthropogenic noise in murrelet nesting habitat, the characteristics and forces of the different noises, as well as the potential mechanisms by which noises may affect behavior and reproduction of murrelets. It is the intent of this chapter to identify what is known about noise disturbance to marbled murrelets and when information on marbled murrelets is lacking, to make inference from studies of other avian species. Secondly, this chapter discusses realistic approaches to minimize the consequences of noise from anthropogenic sources to the marbled murrelet population in the Santa Cruz Mountains.

CHARACTERIZATION OF SOUND AND NOISE

Sound is a vibration or mechanical wave of pressure that moves through the air (or water, if at sea). Sound can vary by wavelength (or frequency) and amplitude (loudness) of the wave (both are related to force). Sound is generated from a source and travels as a wave or waves through the air medium. Sound waves can be reflected or dampened by objects encountered in their path.

Sound is typically measured in decibels (dB) which is a scale of the force (amplitude) of

sound waves. Sound can be readily measured using commercially available meters with different weightings for different frequency distributions. Adherence to the appropriate sampling protocol is very important in order to obtain consistent and relevant measurements (see Prater et al. 2009). Further, sound is more complex than simply amplitude; sound is also characterized by the frequency, the duration, and the speed to which it reaches maximum amplitude (see Gill et al. 2015 for review).

To quantify sound, it is generally measured at a set distance from the source and at a set distance above the ground. However, the most relevant consideration for biological impacts is the distance from the sound source to the animal perceiving the noise (not simply a standard distance from the source). With both amplitude and frequency changing with distance from the source, this is particularly important for nesting murrelets because the nests are high in tall trees. Baker et al. (2006) report the average height of nests in the Santa Cruz Mountains to be 41 m (134 feet); Golightly et al. (2009) report the average nest height in redwoods on the north coast of California to be 48.6 m (160 feet). Sound perception at an elevated position in a tree will generally increase the distance from ground sources and may also alter the potential for terrain to reflect or dampen sounds.

Most environments have a regular stream of sound from a variety of sources that constitute the ambient or background noise. Ambient noise is created from background sources such as wind in the trees, flowing water, or insects. Background noise can range from 20 dB in quiet and sheltered locations up to 50 dB in less sheltered and more complex natural environments. For

example, a library may be 20-30 dB (Dooling and Popper 2007) while background noise in stands of redwood trees range from 31-40 dB (Golightly et al. 2009).

Noise varies with the force of the sound and the distance from where it was produced. An off-road motorcycle may generate an average of 75 dB when measured 15.2 m (50 feet) from the source (see USFWS 2006). Similarly, a generator on a recreational vehicle can generate a constant 75 dB at 15.2 m (50 feet), where as a front-end loader produces 80-84 dB. Traffic noise varies with the road surface, the types of vehicles, and the distance lateral to the highway. In parks, noise in murrelet landscapes adjacent to roads and trails varied from 31-83 dB (Golightly et al. 2009). Vegetation and topography enhance the natural attenuation of noise as distance from the highway increases.

Biologically, sound is perceived via anatomical structures (e.g., the inner ear) that are sensitive to the waves of pressure that travel through the air. Sound perception depends on both frequency and amplitude. There have not been specific studies of hearing in marbled murrelets. With a few exceptions, avian hearing approaches the same level of sensitivity and frequency discrimination as human hearing (Dooling 1992, Dooling and Pooper 2007). However birds may not be able to resolve differences in intensity as well as the human ear.

Although it is important to consider how frequency (in addition to total amplitude) will affect wildlife (Gill et al. 2015), it is less clear how different frequencies will impact wildlife. To interpret alterations in behavior due to frequency, quantitative measurement of frequency and the

concomitant behavior of the animal must be known. Unfortunately this is unavailable for many species of wildlife and is especially difficult to obtain for secretive and difficult to observe species such as the marbled murrelet.

The duration of sound production also contributes to the potential for noise to cause disturbance to wildlife. The duration of sound can be categorized as impulsive (a short energy-intense burst, usually characterized by a very rapid increase in amplitude of the sound), repetitive (occurs repeatedly), continuous (always or generally present, lasting minutes to hours), or chronic (minutes to days, but even if short, continually re-occurring). It is possible in some cases that wildlife will become habituated (see below) to chronic noise or elevated background noise. However, they may or may not become habituated to very loud or repeated impulsive noises.

LEGAL CONSIDERATIONS AND NOISE

Under the federal ESA, noise can result in “harassment” or “take” if the character of the sound causes disturbance adequate to influence behavior or reproduction. For marbled murrelets, noise can change behavior, increase energetic cost through movement or displacement, and change reproductive performance (especially where disturbance increases risk of predation or nest failure).

In northern California, the US Fish and Wildlife Service (USFWS 2006) has provided guidance for assessing the potential impacts of project-induced noise; they characterize a variety of sources and distances to potential nests that may require modifications of project schedules and noise minimization. They consider any noise that

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

causes flushing during breeding or alteration of a breeding attempt to be considered harassment. Their guidance document calls for pre-project measurement of background noise levels, and assumed that background noise would be less at night and up to 2 hours after sunrise (which would adjust downward the total allowable amplitude). Project-generated noise that exceeds 20dB above background, or greater than 90 dB total, at the location of the murrelet should be considered harassment. Project planners should avoid exposing the murrelet to these noise levels if the noise could reach potential marbled murrelet nesting areas.

Their recommendations were primarily based on the characterization of sound by measurement of amplitude (loudness). Their analysis recognized that noise amplitude attenuates at a distance from the source and they recommended specific distances that noise could be considered to be a risk. Noise required consideration in the planning process if the source of the noise production occurred within 402 m (0.25 miles) of a potential murrelet nest. Additionally, they noted the need for specific site considerations including the indirect effect of noise that might cause predators to be attracted to the source. In northern California, Redwood National and State Parks (RNSP) adapted this guidance for their management (RNSP 2007).

MECHANISMS OF NOISE DISTURBANCE IN BIRDS

A bird that perceives a noise disturbance has three behavioral options. First, it can ignore the noise and not alter behavior. Second, it can alter behavior but still remain in place on or at the nest. Third, it can attempt to escape the site and avoid the source of the

noise. Presumably the bird's behavior is driven by the potential for the noise to startle or indicate potential danger. If a bird alters behavior or flushes from the site due to auditory or visual stimuli, it has been exposed and responded to a disturbing event. The behavioral responses to noise threats could include hiding from the danger source (e.g. evoking cryptic behaviors like staying motionless), increasing the level of vigilance, altering communication with conspecifics, or removing themselves from the danger (e.g. flushing). These changes in behavior can be undetectable to a human observer or very obvious. Different avian species may respond differently to the same stimulus (Francis and Barber 2013).

Flushing is a relatively obvious consequence of noise disturbance that is easy to correlate with noise production, when observed.

Flushing may involve considerable energy expenditure and have significant consequences. The metabolic cost of flight may be 5 to 10 times greater than resting metabolic rates (Tucker 1973). This energy expenditure must be compensated for by increased energy acquisition (foraging), less future activity, or reduced commitment to reproductive effort. Flushing by a nesting bird also leaves the egg exposed to the environment and predators.

Even if the response is more subtle than flushing, the effect on the bird may still be of consequence. A noise disturbance may simply have the effect of interrupting normal behaviors. A noise disturbance may also be distracting. If it causes only momentary pause or hesitation, the disturbance may be of little consequence. However, prolonged periods of changed behavior may deprive a bird of foraging time, increase energy expenditures (which may require additional

foraging or result in less energy to allocate to reproduction), disrupt mating behavior, produce physiological changes associated with stress, or expose the bird (or its egg or chick) to increased risk of predation. The consequences of increased energy expenditure and stress may directly affect health.

Although difficult to observe externally, the physiological changes associated with noise induced stress can have profound effects in a variety of wildlife, and in people, including decreased reproduction and increased risk of disease (see review by Kight and Swaddle 2011). It is important to recognize that, although a bird may not flush when disturbed, it may still be exposed to physiological changes, especially if the disturbance is repeated and chronic. Chronic exposure to stress can cause corticosteroids to become elevated which can impact or interfere with reproduction, metabolism, cardiovascular health, and cognition. Although physiological responses to disturbance may initially be beneficial and adaptive as a short term response (e.g. facilitating avoidance of potentially dangerous or harmful events such as predation), the longer term elevation of corticosteroids that results from chronic or repeated disturbance can be harmful.

MARBLED MURRELET RESPONSE TO NOISE

Although disturbance has been studied for several species of seabirds (see Carney and Sydeman 1999, Fuller et al. 2015), there are few studies of the effect of noise disturbance to marbled murrelets. For seabirds in general, disturbance can often be directly observed at colonies and the consequences for nesting species subsequently reported

(Rodway et al. 1996, Piatt et al. 1990, Fuller et al. 2015). The approach by people, aircraft (particularly helicopters), boats, predators, and disruptive visits by other wildlife is known to cause disturbance to seabirds at colonies.

Most reports of noise disturbance that have affected marbled murrelets have come from early anecdotal observations that were incidental to other research. McShane et al. (2004) provide an exhaustive summary of these incidental reports (see also Long and Ralph 1998). These include two marbled murrelet nests in Big Basin State Park; these birds rarely showed signs of agitation in response to nearby trails or the sewage treatment facility (Singer et al. 1991). Singer et al. (1995) also reported that there was little response by the birds to human vocalizations on the ground.

The early anecdotal reports led some biologists to conclude that marbled murrelets were noise tolerant, or at minimum could adapt to sources of noise (see McShane et al 2004). However, this conclusion has not been specifically supported by the scientific evidence from other avian species or more recent systematic investigations of marbled murrelets.

Anecdotal evidence of tolerance was often from localities with roads or human facilities; habituation could have been a confounding factor and was probably not representative of naïve birds or the population as a whole. These reports were often situations where investigators could not distinguish between auditory and visual components of disturbance. More importantly, these were not experimental studies and were not subject to detailed

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

analyses of the bird's reactions to noise. Lastly, the early observations do not preclude the possible effects of many more subtle consequences of noise disturbance, such as physiological effects.

Marbled murrelets and their nests are difficult to observe because the nests are so high in the trees and the adults fly in and out for incubation exchanges only during the very early morning hours. To overcome this difficulty, Hébert and Golightly (2006) used radio telemetry and video techniques in RNSP to systematically assess the behavioral and reproductive response of marbled murrelets to noise associated with human trail-use and distances of nests from recreational trails in the park. Here, visual and auditory stimuli could not be separated, but presumably marbled murrelet responses were most likely associated with noise.

Video was used to record murrelet behavior coincident with human activity on the trails. No murrelets were observed to flush when trails were used by various-sized groups of people. For other avian species, human activity on trails in recreational settings has caused adults birds to flush (Gutzwiller et al. 1997, Miller et al. 1998, Swarthout and Steidle 2001). However, humans are not usually in the canopy of old growth trees and murrelets have not been exposed to them as a potential source of danger. The perception of humans on the ground as a potential threat was thus less likely for murrelets than for other bird species that nest in the forest shrub layer and closer to ground predators. Further, the reproductive success of marbled murrelets could not be ascribed to the proximity to trails (failed nests averaged 0.41 ± 0.2 km, while successful nests averaged 0.71 ± 0.2 km from trails in one year of the study (Hébert and

Golightly 2006), although the power to detect statistical differences was relatively low. This lack of pattern in nest success relative to trail proximity was consistent with early anecdotal reports (summarized in McShane et al. 2004).

In the same investigation, Hébert and Golightly (2006) also experimentally examined changes in behavior associated with noise generated from operating chainsaws; they examined both the behavioral responses of incubating adults, as well as chicks at the nest. It was apparent that individual murrelets recognized the chainsaw noise as an alteration in their environment. At 65-75 dB measured 25m (82 feet) distant from the source and at the base of the tree, approximately 40-50 m (131-164 feet) from the nest, the noise was 20-35 dB above background in that forest. Murrelets rested less during the time that the saw was running and displayed an increase in behaviors that could be interpreted as vigilance. However, these behavior changes were subtle and appeared to preserve the cryptic manner in which murrelets behave at the nest; see below. Moreover, no murrelets flushed and all sat quiescent in the nest during their chain saw exposure events. Neither chronic nor impulsive noise was tested in this study.

A lack of dramatic flushing response to disturbance is not surprising given how murrelets avoid predators at the nest. Cryptic plumage and behavior serve as mechanisms to avoid detection by the predators. This is especially important when a bird is sitting on an egg that it needs to protect from environmental influences (temperature, sunlight, wind, rain) or predators. Murrelets are described as being cryptic on the nest (Carter and Stein 1985,

Hébert and Golightly 2006, 2007, Golightly and Schneider 2009). Murrelets exhibit plumage that is difficult to see in the filtered and spotty lighting on a branch within a tree canopy. It is notable that they also exhibit an array of behaviors to maintain their crypsis. They sit quiescent on a limb when incubating (Nelson and Hamer 1995, Hébert and Golightly 2006, 2007, Golightly and Schneider 2009). Murrelets also turn their eggs during incubation by using only their feet (with little to any assistance from their bill) which Golightly and Schneider (2009) speculated may have evolved so as to assist in being cryptic. Those egg turning events were also restricted to periods of wind (which caused movement in the nearby branches) which could serve to mask the standing and subtle foot movements required to turn the egg. The extensive reliance on crypsis would suggest that the subdued responses to disturbance that have been reported as only slight behavioral changes could actually represent a more significant response (e.g., accompanied by physiological changes). The lack of flushing or other more extreme behaviors was probably a result of their reliance on cryptic behavior to avoid detection and does not necessarily indicate that murrelets are more tolerant of noise disturbance than other birds.

Conversely, marbled murrelets have been reported to flush in a few anecdotal observations when confronted with visual line-of-sight pedestrian traffic (Hamer and Nelson 1998). Flushing from a nest would have the probable consequence of a long flight back to sea (they can nest up to 40 km (25 miles) from the sea in California). In RNSP, flushing from a nest almost always meant a return to the ocean and a prolonged absence from the nest (based on radio-

telemetry and video techniques; Hébert and Golightly, unpublished data). An example taken from one nest illustrates the potential risk to an individual nest; on two separate occasions on two separate days the incubating adult at this nest was flushed (for unknown reasons) and in both cases left the egg unattended. Incubation did not begin again until the following morning when an adult arrived at the nest. There are also two reports of a tree climber interrupting a murrelet bringing food to a chick on a nest (described in McShane et al. 2004). In one of these cases, the adult murrelet flushed from the tree, circled the tree in flight, landed again, and then left the tree without feeding the chick (presumably flying back to sea). In a second and different case, an adult murrelet arrived at a tree and circled the tree in flight until the climber was out of sight, then landed and fed the chick.

Therefore, flushing has three negative consequences for marbled murrelets. First, in the RNSP study, the average nest was 4.7 km (2.9 miles) straight-line distance to the ocean (Golightly et al. 2009), although the actual flight route was probably much further. Consequently there was a prolonged period of higher energy expenditure because of added flight, which would significantly elevate daily metabolic cost. Second, flying away from the nest, especially if outside the dawn/dusk period, could expose the adult to greater predation risk. Third, for an incubating adult that is flushed, the egg is exposed to the environment (and potentially cooled) and also vulnerable to predators.

Hébert and Golightly (2007) reported that unattended murrelet eggs were more likely to be predated than when the incubating adult was on the egg. Further, other surface-nesting seabirds have rarely been observed

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

to leave their eggs unattended (e.g., common murre; *Uria algae*), which could potentially cool the eggs and increase their risk of predation (Golightly and Schneider 2016). Murrelets appear to have evolved to be cryptic rather than flush. These factors suggest that flushing is an extremely significant response for a murrelet with potentially serious negative consequences. Murrelets probably avoid the very extreme consequences of flushing unless threatened with a recognized, immediate, and extreme danger.

In addition to the direct responses to noise, there are several indirect effects of noise that may have deleterious impacts. Novel noise, especially noise associated with human food consumption, such as camping and picnicking, has a potential to attract opportunistic predators (Marzluff and Neatherlin 2006) such as Steller's jays (*Cyanocitta stelleri*) or ravens (*Corvus corax*; hereafter the two species are referred to as corvids). When noise associated with human feeding is created in close proximity to areas with murrelet nests, the nests are likely exposed to higher predation risk because of the attracted corvids. Golightly and Schneider (2009) specifically observed Steller's jays eject an incubating adult murrelet and predate the unprotected egg. Goldenberg et al. (2016) reported that jays in RNSP would routinely travel up to 1 km (0.62 miles) in order to visit campgrounds. In the Santa Cruz Mountains, Steller's jays move up to 2 km (1.24 miles) to visit campgrounds and picnic areas (West et al. 2016). These long-distance movements by jays were presumed to be for obtaining food. The timing and location of anthropogenic food sources and the characteristic noise associated with people may be important

cues for corvids to determine potential for food. The resulting concentrations of predators attracted to noise associated with anthropogenic activity may create elevated levels of risk in important murrelet nesting areas (Golightly and Gabriel 2009). This indirect effect of noise on predation risk during murrelet nesting is important to the assessment of noise and disturbance.

An additional indirect mechanism for noise to impact birds is to mask communication between individual birds or hinder detection of predators (Slabbekoorn and Ripmeester 2008). Because murrelets typically sit motionless and alone, conduct incubation exchanges only in the early morning hours, and do not flush from the nest until the predator is literally at the nest (see Golightly and Schneider 2009), anthropogenic noise may have a low likelihood of masking sound that is important to murrelets. However, the effect of noise masking on marbled murrelets has not been investigated.

Frequency probably has substantial effect on masking, but little is known about how frequency changes might be perceived by marbled murrelets.

Confounding our understanding of how murrelets respond to noise are observations of marbled murrelet nests near highways and roads (Singer et al. 1991, Hamer and Nelson 1998, Hébert and Golightly 2006). In one year of their study, Hébert and Golightly (2006) reported that the average distance to roads for nests that successfully hatched chicks and nests that failed to hatch a chick was similar ($\bar{x}$ =1.7 km, $n = 7$ and 9 respectively). Highway traffic can be loud (90+ dB), and in many cases may represent repeated or continuous noise. In some cases, wildlife can cease to respond to repeated or long term noise (such as a roadway). The

examples of murrelet nests that are reported near highways are probably examples of the noise no longer being “novel” or “startling” and the birds having become “habituated” (Long and Ralph 1998). However, caution is required in assessing whether a habituated bird is really no longer responding to, or affected by, the long term and continuing noise. Physiological responses to stressors such as noise are more difficult to measure (and often invasive) and complicated by time since exposure, level of exposure, and repeated exposures. For example, yellow-eyed penguins (*Megadyptes antipodes*) exposed to chronic disturbance had elevated levels of corticosterone and subsequently lower breeding success; however, they eventually stopped responding behaviorally to the disturbance stimuli and corticosterone levels fell (Ellenberg et al. 2007).

Conversely, Magellanic penguins (*Spheniscus magellanicus*) initially responded behaviorally and physiologically with elevated corticosterone levels to disturbance. After 15 days of disturbance exposure they appeared to have outwardly habituated, ceasing overt behavioral responses, but were still experiencing ongoing physiological response including elevated corticosterone hormones (Walker et al. 2006). Elevated corticosterone hormones result from “flight” responses that can persist and remain elevated after cessation of the stimulus. For murrelets, experiments and observations such as those conducted by Ellenberg et al. (2007) and Walker et al. (2006) are much less feasible, too invasive, or not even possible depending on the exact research question.

An additional issue for assessing the effect of noise on marbled murrelets is the duration and intensity of noise and how it is

perceived by the animal (Pater et al. 2009), which can differentially affect the response of birds. In particular, high intensity impulsive noise (short duration over a range of frequencies; examples include air horns, blasting, impact pile driving, gun shots) was found to produce responses in shorebirds that were related to their decibel level (Wright et al. 2010). Importantly, high-intensity impulsive noise often lacks visual cues (and may be a wholly auditory disturbance). Measurement of impulsive noise requires different equipment and sampling than continuous noise (Pater and Delaney 2002). The effect of high-intensity impulsive noise on marbled murrelets in nesting habitat has not been studied.

Lastly, the sources of noise that can potentially impact murrelets are quite varied and include most noise producing equipment. In addition to human activity, equipment, and traffic, noise generated from aircraft has been a major anthropogenic source of disturbance to other seabirds (Rojek et al. 2007). At first consideration aircraft may not seem to be a relevant source of noise disturbance to nesting murrelets (but see incidental observations in Long and Ralph 1998). However, noise from helicopters is quite loud and has been implicated as having the most profound effect in other seabirds (Fuller et al. 2015). Helicopters are capable of flying low over marbled murrelet nesting trees; thus the nests could be relatively close to this very loud noise source. There are no data specifically for marbled murrelets and helicopter noise. A new but related potential source of aerial noise disturbance has been from a relatively new technology. The recreational use of personal un-maned aerial vehicles (drones) has increased in recent

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

years. The potential for drones to disturb wildlife is now recognized in the scientific literature (see Vas et al. 2015); the noise probably varies with type and size of the drone. The risk of these machines to create disturbance to murrelets is unknown and requires investigation before use in murrelet nesting areas.

TEMPORAL VULNERABILITY TO NOISE

Murrelets fly from the sea to visit nesting areas year round (Naslund 1993). However visits are far fewer outside of the breeding season (Sanzenbacher et al. 2014). Although the period that regulatory agencies identify for nesting birds in California is March 24 to September 15 (Evans Mack et al. 2003), significant nest initiation may not begin until mid to late April, and varies between years (Hébert and Golightly 2006, see Figure 2-2, page 14 Chapter 2, this Plan). Egg laying is concentrated in the latter half of April and May, followed by approximately 28 days of incubation. A murrelet whose nest has failed can, in some cases, attempt to re-nest (Hebert et al. 2003), although the circumstances of where this happens are poorly understood. When it does occur, re-nesting would happen in June or as late as early July and these nests probably represent most of the reported late-nesting birds. Consequently, the period of greatest risk to most of the population may be a shorter period of time than what is presently considered to be the nesting season. Consequently, the period of greatest risk to most of the population is a shorter period of time than the total nesting season.

The actual risk of injury from noise disturbance is not uniform across time, either at fine or gross scales (within a day, within the breeding season, or within a

year). Most seabirds, especially member of the family Alcidae, are very vulnerable to disturbance during incubation and noise impacts can have negative reproductive consequences (Fuller et al. 2015). Murrelets appear to have the same period of vulnerability. Flushing of an adult incubating bird would leave the egg unattended and exposed. Hébert and Golightly (2006) reported that nests where eggs were left unattended were the most likely nests to fail (or be predated; Hébert and Golightly 2007); incubation was the stage of reproduction with the greatest failure. Although fledging success was much better than hatching success (Hébert and Golightly 2006), adults must still access the nest in the early morning, and sometimes early evening, with deliveries of fish. It is possible that noise that occurs during a food delivery could disrupt the feeding event, and if so, cause the chick to receive less energy. Specific data on disruption of food deliveries is not available for murrelets; there are two anecdotal reports of disturbance interrupting a food delivery, but primarily involving human tree climbers (see McShane et al 2004).

MARBLED MURRELET EXPOSURE TO NOISE IN THE SANTA CRUZ MOUNTAINS

In California, most of the remaining old growth forest near the coast is in public ownership, primarily in parks and preserves. Murrelet nesting habitat in the Santa Cruz Mountains reflects this pattern. The nesting habitat in parks and preserves is subject to noise generated by the human use of the parks (camping, picnicking, hiking, auto and truck transportation), as well as construction, facility maintenance, trail and road maintenance, and equipment repair that support park operations and visitor use.

Additionally, land use adjacent to parks has the potential to produce noise that could reach nesting habitat in the parks.

In northern California, Golightly et al. (2009) examined noise levels and their sources in potential murrelet nesting habitat in RNSP. Roads and park facilities were the major sources of anthropogenic noise above background levels and within the murrelet habitat. Major paved highways with variable traffic contributed the most noise and could reach 90 dB. Loud noise could extend 135 m (443 feet) into the adjacent old growth forest before attenuating to background levels. Parking lots contributed noise as loud as 65 dB on average, though the levels were extremely variable. They also measured the noise from visitor centers that extended up to 50 m (164 feet) into the forest. The potential lateral penetration of noise through the forest to the a height of a murrelet nest is unknown. At one nest tree, Golightly and Schneider (2011) placed a recording microphone; that microphone could clearly distinguish trucks driving over rumble strips associated with a paved highway 300-400 m (1000-1300 feet) distant.

Golightly et al. (2009) calculated that 8% of the old growth forest where murrelets could nest in RNSP was potentially affected by noise from roads, campgrounds, parking areas, and visitor facilities. Background noise (excluding anthropogenic sources) was 42 dB in RNSP in northern California redwood forests (Golightly et al. 2009). In Big Basin State Park in the Santa Cruz Mountains background noise was measured at 51dB (Singer and Houston 2006); however in this park there are many other sources of intermittent or continuous noise (e.g. campgrounds) that can raise the ambient noise levels to 71 dB.

There are many sources of noise in the Santa Cruz Mountains that are above background; some sources are associated with human activity in parks and preserves, while others are outside parks associated with roads, residences, and possible forest management (e.g. fire, timber harvest). The characteristics of those noises are also important in formulating an assessment of noise and a management response to protect marbled murrelets. Importantly, the recreational noise in these forests generally overlaps the important periods of incubation and chick feeding by marbled murrelets. Timber harvest also occurs during the drier summer months coincidental with murrelet nesting.

Few studies have evaluated the noise specific to forest management, especially noise associated with timber harvest (but see Grubb et al. 2013). The techniques used to harvest timber, the sizes of trees being removed, and the tools used to remove the timber (trucks, helicopters) are some of the timber operations that can significantly change the noise regime. If harvest occurs in proximity to existing roads, logging trucks operating on previously established roads may have minimal additional effect (Grubb et al. 2013). Conversely, unusual noise or very loud sudden or impulsive noise generated from logging machinery (including trucks, horns, and whistles) would require specific evaluation as disturbance events. Further, in areas without a history of trucking or machinery noise, the injection of new sound into an otherwise quiet background should be assessed as a potentially disturbing noise. Helicopter logging may also produce loud noise at different frequencies and should be evaluated when conducted near murrelet

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

nesting habitat. The sound associated with trees falling to the ground will be loud and sudden at the source. Depending on the size of the trees, additional vibration (both sound as described here as well as transmission through other mediums) can have the potential to disturb murrelets when nesting nearby, and should be evaluated and avoided in a proposed harvest. Lastly, nearby harvest operations can influence the behavior of egg predators by providing food rewards (from human food) associated with common anthropogenic noise. Subsequently, these noises may alter corvid distributions in unknown ways with possible changes in predation risk to murrelet eggs.

MANAGEMENT OF NOISE IMPACTS TO MARBLED MURRELETS

Marbled murrelets are very difficult to observe and species-specific studies of noise impact have been limited, and sometimes impossible to conduct. Clear causal relationships between noise and potential impact or injury (e.g. reduced reproductive success, increased risk of predation) have not been established. Clearly flushing should be considered harmful. Despite the absence of causal studies on marbled murrelets, events that cause flushing cannot be considered as the only harmful noises. Formulation of protective strategies for marbled murrelets requires that assessments consider all information about murrelet life history, as well as the responses to disturbance identified in studies of other seabirds.

Noise levels

Noise that is very loud or impulsive (e.g. blasting, gun shots, trees falling) can potentially cause murrelets to flush. The likelihood that a noise can create an impact

is proportional to the loudness of the noise and the length of time the noise continues (especially as it affects physiological and metabolic responses). Murrelets that are chronically exposed to higher levels of noise may be more tolerant to noise in general, although unseen physiological consequences may still result from the long-term disturbance regimes. Conversely, novel exposures to loud noise may be more likely to cause flushing. Unfortunately there are few specific data for marbled murrelets.

As described earlier, the US Fish and Wildlife Service (USFWS 2006) provides guidance on acceptable amplitudes of noise to avoid harassment or take of marbled murrelets; the guidance considers the source of noise, how noises can relate to background or ambient noise, and how much greater than background noise may be tolerable. Their guidance included assessments of both marbled murrelets and spotted owls (*Strix occidentalis*) using similar criteria, which was logical for a region where the two species co-occur and consistent with the scope identified in their guidance.

However, in other regions and where nesting spotted owls may not be a consideration, mechanisms to avoid harassment by noise can be precisely tailored to the natural history of marbled murrelets and simultaneously provide more specific protections and target activity-restrictions to periods when they will be most effective. Often the location of spotted owl territories, and even nests, are known, whereas murrelet nests are seldom known and project planners must make assumptions about potential nest trees. The impact of different levels of noise and the circumstances of that noise differs with distance between the source and a

nesting bird (and this was addressed in the USFWS Guidance) and ***is not limited to a fixed distance***. Consequently, specific characterizations of the potential for impacts to marbled murrelets should be assessed on a site-by-site, project-by-project, or case-by-case basis.

Assessments of sites where noise will be produced will require calculation of noise exposure, either by methods outlined in the USFWS Guidance document (USFWS 2006) or by direct measurement. To estimate sound amplitude at a potential nest site, there are a range of distances between a noise source and potential nesting sites that are described in the USFWS Guidance document (USFWS 2006).⁶ However, the real attenuation of noise can vary extensively between different types of vegetative cover and different topographic situations, which should be considered for application on a site-specific basis.

Consideration of noise reaching suitable nesting trees may be best informed by the actual measurement of the noise, and specific restrictions on noise developed with the site-specific information. A single rule or guideline would necessarily be restrictive in order to be completely inclusive and in many cases may be inappropriate.

Both the character of the noise and the amplitude need consideration to determine potential noise exposure. Sound meters can be used by planners and managers to measure the amplitude of the sound at distances from a source. Although sound frequency is also an important component of

the sound that can be measured with additional effort, there is presently a lack of quantitative assessments of associated behaviors for most wildlife (and especially for marbled murrelets) in order to implement an appropriate management response to measured frequency changes. Consequently, qualitative descriptions of character of the noise generated must also be considered to the extent possible.

When assessing noise character and amplitude, the site of noise generation should be classified into one of two spatial categories that represent subtle differences in measurement of noise and how the distance from the source to the animal is measured. Measurement of noise that is sourced within a forest stand that is used by murrelets for nesting is different than noise that is sourced outside the forest stand used by murrelets. With the recognition that the important metric is the noise at the location of the bird and not at the source, noise can be measured at a potential nearest nest tree, or the distance from the source readily measured and attenuation calculated (with assumptions about the tree/nest height; see Singer and Houston 2012). Often noise generated within a stand will be closer to the bird (and by definition will be within the nesting habitat) compared to noise generated outside the stand. Outside the nesting stand, noise must be measured at the nearest edge of the stand. There are many factors that can potentially attenuate the sound amplitude and frequency. The assumptions to estimate sound may be

⁶ It is also helpful to know that the noise attenuation rate for sound in open air is 6 dB

+/- 0.5 dB for every doubling of distance from the source.

more varied and potentially less precise for sources outside the nesting stand.

The USFWS Guidance document considered sound greater than 90 dB to be a threshold for impact. Unfortunately, little data exist to specifically identify the impact of very high noise (greater than 90 dB) other than the potential to flush. Other possible impacts are extrapolated from other species. Because of this uncertainty, there is a need to avoid very high noise levels, as well as noise characterized as high-intensity impulsive, or sudden, and characterized by rapid increase in amplitude at any time during the nesting season. These latter characteristics should also be considered as a potential for impact. At lesser levels, noise may be tolerable, especially when it is produced over a short time frame. Specific thresholds for impact are more difficult for noise 25-35 dB above background or for chronic noise. Minimization of noise can occur by reducing the period of high noise level and considering methods to reduce overall noise (for example ensuring that equipment has maintained mufflers, or using creative dampening devices; for example see Singer and Houston 2012) or even block noise by having it occur where topography can be beneficial. The effectiveness of noise reduction procedures for sound amplitude should be measured and monitored to ensure compliance.

Timing of Noise Restrictions

The risk of noise impact can be reduced by timing loud noise-producing events near murrelet nests to times when the birds are least vulnerable. This would be especially important during incubation, but also the time of day during chick feeding when fish deliveries might potentially be disrupted. Because the USFWS (2006) was

considering spotted owl habitat in the same noise analyses, their considerations for restrictions on noise generation did not fully distinguish all nuances specific to marbled murrelet biology that differ from other species. Specifically, the timing of how murrelets use the forest is important to providing flexibility to the imposition of restrictions. Presently, the marbled murrelet nesting season in California is considered to extend from March 24 to September 15 (McShane et al. 2004) and noise restrictions are typically applied to this period (Figure 5-1 page 133). However, for murrelets the potential impacts from noise generation vary with time of day, phase of the nesting season, and time of year and may not require the same types of restrictions at all times. Thus, it may not be reasonable to apply a single set of restrictions or noise mitigations across all times of day and throughout the nesting season. The following section discusses potential alterations of the present noise restrictions that could be considered to ensure protection to murrelets while also providing regulatory flexibility.

Seasonable Variation in Noise Vulnerability

Accurate identification of the beginning and end of the vulnerable nesting period is important for correct imposition of restrictions on noise so as to protect marbled murrelets. The Pacific Seabird Group Survey Protocol (Evans Mack et al. 2003) considered the period for potential breeding and related activities for nesting in California to encompass the period of 24 March to 15 September. In Washington and Oregon egg laying has been described as beginning in late April (McShane et al. 2004). The early beginning of the nesting

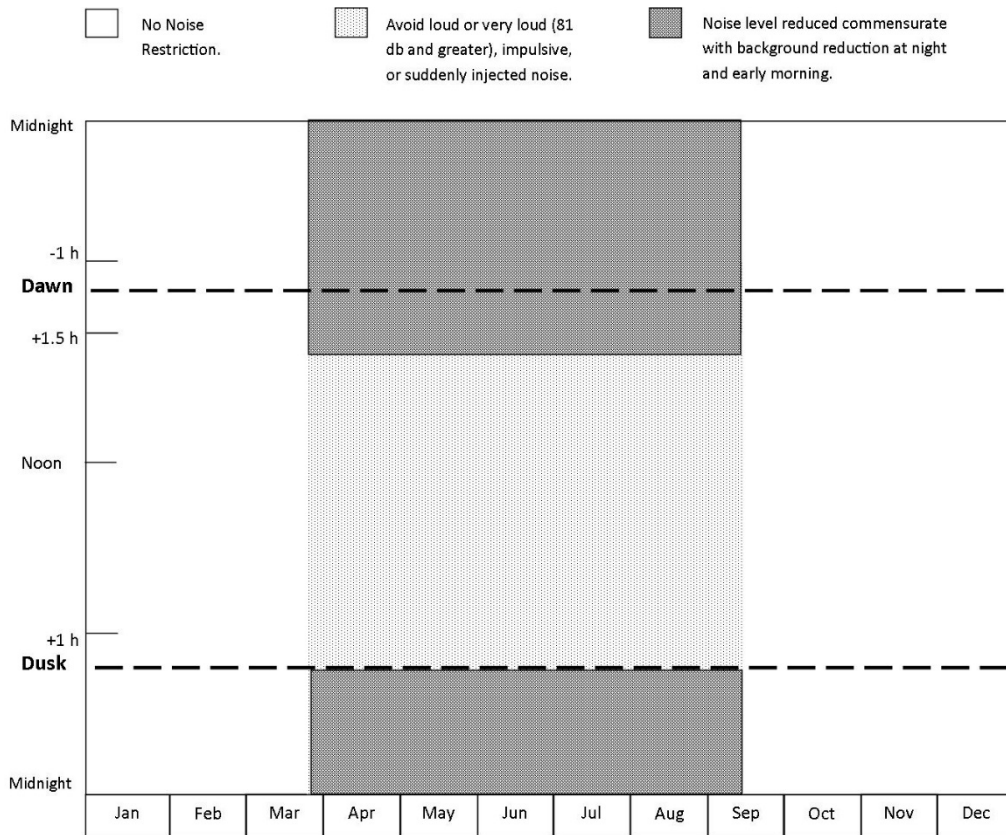


Figure 5-1. Schematic diagram of the existing temporal variation in timing anthropogenic-noise avoidance for Marbled murrelets in the Santa Cruz Mountains. Times are relative to dawn and dusk and are for schematic purposes only (they do not reflect the changing clock-time of dawn and dusk through the year)

period in California results from the back-calculation of grounded downy-chicks (chicks that fall from the nest tree) or grounded fledglings (as described in Hamer and Nelson 1995). Unfortunately, murrelet chicks are difficult to age (except on the day of fledging; downy Alcid chicks without measures of relative size cannot be accurately aged; H.R. Carter, pers com) and consequently exact dates of nest initiation can be uncertain based on back-calculations alone. The early March 24 date was used to be maximally inclusive and ensure a proper period for surveys (Evans Mack et al. 2003). However, additional data are now available to help refine the period for noise vulnerability.

A total of 31 grounded chicks or fledglings were reported for the period 1974 to 2013 in the Santa Cruz Mountains Table 2-3 page 23, chapter 2, this Plan). Based on back calculations, only a few fledglings (including one observed nest) led to a presumed nest initiation prior to 13 April. Further, consistent with the early reports of grounded chicks or fledglings are field notes from 1997 with an observation of “occupied behavior” that was observed as early as 6 April (E. Burkett, field log). Although the observations of the few early chicks or fledglings and the field notes do not represent systematic studies, they do suggest that some murrelet activity in nesting areas has occurred in early April in the Santa Cruz

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

Mountains, at least so in the 1990's. This activity was earlier than has been reported elsewhere in the range of the marbled murrelet.

Since the 1990's, new techniques have added to our understanding of the nesting period and may allow us to refine the limits of the nesting period. Hebert and Golightly (2006) used radio telemetry to follow 72 nests over three years in northern California; the earliest nest was initiated 22 April and the average nest initiation occurred on May 3, May 19, and May 15 in 2001, 2002, and

2003 respectively. Further, during their capture of 102 murrelets, they observed brood patches (a featherless vascularized region on the abdomen that is associated with incubation) on 27 murrelets. Although capture effort began around April 10, no brood patches were detected until the last week of April (R. Golightly, unpublished data). Of the 27 brood patches detected, three were observed on 24, 25, and 30 April while the remaining 24 were observed after May 1. Radio telemetry was also used to follow nests in the Santa Cruz Mountains

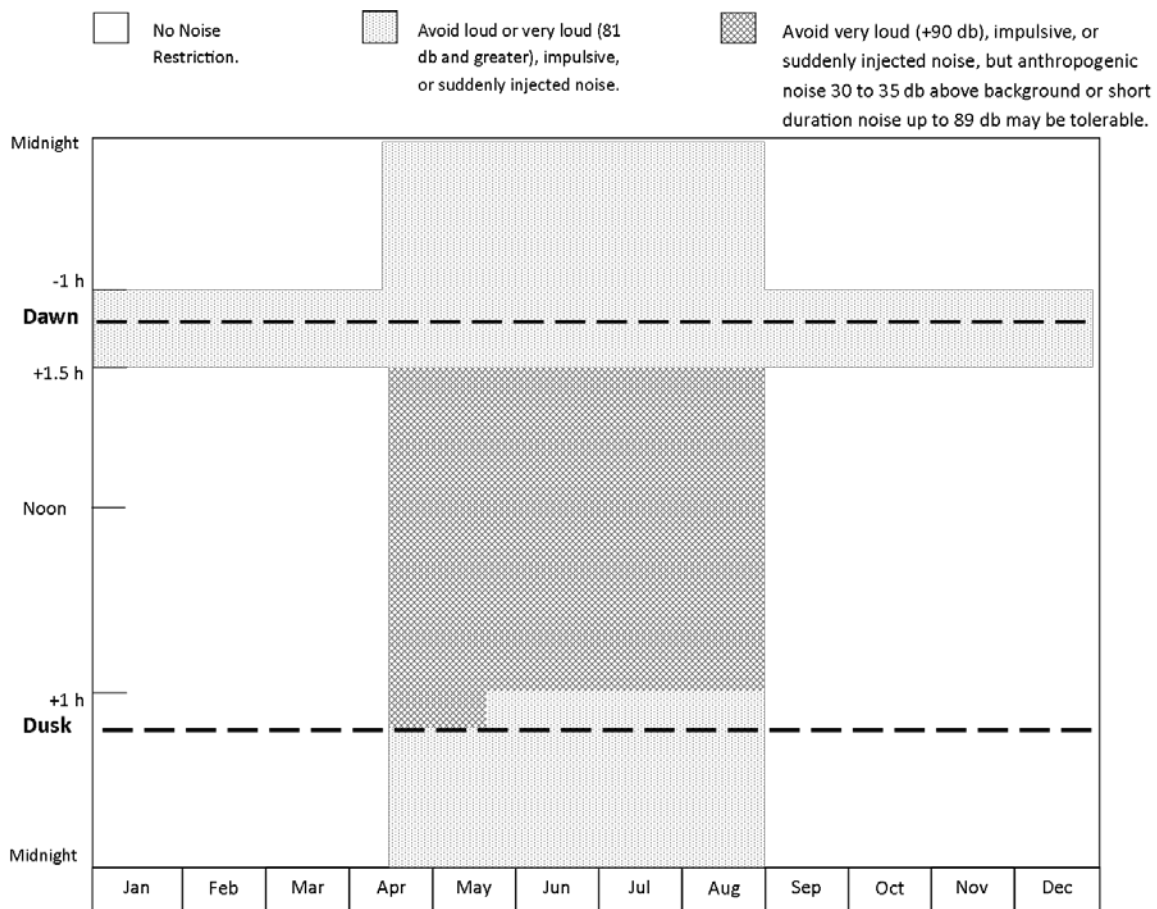


Figure 5-2. Schematic diagram of temporal variation in timing potential anthropogenic noise avoidance for marbled murrelets in the Santa Cruz Mountains if all potential alterations of noise restrictions considered here were adopted. Times are relative to dawn and dusk and are for schematic purposes only (they do not reflect the changing clock-time of dawn and dusk through the year). Noise values are measured at the site of the nest tree or potential nesting stand, and not at the source; both terrain and vegetation can increase noise attenuation between the source and the location of measurement. Very loud noise here is consistent with the “very high” category in the USFWS Guidance (USFWS 2006) and loud noise is consistent with the “high” category in that document.

and the earliest nest initiation was 17 April and average nest initiation was May 17 and 12 June in two years of study (data from Peery et al. 2004). Additionally, in northern California, Sanzenbacher et al. (2014) used radar to detect inward flying murrelets year-round and reported a substantial increase in flights (presumably a response to the initiation of nesting activity) in late April. These findings were thus consistent with both of the previously described telemetry studies in northern California and the Santa Cruz Mountains.

Thus, the existing radar and telemetry studies in California would suggest that a more appropriate start to nesting-season noise restrictions would be later than March 24. Thus, to avoid noise impacts to nesting, an appropriate start to noise restrictions might begin between April 1 and 15, rather than March 24 (see Figure 5-2 page 134). However, this conclusion is in conflict with the observations of grounded murrelets from earlier as well as the observations of murrelet activity in the 1990's. There are several potential explanation of these discrepancies and could include changes in ocean, climate or latitudinal considerations (still the telemetry studies in the Santa Cruz Mountains were consistent with the telemetry and radar studies in northern California). Regardless of explanation, additional radar studies in the Santa Cruz Mountains similar to the work of Sanzenbacher et al. (2014) would be useful to confirm the appropriateness of altering the date to begin nesting season noise restrictions in the Santa Cruz Mountains.

The end of the nesting period in California has also been defined by the recovery of a few downed chicks or fledglings. Here most estimates of the fledging dates were derived

by forward calculating to a date for fledging, unless the grounded bird actually had fledgling feathers. Of the 31 grounded chicks and fledglings reported between 1974 and 2013, only 3 were reported to represent the potential to fledge after 1 September. Using radio telemetry, Peery et al. (2004) reported the last fledging dates were 5 and 18 August in two years of study; similarly, Hebert and Golightly (2006) found that the latest actual (not forward counted and failed nests) fledging was August 17. Radar studies in northern California (Sanzenbacher et al. 2014) showed a precipitous decline in inward flying murrelets in late August and very low levels of inward flights in early September (levels that were lower than, or consistent with, the inward flights during the non-nesting period). It is also important to recognize that late fledglings are probably the product of replacement eggs (they hatched from an egg that was laid after an earlier nesting attempt failed; Hebert et al. 2003). In many other Alcids, the success of replacement eggs is poor (e.g. common murre, Golightly and Schneider 2016). Data from Hebert et al. (2003) indicated that survival to fledging was low for re-nesting attempts by marbled murrelets (overall 89% of re-nest attempts failed and 92% of re-nest attempts failed in the best reproductive year). Most of these nests failed in the incubation stage. The likelihood of failure in replacement eggs illustrates the problem of extrapolation of a fledge date for determination of the outer extent of the nesting period. Thus for purposes of avoiding noise impacts to nesting, September 1 could be appropriate as the end of the nesting period in California (refer back to Figure 5-2 page 134). Note that this should not be used for disturbance factors

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

other than noise unless an appropriate analysis indicated a similar conclusion.

Daily Variation in Noise Vulnerability

Noise has serious potential to negatively impact murrelet behavior and reproduction when murrelets fly inland to visit nests, make exchanges with their mate during incubation, or feed chicks at nests. During the nesting season, the period from approximately 1 hour before sunrise until 1.5 hours after sunrise should be considered a particularly vulnerable time and moderately loud and/or high-intensity impulsive noise production from anthropogenic sources should be restricted (Figure 5-1 page 133). Additionally, in California murrelets may fly inland in the late afternoon (1 hour before sunset; see Hébert and Golightly 2006). The late afternoon/evening flights are associated with feeding chicks at the nest (empirically-observed evening flights were not detected prior to May 22, but can continue until the end of nesting) and there is a similar need to avoid loud or impulsive noise. During all daylight hours during the nesting season, noises that could cause flushing should be avoided (especially very loud, sudden, or impulsive noises). The potential effect of noise that occurs after sunset has not been examined, but background noise generally is reduced at night. In general, anthropogenic noise restrictions after dark should probably follow the other restrictions, but do so with the knowledge that the differential between background and the source will be greater at night. A greater differential in noise level above background could increase the chance of a startle response, flushing, or causing physiological changes in the murrelets (this was the basis for the USFWS 2006 guidance

that noise maximums should be reduced at night and for up to 2 hours after sunrise).

Besides very loud or impulsive noises, the difference between the background level and the noise generated by a project is another consideration for the potential to cause harm. For noise generated from a project during daylight hours, Hébert and Golightly (2006) found that noise about 30-35 dB above background did not produce flushing. Consequently, short periods of noise (eg.: such as using a chainsaw or power blower) that is less than 30-35 dB above background (measured from the nest or potential nest tree) would probably have minimal impact and thus be tolerable during most daylight hours (outside the 1.5 hours after sunrise and the hour before sunset). Likewise, noise that is consistent in amplitude, duration, and frequency with the existing sources of noise at the site, even if somewhat louder than usual background, would be unlikely to be a problem. Conversely, noise that is suddenly injected into the environment may be more likely to cause a response that may be deleterious.

Noise Outside the Nesting Period

Murrelets also visit, though at much reduced levels, their nesting areas in terrestrial habitat outside the nesting season (Naslund 1993b, Sanzenbacher et al. 2014). Because sound regimes influence the quality of the habitat, noise generated outside the nesting season may have potential to influence murrelets in unknown ways. Because birds visiting nesting areas are generally in flight, flushing in a traditional sense is unlikely. Still, very loud or sudden impulsive noise could have the potential to change behavior (such as assessment of nest sites, communication of conspecifics, or changes in flight paths; there is little objective study

of this topic). Thus the most conservative approach for projects generating very high noise or impulsive noise would be to avoid producing that noise in the early morning (1 hour prior to and 1.5 hours after sunrise), even outside the nesting season. Avoidance up to 1.5 hours after sunrise would include most the period that murrelets fly inland to nesting areas. Hébert and Golightly (2006) found that most flights initiated before sunrise and up to a few minutes after sunrise. Consistently, the PSG survey protocol (Evans Mack et al. 2003) only attempts to detect murrelets for the first 75 minutes after sunrise. Thus another potential alteration of the present noise restrictions would be to avoid any loud or sudden impulsive noise up to 1.5 hours after sunrise both during and outside of the nesting season. One possible exception could be during September when murrelets molt their feathers while at sea and are flightless (Peery et al. 2008) and would not be able to fly to inland locations.

It is reasonable to consider the adjustments to the timing of noise restrictions to match the timing of greatest risk. Research conducted since the original establishment of recommendations for noise restrictions suggests that there is need to reconsider the exact dates and timing of imposing restrictions, as well as the level of acceptable noise during those periods of noise restriction. Improved match of risk could allow projects or other activities to occur later in the spring or earlier in the fall, as well as provide additional protections that do not presently exist. This potential to adjust the timing of restrictions requires additional information on the current timing of inward flying murrelets, possibly using radar techniques, and subsequent discussion

between researchers, land managers, and the regulatory agencies.

INDIRECT EFFECTS OF NOISE

Noise can indirectly affect marbled murrelets and should be considered in the assessment of ongoing or new noise-generating projects. Situations where noise attracts corvids can significantly increase the risk of predation or nest failure. This is more about the character of the noise being recognizable to the corvids as a source of food than it is about the noise level itself. Efforts should be made to discourage the association of noise with food by corvids; this is most effectively done by eliminating any food reward to corvids that can be associated by sound. This in general requires strong measures for food management (in campgrounds, lunch areas at project sites). All project activity should require garbage control, strict prohibition against feeding, and management incentives that ensure strict compliance.

MANAGEMENT INFORMATION NEEDS

Adjustments to the restrictions on noise requires accurate identification of the timing of nesting and flights by murrelets. Where existing evidence is ambiguous or different approaches provide conflicting direction, the adjustment of the timing of noise restrictions will need to be informed by new and current information on the timing of inward flights by murrelets. This might be best accomplished by conducting radar-based investigations modeled after Sanzenbacher et al. (2014) that can detect the increase in flight activity associated with nesting and the decrease associated with the end of nesting. It is important to note that the design used by Sanzenbacher et al. (2014) is different than radar used during the nesting

Chapter 5 Evaluation of Noise Impacts on Murrelets in Zone 6

season to identify potential nesting habitat or flyways. Depending on the opportunities for continued monitoring of inward flights, data might be produced that could inform managers of much more accurate annual assessments of the timing of the nesting season and allow real-time adjustments of noise or other protections.

Noise maps overlaid on potential murrelet nesting habitat (similar to Golightly et al. 2009) may help forest managers anticipate minimizations or mitigations that may be necessary for a particular site, land use, or project. These could be developed empirically or simply extrapolated from the work of others (e.g. Singer and Houston 2006, USFWS 2006, Golightly et al. 2009, Singer and Houston 2012) and described on maps using Geographical Information Systems. It would be important to recognize that sound amplitude by itself does not represent all aspects of noise. However, this could serve to improve the understanding of cumulative effects of noise or pre-existing noise on potential nesting habitat. When it becomes possible to understand the effects of frequency or other parameters due to technology improvements, these parameters could be added to the spatial detail.

It is also important that whenever a nest has been identified, or a group of trees found with a downed chick or fledgling, that efforts be made to accumulate location information and both short and long term noise descriptions noted about the sites during the nesting period. If a nest is active, it is useful to determine the nest fate. If a nest tree or stand is located by finding a downed chick, background on the site and noise attributes should be described and recorded; by doing so the association and timing of noise in areas used by murrelets.

In summary, very loud or high-intensity impulsive noise should be avoided up to 1.5 hours after sunrise throughout the year and at all hours during the nesting period (Figure 5-2). Other noise produced during the nesting period should be evaluated on a case-by-case basis considering vegetation and topography at a site, existing noise levels, distance to potential nest trees, the character and loudness of the noise, and the potential to dampen or minimize the noise. Sounds associated with activities that attract corvids are difficult to avoid, but food and garbage should be strictly controlled in all cases.

MANAGEMENT PLAN RECOMMENDATIONS

Recommendations to Mitigate Noise Impacts

1. The USFWS should implement noise disturbance studies to determine the true impact of noise on marbled murrelets. Studies should consider the effects of differing frequencies of sound (including infrasound), types of sound (such as chainsaws, heavy equipment, and electronic amplification) and the timing and duration of sound.
2. Given the uncertainty in our knowledge of how murrelets perceive sound, regulatory agencies may wish to consider revising the seasonal period in which > 90 dB noises are prohibited by shortening it to April 15 to Sept. 1.

3. Because noise varies considerably through space, noise and associated impacts should continue to be assessed on a case-by-case basis. Until any changes to the current regulations are established, potential noisy activities will be assessed using the guidelines in the 2006 USFWS Memo.
4. Efforts should be made to ensure that corvids are not inadvertently trained to associate specific noises with food rewards.
5. Damage thresholds for chronic noise, changes in background noise, or changes in frequency are unclear. However, at all times during the nesting season and year-round from 1 hour before sunrise to 1.5 hours after sunrise additional noise restrictions should be in place that address any chronic noise production or new noise that is 30-35 dB above background. These noises should be carefully evaluated, and to the extent possible minimized.
6. Loud impulsive noise that quickly reaches maximum amplitude (e.g. gun shots, explosions, felling of large trees) should be completely avoided at any time from April 15 to Sept 1, and year-round for 1 hour before to 1.5 hours after sunrise.

CHAPTER 6 BEST MANAGEMENT PRACTICES FOR REDUCING PREDATION ON MURRELET NESTS

Portia Halbert Senior Environmental Scientist, Santa Cruz District of California State Parks

This chapter presents the Best Management Practices (BMPs) being implemented by California State Parks to reduce corvid depredation of marbled murrelet nests in state parks in the Santa Cruz Mountains. A BMP, as used here, is a practice that is determined to be the most effective and practical means of controlling the predation of murrelet nests by corvids.

Sixty-four percent of the remaining old-growth forest habitat used by the marbled murrelet in the Santa Cruz Mountains is found in state parks (Table 2-9, Chapter 2—this Plan). But it wasn't until 30 years after the first marbled murrelet nest was found in Big Basin State Park (see Appendix A—Historic Occurrences of Murrelets in the Santa Cruz Mountains- this Plan) that park managers began to consider the impacts of park management and visitor use on nesting murrelets. This was because the murrelet is an elusive species, difficult to study, and both the vulnerability of the population and threats to the population were poorly known. The instigation of research and monitoring efforts in the 1990's revealed that too few young birds were being recruited in to the population to compensate for adult mortality (Chapter 7—this Plan). During the same period of time, the discovery and observation of a number of active murrelet nests revealed that nest predation by corvids was a major problem (Chapter 3—this Plan).

Managing for murrelets changed in 2004 when the Santa Cruz District of California State Parks received funding from several oil-spill restoration funds (Command 2004, Luckenbach 2006, and Cosco Busan 2012) to begin focusing on the problem of nest predation by murrelets.

State Parks took the lead in developing these BMPs because their lands contained most of the murrelet nesting habitat. Recommendations from these oil-spill restoration plans for managing murrelets in the forest environment focus on reducing nest predation by common ravens and Steller's jays which are the two species of corvids known to be effective murrelet nest predators. From Chapter 3 we note the increased numbers of these predators in areas around development due to the availability of human foods. In parks, most of the facilities are located within old-growth, as that is what most park visitors come to see. To reduce nest predation we must reduce the availability of food to predators and subsequently their overall numbers.

Food subsidy reduction must begin with preventing overflowing and open trash receptacles. These must be replaced by ones that are animal proof and well maintained by staff.

Campers need secure places to store their food while camping. They also need a place to wash their dishes instead of the water spigot where crumbs can accumulate on the gravel pad below and provide a food source for corvids. Campers and picnickers also need to know what to do with food scraps left on their plate (Figure 6-2. Camp Dishes 101 sign developed for novice camper education).

Reducing all food subsidies in areas with new visitors daily is a challenge and must include a multi-pronged approach to reduce passive and active food subsidies to wildlife. This includes discouraging visitors from feeding wildlife, (intentionally or unintentionally) by effective interpretive messaging, and enough enforcement

to insure compliance with the rules. Of these approaches, improving the interpretive message to guide visitor behavior proved most difficult. To explain this multi-layered impact to murrelets was a challenge. For example, “Don’t feed the birds because they will increase in number and when they aren’t eating your food they will likely find and eat the eggs and babies of the endangered marbled murrelet (which is a seabird by the way and you are miles from the ocean) and you’ll never see or hear it while you are here”. The message is cumbersome and is hard for many visitors to understand easily.

In 2011 Ward (2011) reported results from a study on communication strategies which included suggestions on how to better educate visitors on the impact of food on wildlife. As a result of this report, murrelet related signage was

revamped as the “Crumb Clean Campaign” using the guidelines listed below (Figure 6-1).

1. Provide the primary target message at the top of the sign- using largest print and located first.
2. Locate materials closer to trailheads, parking lots and in closer proximity to the visitor’s opportunity to read and/or take them.
3. Use short, simple, specific messages. Don’t spend so much time describing and explaining the importance of the murrelet. Get to the target behavior quickly.
4. Provide a very specific behavioral request. Define the behavior desired; Is it “crumb clean” or “do not feed the corvids” that is the primary targeted behavior?



Figure 6-1. Keep it Crumb Clean signage



Figure 6-2. Camp Dishes 101 sign developed for novice camper education

5. Provide graphics that define and describe the subject of the target behavior: corvids getting access to visitors' food. Graphics of the murrelet are less important.
6. Include both pre-conventional (monetary fine-fear of punishment appeals) and post-conventional (future generations-ethical appeals) sanction messages.”

RECOMMENDED BEST MANAGEMENT PRACTICES

Many of these management actions have already been implemented to one degree or another. Only one, in italics, is a proposal new to this plan.

Reduce/Eliminate Food and Trash Subsidies

- All trash receptacles should be animal proof
- Trash receptacles should not be allowed to overflow (emptied regularly)
- Garbage trucks will housed where animals cannot gain access
- Animal proof food storage lockers will be installed in all campsites
- Dishwashing stations will be installed in all campgrounds (in progress)
- Water spigots will have grates installed which allow food to fall out of reach of predators
- Water spigots will have a no dishwashing sign on them
- The Camp-dishes 101 sign will be placed throughout the campground

Interpretive Messaging

- Begins during campsite check-in, campers will sign the Crumb Clean Commitment
- All food lockers will have the Keep it Crumb Clean sign on them
- All trail heads will have the Keep it Crumb Clean at their entrance
- All Kiosks will have the Keep it Crumb Clean sign on them
- The Crumb Clean Campaign will be used at all park facilities
- All campers will watch the marbled murrelet video prior to securing a reservation
- Each picnic table will have the Keep it Crumb Clean sign
- The murrelet will be a feature during every campfire talk
- The murrelet will be mentioned during all junior ranger programs, interpretive walks/talks and interactions
- Murrelet materials like stickers and magnets will be given out to help raise awareness and support for the murrelet.

Enforcement

- Campgrounds will be patrolled by park rangers first thing in the morning for enforcement
- Campgrounds will be patrolled by interpretive rangers in the evening cooking hour for interpretive education

Active Corvid Removal

2. Ravens and crows may be removed to reduce predation pressure (but see Chapter 3-this Plan, raven subchapter)

Conditioned Taste Aversion

3. Use aversive conditioning with mimic eggs for Steller's jays to reduce egg predation

Forest Management

4. Prescribed fires will be planned and conducted as possible
5. Second growth forest management will be part of managing forests for murrelets

Noise Management

6. Adhere to existing USFWS standards for noise reduction during the breeding season while studies to refine the standard are conducted.

Outside of Parks

7. Work with surrounding community to implement actions to reduce availability of food subsidies

This innovative BMP was implemented in Santa Cruz Mountains old-growth state parks and warrants additional discussion here.

CONDITIONED TASTE AVERSION

The following is modified from Gabriel et al. (2016). Aversive conditioning techniques for Steller's jays that exposed the jays to murrelet-colored and sized eggs treated with carbachol (carbamylcholine chloride) effectively induced subsequent aversion to the murrelet-mimic eggs in laboratory and field tests (Gabriel and Golightly 2014). In 2012, the aversive conditioning technique was introduced in the Santa Cruz mountains; carbachol-laced murrelet-mimic eggs were deployed at densities of 0.5 – 2 eggs / ha, and the technique reduced corvid predation on murrelet-mimic eggs by 44% to 80% (Gabriel et al. 2013). The treatment was successfully repeated in spring 2013, when aversive conditioning was again applied in Butano State Park and Portola Redwoods State Park, and for the first time in campgrounds at Memorial County Park (Gabriel et al. 2014).

Consistently low predation rates on murrelet-mimic eggs deployed outside of campgrounds in 2013 suggested that jays that were treated in 2012 and were still resident in the treatment areas in 2013 continued to avoid mimic eggs in 2013. Gabriel et al. (2014) concluded that the length of retention of the aversive conditioning lasted at least one year. In 2014, murrelet-mimic eggs were deployed in some previously treated areas and also in some new areas in Butano State Park, Portola Redwoods State Park, Memorial County Park, Pescadero Creek County Park, and Sam McDonald County Park. The success of the 2014 treatment was difficult to assess due to the variable treatment histories of deployment areas, discontinuity of treatment areas, and likely also the effects of the severe drought conditions in 2014 (Gabriel et al. 2015).

In 2015, treatment was again applied in some previously treated areas and also in some new areas in Memorial County Park, Pescadero Creek County Park, and Sam McDonald County Park, and for the first time in Big Basin State Park. Overall low initial predation rates in 2015 suggested that the overall goal of successful and sustainable aversive conditioning of the Steller's jay populations in the Santa Cruz

mountains is sustained by the continuing treatments; a strong increase in predation rates in Big Basin State Park during the second treatment meanwhile indicated that a different treatment density and timing may be necessary to maximize treatment of the large influx of jays into the extremely large campgrounds of Big Basin State Park later in the season.

To ensure the likelihood of improved reproductive success for murrelets in central California, aversive conditioning of Steller's jays was again applied as a management technique with some improvements in Big Basin State Park, Memorial County Park, Pescadero Creek County Park, and Sam McDonald County Park in spring 2016.

In 2016, initial predation rates on mimic eggs (28-55%, depending on treatment area, with an overall estimated 39.5% rate) continued the general pattern of lesser initial predation rates compared to the first treatment year of 2012 (51% overall estimated initial predation rate). This observation may confirm the continuation of a downward tendency in initial predation over time that we also observed in previous treatment years (Gabriel et al. 2014; Gabriel et al. 2015; Gabriel et al. 2016), suggesting persistence of the conditioned aversion across years.

Another indication for the retention of acquired aversions by the resident corvid populations may be that in most treatment areas, specifically those with already low initial predation rates, we did not detect significant changes in predation rates between first and second treatments; thus, we may expect to observe consistently small predation rates in areas in which fairly pervasive treatment has been achieved, and only small numbers of untreated individuals may be expected to visit or immigrate into the treatment area between years and between treatments within years.

In addition, and as noted previously (Gabriel et al. 2016), the vast majority of predation was attributable to eggs classified as possibly corvid predated, not to eggs classified as corvid predated. These findings may on one hand support the speculation that at least some, maybe much of the egg predation was attributable to predation by non-corvids, and that the conditioned aversion is indeed increasingly spreading through the jay population in the central California parks region. On the other hand, we acknowledge that this apparent success in reducing corvid predation also greatly reduces the power of detecting changes in corvid predation in our comparative analyses.

CHAPTER 7 MURRELET AT SEA ABUNDANCE, PRODUCTIVITY, AND PREY RESOURCES IN ZONE 6

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INTRODUCTION

Marbled murrelets are seabirds, and like other true seabirds, they spend much of their lives at sea and rely solely on the ocean for their food. During the breeding season murrelets forage in nearshore waters adjacent to terrestrial nest sites to provision themselves and their chicks (Piatt and Ford 1993, Raphael et al. 2015, Lorenz et al. 2016, Becker and Beissinger 2003). During this time regional population estimates can be made using vessel-based surveys and line transect methodology (Becker and Beissinger 1997). This method is not a direct measure of regional population numbers and often subject to high variance. Density estimates from sea surveys may be influenced by multiple sources of error including: variation in murrelet density in and out of the survey area (Ralph and Miller 1995, Strong 1995, Strong et al. 1995), variation in viewing conditions (Buckland et al. 2001, Ralph and Miller 1995) and observer bias (Ryan and Cooper 1989). Furthermore, at sea surveys can have low power to detect small changes in annual decline (Becker et al. 1997, Peery et al. 2010). Despite these caveats, at sea surveys remain the best tool for estimating regional population abundance and detecting overall trends in abundance. Fledgling murrelets fly from inland nest sites to adjacent nearshore waters where they are distinguishable from adults for a few weeks until adults molt into basic plumage (Wong et al. 2008, Long et al. 2001). Observations of juvenile and adult

murrelets made during at sea surveys conducted in this time window and can be used to produce age ratio estimates. Resulting estimates often have high standard error related to small sample size and infrequent observations of juveniles at sea, however, they remain as our best measure of overall productivity in Zone 6 (Peery et al. 2007).

Like other seabirds, both “top-down” processes (predation of adults and nests), and “bottom-up” processes (variability in food supply) regulate murrelet population growth. Much research has been conducted regarding the effects of changes in food supply on seabird populations, primarily as ocean conditions (presumed to cause changes in food supply) affect the number of chicks fledged (Ainley et al. 1995, Schmidt et al. 2015), but also survival rates (Jones et al. 2002, Nur et al. 2007). However, less information is available regarding these effects specifically on marbled murrelets, in part because annual changes in reproductive success are difficult to measure in murrelets, and because less is known regarding changes in the nearshore forage fish populations upon which marbled murrelets rely.

In this chapter we summarize abundance and juvenile ratio estimates for marbled murrelets breeding in Zone 6 derived from at-sea surveys in adjacent near shore waters. We also includes a temporal analysis of relative murrelet abundance in the Northern, Central, and Southern portions of the Zone 6 survey area. Lastly, we review ocean

Chapter 7 Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6

conditions in Zone 6 and how they influence the availability of marbled murrelet prey resources.

METHODS

At-sea surveys

At-sea surveys for marbled murrelets in Zone 6 began in 1995 and covered the core area of Zone 6 nearshore waters from Pigeon Point south to Greyhound Rock (Becker et al. 1997). These original surveys were run at constant distances from shore (400-4400m) and provided data for calculation of juvenile ratio estimates (Peery et al. 2007). Resulting data were also used to refine line transect survey methodology for abundance estimation that is in use today (Becker et al. 1997). In 1999 Becker and Beissinger (2003) initiated zig-zag transects 200-2500m offshore from Half Moon Bay to Soquel Point. These transects covered the length of nearshore habitat adjacent to breeding populations and allowed for estimation of both juvenile ratio and murrelet density across the entire Zone 6 breeding area. Ongoing monitoring of murrelet juvenile ratio and abundance has continued via zig-zag surveys from 1999–2016 with a short hiatus from 2004–2006 (Peery and Henry 2010a, Henry et al. 2012, Henry and Tyler. 2016).

Estimating Abundance

Annual sea surveys (n ranging from 4 to 15 transects per year) for marbled murrelets between Half Moon Bay and Santa Cruz (1 June to 24 August) were performed from 1999-2016 with the exception of 2004-2006. Young of year and adults were identified during surveys following methods of Strong (1998). Surveys were approximately 100 km long and followed zig-zag transect routes consistent with surveys conducted from

1999 through 2003, and 2007 through 2011 (Peery et al. 2006a, Henkel and Peery 2008, Peery et al. 2009, Peery and Henry 2010a, Henry et al. 2012). Surveys began at a random distance (200-2500 m) from shore, immediately outside of the Half Moon Bay Harbor and continued SSE to Pleasure Point, Santa Cruz. Transects included both a “nearshore” (200-1350 m from shore) and “offshore” stratum (1350-2500 m from shore), with approximately four times greater effort surveying the nearshore stratum due to historically greater bird densities near shore.

Beginning in 2001, an equal number of routes were drawn using starting points at the north and south ends of the survey area. Survey routes drawn from the South tend to place more route waypoints in embayments where marbled murrelets aggregate and are easier to detect. South drawn surveys increase the percentage of habitat surveyed in leeward bays, which can hold increased concentrations of marbled murrelets and previous analyses show that transects drawn from the south yield higher densities than transects delineated from the north. Surveys were compiled separately (depending on direction drawn), in order to examine any bias, and to allow for comparability with 1999-2000 surveys.

Briefly, line transect methods following Becker et al. (1997) and Peery et al. (2006a) were used for all surveys. Two observers, standing on either side of a 6-m open skiff, recorded the angle off of the transect line and the distance to all groups of marbled murrelets. We analyzed sighting data using DISTANCE v.6.0 release 2 to derive abundance from density estimates which were scaled to the total area of the stratum (104.65 km² for both strata).

Estimating Juvenile Ratios

Juvenile ratios (the ratio of hatch-year to after-hatch-year individuals) were estimated for marbled murrelets based on surveys conducted from 10 July to 24 August. Prior to 10 July, few (34%) young are expected to fledge, and in late August, hatch-year and after-hatch-year murrelets become indistinguishable as the latter progress in their pre-basic molt (Peery et al. 2007). Analyses followed previous work (Peery et al. 2007, Henry and Tyler 2016). Briefly we included surveys performed on or before Aug 24, having confidence that we correctly identified hatch-year birds following techniques outlined by Long et al. (2001). Only birds of known age class were included in juvenile ratio calculations.

Juvenile ratios potentially suffer from a positive bias due to incubating after-hatch-year birds not being on the water during at-sea surveys. However, based on radio-telemetry, the proportion of after-hatch-years incubating between 10 and 17 July was <6%, and no incubation was observed after 17 July (Peery et al. 2004a, Peery et al. 2007). Nevertheless, to minimize potential biases due to the absence of incubating murrelets during at-sea surveys, we corrected the number of AHYs observed during surveys conducted from 10 to 17 July following Peery et al. (2007). The proportion of breeders for each year is unknown and we did not correct juvenile ratios for variation in the expected number of breeding birds.

Zonal Relative Abundance Estimates

We were interested to know if murrelet population numbers have shifted by latitude within Zone 6 over time, potentially in response to land management activities that influenced nesting success. We divided the

Zone 6 at sea survey area into three Zones: Northern (Half Moon Bay to Franklin Point); Central (Pigeon Point to approximately Greyhound Rock); and Southern (Greyhound Rock to Santa Cruz) (Figure 7-1 page 148). The Northern Zone is adjacent to terrestrial habitat with relatively low human population and related development. The Central Zone is situated in close proximity to prime murrelet nesting habitat with intensive human use (i.e., Big Basin Redwood State Park) and activities that subsidize murrelet nest predator populations (West et. al. 2016). The Southern Zone is dominated by rural and populated semi-urban habitat and contains the largest human footprint of the three Zones.

Zones were delineated to reflect nearshore waters adjacent to watershed units. For example the Cascade and Waddell watersheds bound the Central Zone. We performed a temporal analysis of relative murrelet abundance in these three zones. We used observations made during zig-zag surveys made between June 1 and August 23 that covered the entire length of the Zone 6 survey region which limited our temporal span from 1999–2016. We included all observations, attributing each sighting with one of the three zones. For each survey we calculated relative abundance of murrelets observed in each zone, (i.e. the proportion of the total birds observed during the survey observed in each zone). We then ran an

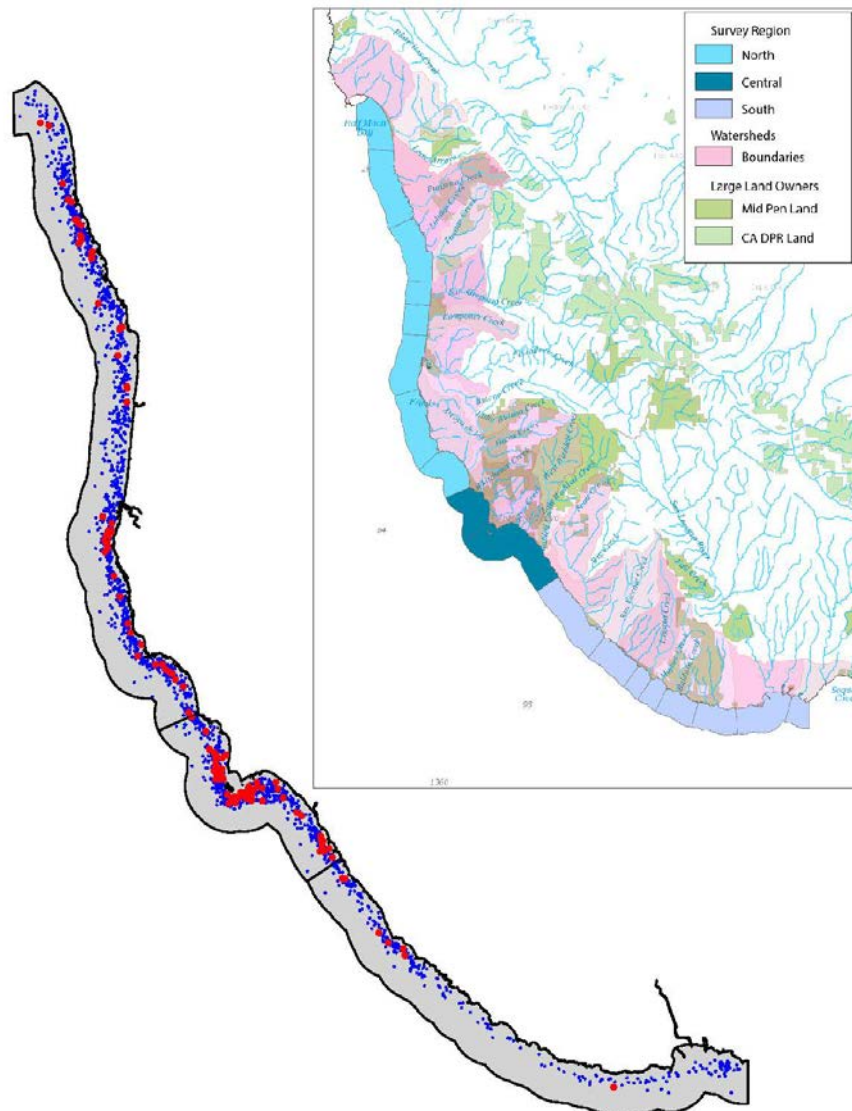


Figure 7-1. Inset map showing the North, Central, and South areas within the Region 6 at sea survey area. Locations of Marbled Murrelet adults (blue) and juveniles (red) detected during at sea surveys in central California during all zig-zag surveys from 1996-2016.

ordinary linear model with the proportion of birds as the response and year and zone as predictors. We also modeled the interaction between year and zone. We completed geographic and statistical analyses in R (version 3.2.2, 2015-08-14).

RESULTS

Abundance Estimates

We analyzed zig-zag surveys from Half Moon Bay to Santa Cruz during 1999-2016 which included 2,919 observations representing 5,123 murrelets, with 4,888 (95.4%) of birds observed within the 120m of the vessel track line. Murrelets were detected throughout waters between Half

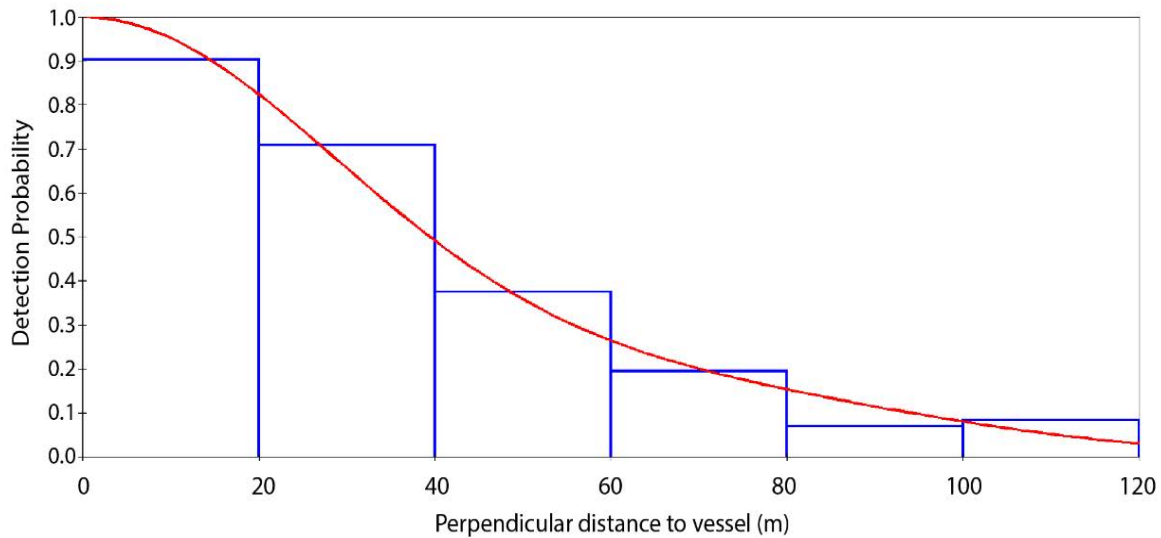


Figure 7-2. Example of detection probabilities for Marbled Murrelet surveys conducted in central California. Representative data are for during the 2015 breeding season ($\chi^2 = 2.02$, $df = 3$, $P = 0.57$).

Moon Bay and Santa Cruz during the breeding season of all years (Figure 7-1). Figure 7-2 page 149 shows a representative example of detection probabilities from the 2016 breeding season. As was the case for all years, the 2016 sighting data was not significantly different from those expected using the half-normal detection model with cosine adjustments ($\chi^2 = 2.97$, $df = 3$, $P = 0.40$). The detection probability approaches zero at 120m and we therefore excluded observations >120m from the transect line for all abundance estimates for all years.

Abundance estimates are shown in Table 7-1 page 150 and Figure 7-3 page 151. As noted by Peery and Henry (2010a) the 2007 and 2008 estimates are well below estimates made during 1999-2003. The trend for abundance estimates from 1999 to 2016 using transects drawn from the North, our longest running dataset, is negative and significant at the $p=0.1$ level ($F(1,13)=3.152$, $p=0.09924$, $R^2 = 0.1332$). The trend for results using estimates from 2001 to 2016 using transects drawn from both

directions is also negative but not significant. ($F(1,11)= 1.644$, $p=0.2262$, $R^2 = 0.13$).

We also compared abundance estimates before and after land managers implemented measures to control corvid predation in prime murrelet nesting habitat. Since we were interested if the population has recovered to early 2000 estimates, we omitted data from the lowest abundance estimates in 2007 and 2008. This allowed for a 3-year lag time for corvid predation pressure to respond to control measures first implemented in 2006. Corrected abundance estimates remain significantly higher before corvid control (1999-2003, $\bar{x}= 572.6$, $SD=74.5$) than after (2009-2016, $\bar{x}=409.75$, $SD=98.3$), ($t(10) = 3.39$, $p = 0.006$).

Comparison of the three recent highest estimates show estimates for 2009, 2013, & 2016 ($\bar{x}=481$, $SD=37.4$) were only marginally significantly lower than those of 1999-2003 ($\bar{x}= 572.6$, $SD=74.5$), ($t(6)=2.39$, $p = 0.062$).

Chapter 7 Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6

Juvenile Ratio Estimates

Annual estimates of hatch-year to after-hatch-year ratios (R) and standard errors (SE) for marbled murrelets are presented in Figure 7-2 page 149 and Figure 7-3 (A and B) page 151. Corrected juvenile ratios varied from lows ranging from 0-0.00626 between the mid 1990's and 2008 to a recent high of 0.108 in 2016. Juvenile ratios show an increasing trend across all years, 1996-2016 ($F(1,16)=10.25$, $p=0.006$, $R^2 = 0.3904$), prior to corvid control (1996-2003, $F(1,6)=13.75$, $p<0.001$, $R^2 = 0.6962$), and after implementation of corvid control in 2006 (2007-2016, $F(1,8)=5.895$, $p=0.041$, $R^2 = 0.4243$).

We compared abundance estimates before and after land managers implemented measures to control corvid predation in prime murrelet nesting habitat. We included a 3-year lag time for corvid predation pressure to respond to control measures because control measures were phased in starting in 2006. Corrected juvenile ratio estimates are significantly higher following corvid control (2009-2016, $x=0.070$, $SD=0.028$) than prior to corvid control (1996-2008, $x=0.035$, $SD=0.022$), ($t(13.2) = -2.90$, $p = 0.012$).

Table 7-1. Population estimates for marbled murrelets in central California between 1999 and 2016; no surveys were conducted from 2004 to 2006. Surveys conducted using transects delineated from the north and south are presented separately because surveys from the south typically yield greater population estimates

Year	Both Directions			North			South		
	<i>N</i>	95% CL	<i>n</i>	<i>N</i>	95% CL	<i>n</i>	<i>N</i>	95% CL	<i>n</i>
1999	N/A			487	333-713	5	no surveys		
2000	N/A			496	338-728	8	no surveys		
2001	661	556-786	15	637	441-920	8	733	583-922	7
2002	683	561-832	15	628	487-809	9	729	494-1075	6
2003	699	567-860	12	615	463-815	6	782	570-1074	6
2004	no surveys			no surveys			no surveys		
2005	no surveys			no surveys			no surveys		
2006	no surveys			no surveys			no surveys		
2007	378	238-518	4	269	109-429	2	488	349-626	2
2008	174	91-256	4	122	61-184	1	225	131-319	3
2009	631	449-885	8	495	232-1054	4	789	522-1193	4
2010	446	340-585	7	366	240-559	4	560	343-925	3
2011	433	339-553	6	320	225-454	2	452	331-618	4
2012	487	403-588	6	475	373-605	3	501	359-699	3
2013	628	386-1022	6	439	233-827	3	556	126-2456	3
2014	438	307-624	9	444	258-765	4	434	231-817	4
2015	243	152-386	9	225	136-370	4	296	159-549	5
2016	657	406-1063	7	510	358-726	3	720	297-1747	4

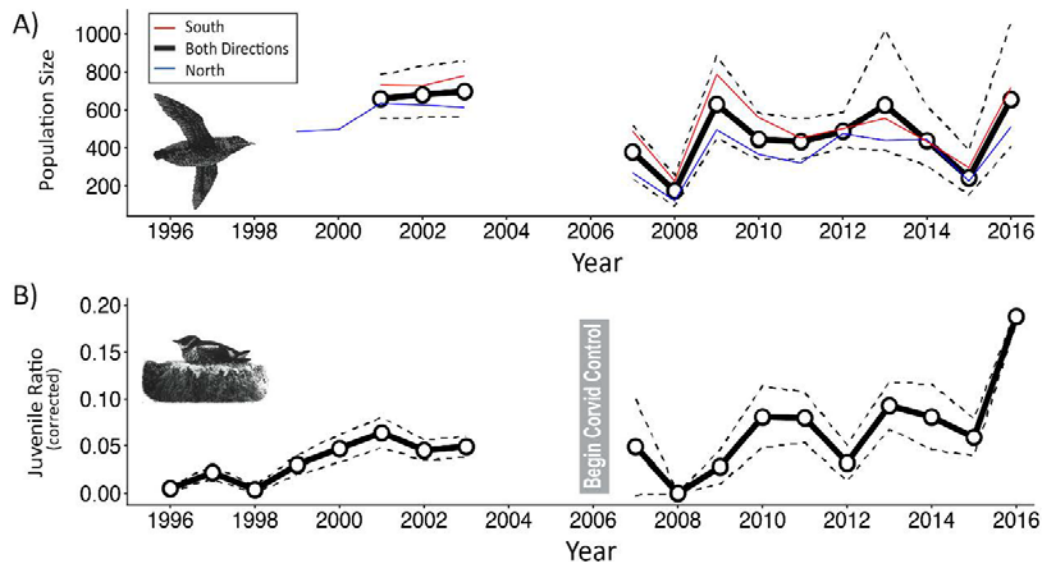


Figure 7-3. A) Abundance estimates for the central California population of marbled murrelets based on at sea surveys, 1999-2016 (dashed lines 95% confidence intervals for surveys drawn in Both directions). Data absent from years 2004-2006. Zig-zag surveys were not conducted prior to 1999 and from 2004-2006.

B) Abundance estimates for the central California population of marbled murrelets based on at sea surveys, 1999-2016 (dashed lines 95% confidence intervals for surveys drawn in Both directions). Data absent from years 2004-2006. Zig-zag surveys were not conducted prior to 1999 and from 2004-2006.

Zonal Relative Abundance Estimates

The relative abundance of murrelets were highest in the nearshore waters between just of north of Año Nuevo to north of Scott's Creek (Figure 7-1 page 148). This area is adjacent to prime old-growth breeding habitat in Big Basin. Murrelet density was consistently low in the Southern portion of the survey area where adjacent old growth habitat is sparse. The linear models for relative murrelet abundance in the North, Central, and South Zones are shown in Figure 7-4 page 152. A simple linear regression for each Zone shows a marginally significant increasing trend proportion of birds in the North over the survey years ($F(1,120)=3.629, p=0.059$), adjusted $R^2 = 0.021$), no trend in the Central ($F(1,120)=0.177, p=0.674$), adjusted $R^2 = -0.007$), and a significant decreasing trend in the South ($F(1,120)=4.538, p=0.035$), adjusted $R^2 = 0.028$).

Prey Resources

Marbled murrelets feed exclusively in nearshore ocean waters and their diet in the listed portion of their range is uncertain. Potential prey resources for marbled murrelets throughout the species' range are included in Burkett (1995), indicating that typical murrelet prey included smelts, sand lance, herring, juvenile rockfish, and crustaceans such as krill. Very little information is available on specific marbled murrelet prey in central California. Becker et al. (2007) found that stable isotopes from marbled murrelets captured in Zone 6 between 1998 and 2002 indicated that they likely fed substantially on krill during the time of their spring molt, prior to the breeding season. It should, however, be noted that feather isotope analysis can be confounded by multiple factors (Hobson and Clark 1992, Bond and Jones 2009). Henkel and Harvey (2006) conducted trawls for forage fish in Año Nuevo Bay, where murrelets are frequently observed during the

Chapter 7 Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6

breeding season, between 2000 and 2002, and found that potential prey included northern anchovy, night smelt, white croaker, speckled sanddab, market squid, and juvenile rockfish, among others.

Overall, it is likely that marbled murrelets prey on whatever small fish, krill, or copepods are most available, and that in Zone 6 during the breeding season, these likely typically include northern anchovies and juvenile rockfish.

To assess their dietary patterns, Rick Golightly and Zach Peery are using next-generation-sequencing techniques to characterize prey species present in the fecal material of marbled murrelets. In September

2016, they captured murrelets off the central California coast near Año Nuevo and obtained several fecal samples. Preliminary analyses for a small number of these samples detected northern anchovies (*Engraulis mordax*), Pacific sand lance (*Ammodytes hexapterus*), juvenile rockfish (*Sebastes* sp.), California lizardfish (*Synodus lucioceps*), and Pacific sardines (*Sardinops sagax caeruleus*). However, laboratory techniques have not yet been refined to determine the extent to which murrelets are consuming invertebrate prey and use of invertebrates is still being investigated. Additional fieldwork is planned for 2017 to increase sample sizes.

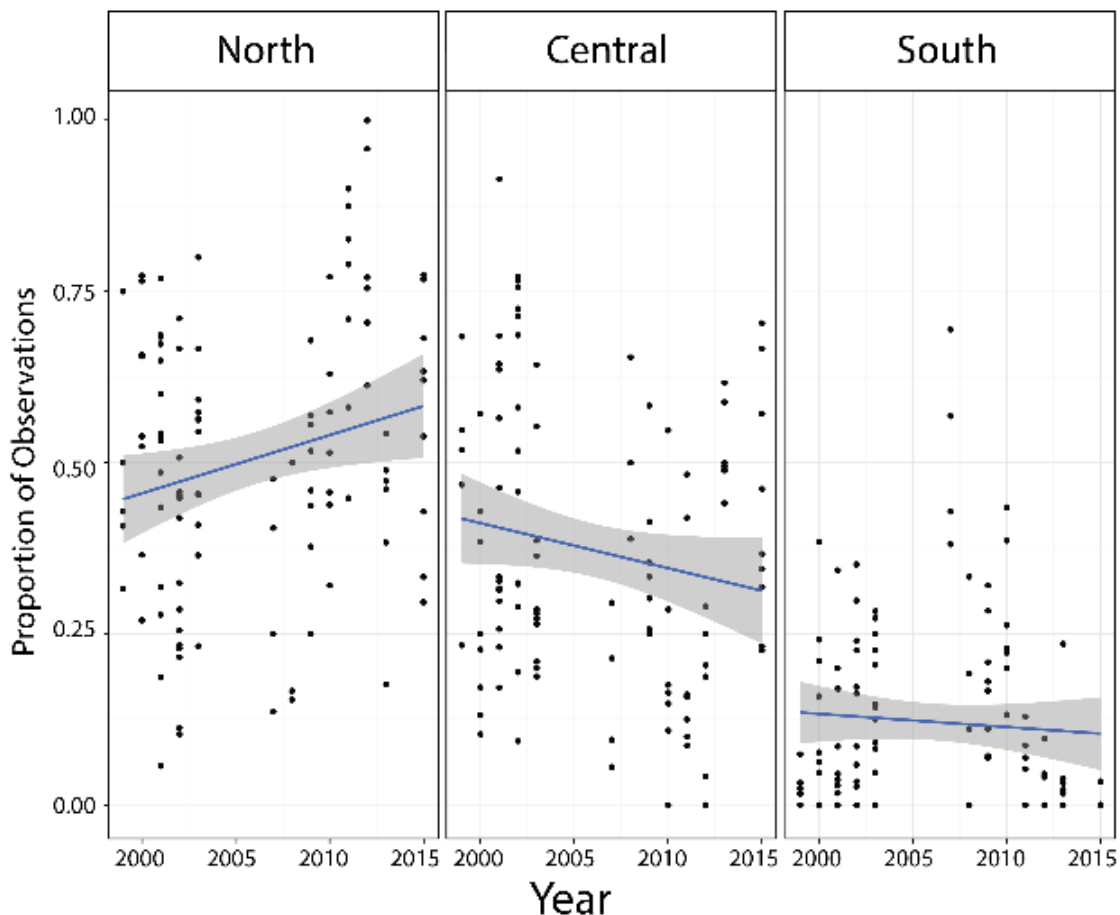


Figure 7-4. Trends for the relative abundance of all murrelets observed over time (1999-2016) in the North, Central, and South Zones of Region 6.

Factors Affecting Prey Availability

Major ocean climate indices that have been used to track ocean climate and that have been correlated with forage fish abundance include upwelling intensity and timing, the El Niño Southern Oscillation (ENSO) intensity, and the phase of the Pacific Decadal Oscillation (PDO), although various other indices may also be relevant (Ainley et al. 1993, Bakun 1996, Sydeman et al. 2014b). The relationships between ocean climate, prey species composition and availability, and seabird reproductive success and survival are complex and are the subject of considerable ongoing research.

Within Zone 6, diet of rhinoceros auklets has been studied at Año Nuevo Island for more than 20 years (Carle et al. 2016), providing perspective on variability in local seabird prey availability (Figure 7-1 page 148). Rhinoceros auklets feed farther offshore than marbled murrelets, thus this auklet diet information should not be interpreted as a proxy for local marbled murrelet diet. However, these data do provide one index of local prey availability and thus insights into how potential murrelet prey varies over time. That said, northern anchovy dominate diets in most years, and substantial proportions of juvenile rockfish in some years), and show how prey species composition (presumably a function of availability) can vary dramatically from year to year.

Becker et al. (2007) analyzed potential relationships between marbled murrelet productivity in Zone 6 (based on juvenile ratios from at-sea surveys), ocean conditions, prey availability based on National Marine Fisheries Service (NMFS) trawl data, and possible murrelet diet based on stable isotope analysis of feathers grown

before and after the breeding season between 1998 and 2002. They found that murrelet productivity was not related to any oceanographic index they assessed (including PDO and local upwelling), but that productivity was positively related to abundance of juvenile rockfish and krill on NMFS trawls off central California.

Additionally, isotopic values in post-breeding feathers were consistent with a dominance of rockfish (mid-trophic level prey) in murrelets' diets. Thus, abundance of juvenile rockfish may be beneficial for marbled murrelet productivity, as it is for various other seabird species (Sydeman et al. 2009, Carle et al. 2016)

While more recent studies regarding ocean conditions and murrelet productivity in Zone 6 have been conducted, an unusual event in 2009 provided some insights into the response of murrelets to changes in prey availability. Beginning in 2008, abundance of northern anchovy off central California declined precipitously, apparently due to natural causes rather than overfishing (Leising et al. 2015, McCall et al. 2015). In response to this sharp reduction in availability of a primary prey species, starvation-related die-offs occurred in early 2009 for brown pelicans, California sea lions, and Brandt's cormorants. Brandt's cormorants had complete breeding failure locally (CDFW, USFWS, and NOAA unpubl. data; Warzybok and Bradley 2009). Although anchovy abundance remained low in subsequent years, diet studies in other seabird species indicated that seabirds were able to shift to other prey species in 2010, and resume fairly normal breeding (Elliot et al. 2015, Beck et al. 2015). During this catastrophic year for other seabird species, A-V surveys for marbled murrelets had

Chapter 7 Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6

unprecedentedly low total detection numbers at all sites surveyed (Figure 2-4 page 16, chapter 2—this Plan). Concurrently, there was a sharp increase in the at-sea population (Figure 7-3 page 151). Thus, marbled murrelets likely had a much reduced breeding effort in Zone 6 during 2009, and primarily remained at sea rather than making inland flights. This information indicates that northern anchovy likely were an important prey species for murrelets locally, and like other birds and mammals, murrelets were unable to find sufficient alternate prey that year. Similarly, during the ENSO event of 1998, a year of low prey availability (Thayer and Sydeman 2007), radio-tagged birds failed to fly inland (CDFW, unpubl. data).

More recently, anomalously warm water throughout the northeast Pacific Ocean was present beginning in late 2014 and persisting through 2015 (Leising et al. 2015). This event (known as the “The Blob”) disrupted marine food webs and was apparently responsible for substantial die-offs of Cassin’s auklets during the winter of 2014/2015, and of common Murres the following winter (BeachCOMBERS and Beach Watch, unpubl. data). It is unknown what affect The Blob had on marbled murrelets in Zone 6.

It is not clear how future continuing climate change may affect prey resources for marbled murrelets in Zone 6. Climate change may lead to various deleterious conditions, including reduction of fish biomass related to lower oxygen levels, reduction of invertebrate prey due to ocean acidification, and changes in upwelling intensity (Sydeman et al. 2014a, Deutsch et al. 2015). Climate change may also lead to an increase in harmful algal blooms (e.g.,

domoic acid-producing algae; Gobble and Hoover in press). However, future conditions are very difficult to predict with any accuracy.

At-sea Distribution

Studies elsewhere have found that at-sea distribution of marbled murrelets during the breeding season is typically correlated with proximity to nesting habitat (Raphael et al. 2015, Lorenz et al. 2016). In Zone 6, Becker and Beissinger (2003) found that marbled murrelets were spatially associated with both primary nesting habitat and with cool, recently upwelled water which presumably supported a greater abundance of prey.

During periods of low prey availability, at-sea distribution may change, as evidenced by a southerly shift in murrelet distribution off Zone 6 during the 1998 ENSO event (CDFW unpubl. data, Becker and Beissinger 2003). Very little information is available on winter (non-breeding season) distribution of marbled murrelets, although some murrelets are known to disperse south from Zone 6 as far as San Luis Obispo County (Peery et al. 2008b). Critical Habitat in the marine portion of the marbled murrelet’s range has not been designated by the USFWS.

DISCUSSION

Abundance Estimates

The marbled murrelet population in central California appeared to experience a significant and rapid decline from 2003 to 2007. This decline continued in 2008 when abundance estimates reached a nadir of 174 individuals. Recent population estimates from 2009-2016 have increased. This increase follows corvid population/predation control measures that the California Department of Parks and Recreation (CDPR) began implementing in 2006.

CDPR corvid management actions may have contributed to recent increases in population estimates; however, the murrelet population still remains low.

Researchers have evaluated several hypotheses to explain recent dip and subsequent increases in population estimates. Low juvenile ratio data prior to increased population estimates indicate local production is not a primary driver for the recovery. Juvenile ratio data for 2004-2006 is lacking and these years would produce 3-5 year old breeding age recruits that could contribute to observed increased population estimates of 2009. However, in order to account for increased population estimates, juvenile ratios would have needed to more than 3-4 times the maximum values observed to date which is unlikely.

Peery et al. (2010) evaluated a '*rescue hypothesis*' where immigrants from northern populations contributed to recoveries. They found that significant dispersal from northern populations does occur into central California, but also that dispersing individuals, being migrants or immigrants that attempted to breed, are involved in few parent-offspring pairs and result in too little reproduction to rescue the population. They also found that while migrant ratios of 1.4% or more could mask a decline in residents without rescuing the breeding population, differences in genetic structure between pre- and post-recovery populations were less than between the pre- and post- populations and northern populations (2010). Vásquez-Carrillo et al. (2013) contrasted the '*rescue hypothesis*' with a '*distribution hypothesis*' where, during years of low population estimates, birds did not breed but remained outside the Zone 6 area. They present additional genetic analyses, which support

the assertion that birds in the post-recovery Zone 6 population are more similar to the pre-decline population than birds from northern populations. They concluded that the estimated percentage increase in abundance due to northern migrants in the post-recovery period was small (<9%) and much less than the observed 200% increase in population size, suggesting the rebound was a not result of immigration (Vásquez-Carrillo et al. 2013).

The '*distribution hypothesis*' is further supported by previous observations of long distance movements during the breeding season (Burkett unpublished data, Peery et al. 2008b, Henkel personal communication). Conclusive documentation of this phenomenon is prohibitive due the difficulties with assessing murrelet distribution over the large area that murrelets may move to during years of high dispersal (Henry and Tyler 2016).

Movement in and out of the survey area can influence abundance estimates and perceived population trends. It is important to acknowledge that this variability will likely continue and is a limitation of at-sea surveys which will pose ongoing challenges for estimating population size.

The large decline and subsequent increase in population numbers does not appear to be related to changes in methodology, as survey and data analysis techniques have remained consistent across years. However, sample size and at sea weather conditions can influence survey estimates (Becker & Beissinger 1997). Sea state could be incorporated into future DISTANCE

Chapter 7 Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6

Table 7-2. Annual estimates of hatch-year to after-hatch-year ratios (R) and standard errors (SE) for Marbled Murrelets from at-sea surveys conducted in the breeding season in central California, 1996-2003 and 2007-2016. Surveys used to estimate ratios were limited to 10 July to 23 August. Corrected estimates were corrected for the proportion of hatch-year murrelets that had not fledged and the proportion of after-hatch-year murrelets still incubating at the time the survey was conducted (see Peery et al. 2007). n_{inds} = the number of individuals observed and n_{surveys} = the number of surveys conducted

Year	<u>Uncorrected</u>		<u>Corrected</u>		n_{hy}	n_{inds}	n_{surveys}
	R	(SE)	R	(SE)			
1996	0.00626	(0.00255)	0.01033	(0.00337)	4	643	4
1997	0.010086	(0.00275)	0.02235	(0.00669)	7	701	5
1998	0.006881	(0.00321)	0.01304	(0.00579)	3	439	6
1999	0.016105	(0.00492)	0.03274	(0.01024)	11	694	10
2000	0.023916	(0.00813)	0.04917	(0.01585)	16	685	9
2001	0.033505	(0.00835)	0.06997	(0.0215)	13	401	8
2002	0.02551	(0.00377)	0.05083	(0.00936)	15	603	11
2003	0.024155	(0.00515)	0.04915	(0.0107)	10	424	8
2007	0.016667	(0.01792)	0.04877	(0.05182)	2	122	3
2008	0	NA	0	NA	0	60	4
2009	0.015152	(0.01075)	0.02837	(0.01758)	3	201	4
2010	0.036765	(0.01756)	0.08135	(0.03863)	5	141	3
2011	0.053191	(0.01545)	0.08001	(0.0172)	5	99	4
2012	0.020492	(0.01418)	0.03179	(0.01918)	5	249	5
2013	0.051282	(0.01808)	0.09291	(0.02491)	16	328	6
2014	0.048689	(0.02455)	0.08119	(0.03493)	13	280	6
2015	0.031496	(0.0109)	0.05885	(0.02046)	4	131	6
2016	0.060773	(0.03007)	0.1079	(0.05084)	11	192	5

analyses (Falxa et al. 2016). Observers varied within and between survey years and could be a possible source of error and invariably contribute to observed variation. Accounting for this error source in analyses requires that each observer conduct a large number of surveys, which was not the case. Future use of models that incorporate continuous habitat data such as depth and distance to shore (Gerrodette & Eguchi 2011) might improve our estimates.

Juvenile Ratio Estimates

Juvenile ratio estimates have remained low between 1996 and 2016 ($R^{\text{corrected}}_{\text{x}}=0.05048$, $\text{sd}=0.030513$, from Table 7-2). These observed ratios do not reflect productivity necessary to support stable murrelet populations, which is estimated to require juvenile ratios between 0.18 and 0.28 (Beissinger & Nur 1997 in Peery et al. 2004). However, in 2016 we observed a record corrected juvenile ratio of 0.1079 ($\text{SE}=0.05084$). While an improvement over

previous Zone 6 estimates, this single observation remains ~30-50% of the ratio thought to support stable population growth (λ). The 2016 survey effort and protocols were consistent with previous years.

The 2016 population and juvenile ratios estimates followed low estimates from the previous year when the 2015 El Niño event dominated ocean conditions in Zone 6. El Niño is associated with poor reproduction in seabirds in upwelling systems (Barber & Chavez 1983). However work by Hester et al. (2016) did not reflect catastrophic nest failure of seabirds nesting on Año Nuevo, in the center of the Zone 6 survey area. The observed record murrelet numbers and juvenile ratios following the El Niño may be in response to a return to more favorable ocean conditions and associated prey availability. The total number of breeding birds may also influence juvenile ratios, where birds nesting in high predation sites have disappeared from the population over time. As these birds with low reproductive output have died out, fewer breeders with high productivity may now dominate a population of reduced size. If true, this scenario may suggest that availability of nest sites with low predation and fragmentation regulate the population. Hopefully productivity will continue to increase over time, reaching a level necessary to sustain a positive growth rate.

Zonal Relative Abundance Estimates

The zonal relative abundance analyses suggest an increase in relative abundance in the Northern and decline in the Southern portions of the study area. Terrestrial attributes (nesting habitat) are the strongest contribution to at sea distribution of murrelet populations in Northern California, Oregon, and Washington (Raphael et al. 2015). The

influence of anthropogenic impacts (i.e., camping and rural housing footprint) is lowest in the Northern Zone and highest in the Southern Zone and may contribute to patterns of at-sea distribution. If ongoing enhancements of nesting habitat create safe nest sites we might see a shift in relative abundance back towards the Central Zone, which is adjacent to the largest tracts of intact old-growth habitat.

The changes in at-sea distribution could also reflect changes in prey availability over time. This could be driven by changes in ocean conditions and perhaps, by response to ocean management, such as heavy market squid fishing pressure in the South or spillover effects of enhanced rock fish recruitment from the Año Nuevo Marine Reserve.

A large component of the West Coast market squid (*Doryteuthis opalescens*) fleet operates within our survey zone and may influence prey for murrelets. This is the highest value fishery in California. The total market squid catch (in mt) in California was down in 2015/16 (2011/12 = 120,761.87mt; 2012/13 = 98,979.40mt; 2013/14 = 106,296.10mt; 2014/15 = 104,277.65mt; 2015/16 = 40,921.34mt, CDFW). Some have suggested that low catch across western North America increases fishing pressure on those places where squid have remained relatively abundant such as the Monterey Bay waters. Hence in 2015 and 2016 there were large numbers of purse seiners fishing in Zone 6 waters, including vessels from ports as distant as Alaska.

While market squid are not the ideal high caloric prey species for marbled murrelets (Becker et al. 2007), low squid numbers may indicate a perturbation in the system.

Chapter 7 Murrelet At Sea Abundance, Productivity, and Prey Resources In Zone 6

Interactions with the market squid fleet are not well studied. Bright lights may impact marbled murrelets, although Peery reported that murrelets do not appear to be highly active or respond to lights from fishing vessels at night (Peery per obs). There may be potential for displacement of murrelets during the day at heavily-fished market squid breeding sites where light boats and recreational fishermen aggregate to follow the squid school and to fish for squid predators respectively. Over the past 7-8 years the market squid population seems to have high fidelity to specific breeding sites, which are fished year to year (Henry pers obs). The removal of large amounts of squid biomass from the Zone 6 system likely affects other fish species, including rockfish. Juvenile rockfish are likely important dietary components of Zone 6 murrelets.

Recruitment of Young of Year (YOY) Rockfish (*Sebastes spp*) has high inter-annual variability. YOY Rockfish have high caloric value and regional seabird productivity appears to respond favorably to high YOY recruitment. During 2015 YOY Rockfish abundance was high at sea as reported by NOAA's Southwest Fisheries Science Center (SWFSC) however this may not translate to high local nearshore recruitment where murrelets feed. The Ramondi/Carr Lab at UCSC historically examined rockfish recruitment in Zone 6 however these efforts have been discontinued.

Data on patterns of recruitment and distribution of nearshore juvenile rockfish, market squid, and others including northern anchovy, Pacific sandlance, and Pacific sardine would help shed light on the connection between local prey availability and dynamics of the murrelet population

size and distribution. These data would also contribute to active investigations in murrelet diet using next generation DNA sequencing techniques.

Prey Resources and at sea conditions

Although there is evidence that fluctuations in prey availability can negatively impact marbled murrelets locally (e.g., as evidenced by lack of inland activity in 2009), we don't have much information on the relative importance of prey availability vs. "top-down" factors. In fact, like many other seabirds, marbled murrelets may have some flexibility in their time-budgets, providing a buffer against minor fluctuations in prey availability (Henkel et al. 2004). Additional work synthesizing existing data on at-sea population size, at-sea distribution, and reproductive success (based on at-sea juvenile ratios) in relation to available oceanographic indices and measures of prey availability, may help elucidate the importance of marine factors in limiting the marbled murrelet population in Zone 6.

Management of forage fish in the California Current System is currently a topic of interest among various conservation organizations (Ainley et al. 2014). Among potential prey species for marbled murrelets in central California, the most targeted commercial species are market squid, Pacific sardine (when available), and northern anchovy. Marine Protected Areas (MPAs) have been established at several locations within the at-sea range of murrelets in Zone 6, including the Año Nuevo State Marine Reserve.

Relatively little information is available regarding the benefits of MPAs to seabirds. However, protection of rockfish in MPAs may result in a greater

abundance of juvenile rockfish available as prey, whereas other more pelagic schooling fishes may be less affected.

CONCLUSION

Recent trends in abundance and juvenile ratio estimates show an iota of optimism for the future of the Zone 6 marbled murrelet population. While correlation does not signal causation, the initiation of corvid management by the California Department of Parks and Recreation is followed by positive trends in murrelet juvenile ratios.

More research and mitigation of corvid predation and other drivers of murrelet productivity will help accelerate the possibility of recovery of the Zone 6 marbled murrelet population. We recommend continuation of consistent at-sea surveys as the best method for estimating the Zone 6 marbled murrelet population until positive population growth and rising population numbers are consistently documented.

POTENTIAL AT-SEA THREATS

- Oil spills
- Bycatch in fisheries (relatively unlikely in central California)
- Harmful algae blooms
- Perturbations in food supply including large-scale climatic/oceanographic changes

MANAGEMENT PLAN RECOMMENDATIONS

Recommendations for Monitoring Population Size and Trend

1. Continue to conduct at-sea boat surveys of adult and hatching-year murrelets on an annual or biannual basis. Surveys should cover the entire area off-shore of the murrelet breeding range in the Santa Cruz Mountains.
2. Use 2 or more automatic continuous-recording radar tracking devices to determine murrelet numbers at the lower end of important murrelet flyways.
3. Synthesize the findings from at-sea surveys with flyway survey data.

Recommendations to Learn More About Murrelet Foraging Behavior and Their Prey Base

1. Perform DNA analysis of murrelet feces to determine their diet.
2. Investigate how at-sea and inland distributions compare, and how both change over time. Collect inland distribution data from observers, ARU sensors, or radar.

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REFERENCES

- Ackerman, J.T., J. Adams, J.Y. Takekawa, H.R. Carter, D.L. Whitworth, S.H. Newman, R.T. Golightly, and D.L. Orthmeyer. 2004. Effects of Radio transmitters on the Reproductive Performance of Cassin's Auklets. *Wildlife Society Bulletin* 32:1229-1241.
- Ainley, D., P. Adams, and J. Jahncke. 2014. Towards ecosystem-based fishery management in the California Current System—Predators and the preyscape: A workshop. Unpubl. Rept., Point Blue Conservation Science, Petaluma, CA.
- Ainley, D.G., W.J. Sydeman, and J. Norton. 1995. Upper-level predators indicate interannual negative and positive anomalies in the California Current food web. *Marine Ecology Progress Series* 118: 69-79.
- Ainley, D.G., W.J. Sydeman, R.H. Parrish, and W.H. Lenarz. 1993. Oceanic factors influencing distribution of young rockfish (*Sebastes*) in central California: a predator's perspective. *CalCOFI Reports* 34: 133-139.
- Alvo, R., and P. J. Blancher. 2001. Common raven, *Corvus corax* observed taking an egg from a common loon, *Gavia immer*, nest. *The Canadian Field Naturalist* **115**:169.
- Anderson, M. P., and H. O. Jenkins. 1903. A list of birds from the Santa Cruz Mts., California. *The Condor* 5:153-155.
- Anderson, V.L. 1972. The Murrelet's Secret. *Pacific Discovery* 25(3): 25-26.
- Andren, H. 1992. Corvid density and nest predation in relation to forest fragmentation - a landscape perspective. *Ecology* **73**:794-804.
- Anon. 1994. Predator control. The Game Conservancy, Hampshire, UK.
- Anon. 1999. Plover Distribution and Reproductive Success Along the Oregon Coast—1999. Unpublished report submitted to Oregon Dept. of Fish and Wildlife, Coos Bay BLM, Oregon Dunes National Recreation Area, TMM Company, LTD, and USFWS.
- Audubon Field Notes. 1970. Audubon Field Notes Discovery Award. *Audubon Field Notes* 24(5): 654.
- Austin, J. E., and C. D. Mitchell. 2010. Characteristics of common raven (*Corvus corax*) predation on sandhill crane (*Grus canadensis*) eggs. *Northwestern Naturalist* **91**:23-29.
- Avery, M. L., E. A. Tillman, and J. S. Humphrey. 2008a. Effigies for dispersing urban crow roosts. Pages 84-87 in *Proceedings of the 23rd Vertebrate Pest Conference*, U. C. Davis.
- Avery, M. L., C. A. Yoder, and E. A. Tilman. 2008b. Diazacon inhibits reproduction in invasive Monk Parakeet populations. *Journal of Wildlife Management* **72**:1449-1452.
- Avery, M. L., D. L. Bergman, D. G. Decker, R. D. Flynt, and C. E. Knittle. 1993. Evaluation of aversive conditioning for reducing raven predation on eggs of California Least Terns, Camp Pendleton, California-1992. U.S. Dept. Agric., Denver Wildl. Res. Center, Florida Field Stn., Gainesville.

References

- Avery, M. L., M. A. Pavelka, D. L. Bergman, D. G. Decker, C. E. Knittle, and G. M. Linz. 1995. Aversive conditioning to reduce raven predation on California least tern eggs. *Colonial Waterbirds* **18**:131-138.
- Baker, L. M., M. Z. Peery, E. E. Burkett, S. W. Singer, D. L. Suddjian, and S. R. Beissinger. 2006. Nesting Habitat Characteristics of the Marbled Murrelet in Central California Redwood Forests. *Journal of Wildlife Management* 70:939–946.
- Bakun, A. 1996. Patterns in the Ocean: Ocean Processes and Marine Population Dynamics. California Sea Grant College System, La Jolla, CA.
- Barbaree, B.A., S.K. Nelson, B.D. Dugger, D.D. Roby, H.R. Carter, D.L. Whitworth, and S.H. Newman. 2014. Nesting Ecology of Marbled Murrelets at a Remote Mainland Fjord in Southeast Alaska. *The Condor: Ornithological Applications* 116:173-184.
- Barber, J.R., K.R. Crooks, and K.M. Fristrup. 2010 The costs of chronic noise exposure for terrestrial organisms. *Trends in Ecology and Evolution* 25: 180-189.
- Barber, R. T., & Chavez, F. P. (1983). Biological Consequences of El Nino. *Science*, 222 (May), 1203–1210. <http://doi.org/10.1126/science.222.4629.1203>
- Beck, J., R. Carle, D. Calleri, and M. Hester. 2015. Año Nuevo State Park seabird conservation and habitat restoration: Report 2015. Unpubl. Rept., Oikonos Ecoystem Knowledge, Santa Cruz, CA.
- Becker, B.H., and S.R. Beissinger. 1997. At sea density monitoring of marbled murrelets in central California: methodological considerations. *Condor* 99 (3): 743-755.
- Becker, B. H., & Beissinger, S. R. (2003). Scale-dependent habitat selection by a nearshore seabird, the marbled murrelet, in a highly dynamic upwelling system. *Marine Ecology Progress Series*, 256, 243–255. <http://doi.org/10.3354/meps256243>
- Becker, B. H., Beissinger, S. R., & Carter, H. R. (1997). At-Sea Density Monitoring of Marbled Murrelets in Central California : Methodological Considerations Author (s): Benjamin H . Becker , Steven R. Beissinger and Harry R . Carter Published by : Cooper Ornithological Society Stable URL : <http://www.jstor.org>, 99 (3), 743–755.
- Becker, B. H., M. Z. Peery, and S. R. Beissinger. 2007. Ocean climate and prey availability affect the trophic level and reproductive success of the marbled murrelet, an endangered seabird. *Marine Ecology-Progress Series* **329**:267-279.
- Becking, R.W. 1991. Eggshell Fragments of the Marbled Murrelet (*Brachyramphus marmoratus*) in San Mateo County, California. *Northwestern Naturalist* 72:74-76.
- Beissinger, S. R., and N. Nur. 1997. Population trends of the marbled murrelet projected from demographic analysis. Pages B1-B35 in Re-covery plan for the marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. U.S. Fish and Wildlife Service, Portland, Oregon.
- Beissinger, S. R. and M. Z. Peery. 2007. Reconstructing the historic demography of an endangered seabird. *Ecology* **88**:296-305.
- Ben-David, M., and E. A. Flaherty. 2012. Stable isotopes in mammalian research: a beginner's guide. *Journal of Mammalogy* 93:312–328.

- Benson, K. J. 2008. Forest and beach corvid monitoring and management, Redwood Creek corvid and backcountry campsite mapping, trail and backcountry management plan implementation–2008 progress report., National Park Service, Redwood National and State Parks, Orick, CA.
- Bertram DF, 1995. The roles of introduced rats and commercial fishing in the decline of ancient murrelets on Langara Island, British Columbia. *Conservation Biology* 9(4): 865 - 872.
- Bigger, D., M.Z. Peery, J. Baldwin, S. Chinnici, and S.P. Courtney. 2006a. Power to Detect Trends of Marbled Murrelet Breeding Populations Using Audiovisual and Radar Surveys. *The Journal of Wildlife Management* 70(2):493-504.
- Bigger D, Peery MZ, Chinnici S, Courteney SP, 2006b. Efficacy of audiovisual and radar surveys for studying marbled murrelets in inland habitats. *The Journal of Wildlife Management* 70: 505 - 516.
- Binford, L.C., B.G. Elliott and S.W. Singer. 1975. Discovery of a Nest and the Downy Young of the Marbled Murrelet. *The Wilson Bulletin* 87(3): 303-319.
- Birkhead, R.R. 1977. Effect of Habitat and Density on Breeding Success in the Common Guillemot *Uria aalge*. *J. Animal Ecology* 46: 751-764.
- Blickley J.L., and G.L. Patricelli. 2010. Impacts of anthropogenic noise on wildlife: Research priorities for the development of standards and mitigation. *J. International Wildlife Law & Policy* 13: 274-292.
- Blickley, J.L., D. Blackwood, and G.L. Patricelli. 2012. Experimental evidence for the effects of chronic anthropogenic noise on abundance of greater sage-grouse at leks. *Conservation Biology* 26: 461-471.
- Boarman, W. I. 2003. Managing a subsidized predator population: Reducing common raven predation on desert tortoises. *Environmental Management* 32:205-217.
- Boarman, W. I., and B. Heinrich. 1999. Common Raven (*Corvus corax*). *The Birds of North America, Life Histories for the 21st Century*. Cornell lab of Ornithology, Ithaca, NY, U.S.A.
- Bodey, T. W., R. A. McDonald, and S. Bearhop. 2009. Mesopredators constrain a top predator: competitive release of ravens after culling crows. *Biology Letters* 5:617-620.
- Bond, A. L., & Jones, I. A. N. L. 2009. A practical introduction to stable-isotope analysis for seabird biologists: approaches, cautions and caveats. 188:183–188.
- Borker, A.L., P. Halbert, M.W. McKown, B.R. Tershy, and D.A. Croll. 2015. A Comparison of Automated and Traditional Monitoring Techniques for Marbled Murrelets Using Passive Acoustic Sensors. *Wildlife Society Bulletin* 39(4): 813-818.
- Boutin, S. 1990. Food supplementation experiments with terrestrial vertebrates: patterns, problems, and the future. *Canadian Journal of Zoology* 68:203–220.
- Bradley, J. E., and J. M. Marzluff. 2003. Rodents as nest predators: Influences in predatory behavior and consequences to nesting birds. *The Auk* 120:1180-1187.

References

- Bradley, J. E., J. M. Marzluff, M.G. Raphael, and D.E. Varland. 1999. On the Importance of Small Mammals As Nest Predators of Marbled Murrelets. Abstract, Proceedings of the 26th annual PSG meeting, Blaine, Washington. Pacific Seabirds 26 (1): 32.
- Brand, L. A., and T. L. George. 2001. Response of passerine birds to forest edge in coast redwood forest fragments. The Auk 118:678–686.
- Brown, J. L. 1963. Aggressiveness, Dominance and Social Organization in the Steller Jay. The Condor 65:460–484.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, UK.
- Bugnyar, T., and K. Kotrschal. 2002. Observational learning and the raiding of food caches in ravens, *Corvus corax*: is it 'tactical' deception? Animal Behaviour 64:185-195.
- Burger, A.E. and V. Bahn. 2004. Inland Habitat Associations of Marbled Murrelets on Southwest Vancouver Island, British Columbia. J. Field Ornithol. 75(1): 53-66.
- Burger, A. E., I. A. Manley, M.P. Silvergieter, D.B. Lank, K.M. Jordan, T.D. Bloxton, and M.G. Raphael. 2009. Re-use of Nest Sites by Marbled Murrelets (*Brachyramphus marmoratus*) in British Columbia. Northwestern Naturalist 90:217-226.
- Burger, A.E. and F. L. Waterhouse. 2009. Relationships between Habitat Area, Habitat Quality, and Populations of Nesting Marbled Murrelets. BC Journal of Ecosystems and Management 10(1): 101-112.
- Burkett, E. E. 1995. Marbled Murrelet food habits and prey ecology. Pp. 223-246 in Ralph, C.J., G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt (eds), Ecology and Conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152, US Forest Service, Albany, CA.
- Burkett, E. E., H. R. Carter, J.Y. Takekawa, S. Newman, R.T. Golightly, and J.L. Lanser. 1999. Marbled Murrelet Radio Telemetry in Central California in 1997 and 1998: A Reduced Breeding Effort Noted in an El Nino Year. Abstract, Proceedings of the 26th annual PSG meeting, Blaine, Washington. Pacific Seabirds 26 (1): 32.
- Butchko, P. H. 1990. Predator control for the protection of endangered species in California. in Proceedings of the 14th Vertebrate Pest Conference, U. C. Davis.
- Butchko, P. H., and M. A. Small. 1992. Developing a strategy of predator control for the protection of the California Least Tern: a case study. Pages 29-31.
- Bynum, K. S., C. A. Yoder, J. D. Eisemann, J. J. Johnston, and L. A. Miller. 2005. Development of nicarbazin as a reproductive inhibitor for resident Canada Geese, in Proceedings of the 11th Wildlife Damage Management Conference.
- Caffrey, C. 1992. Female-biased delayed dispersal and helping in American Crows. Auk 109:609-619.
- Caffrey, C. 1994. California Least Tern breeding survey, 1993 season. Report 94-07. California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section, Sacramento, California.

References

- California Department of Fish and Game. 2002. June 12, 2002 Letter from Robert W. Floerke, Regional Manager, to Mr. David Herman. Response to Pre-consultation Request for Marbled Murrelet on the Redtree - Butano Timber Harvest Plan (Not Yet Submitted).
- California Department of Fish and Game. 2003. Marbled Murrelet Survey Protocol Guidelines. Unpublished report. Prepared by the Habitat Planning Branch, Sacramento, CA.
- California Department of Fish and Wildlife. 2013. May 2, 2013 Memorandum from Scott Wilson, Acting Regional Manager, to Ms. Leslie Markham, Deputy Chief, California Department of Forestry. Subject, Marbled Murrelet Consultation for the Gazos 6 Timber Harvesting Plan (1-13-017 SMO), Redwood Empire Ownership, Gazos Creek Watershed, San Mateo County.
- California Department of Fish and Wildlife. 2015. Marbled Murrelet Database, December 2015.
- California Forest Practice Rules. 2012. Title 14 California Code of Regulations, chapters 4, 4.5, and 10 combined, art. 9, sec. 919.11.
- California State Parks Department. 1959-1984. Natural history record cards, Big Basin State Park, Boulder Creek, CA.
- Canadian breeding grounds (Cir. 433). U.S. Department of Agriculture.
- Careau, V., N. Lecomte, J. F. Giroux, and D. Berteaux. 2007. Common ravens raid arctic fox food caches. *Journal of Ethology* **25**:79-82.
- Carle, R., J. Beck, D. Calleri, and M. Hester. 2014. Año Nuevo State Park Seabird Conservation and Habitat Restoration. Unpublished report.
- Carle, R., J. Beck, N. Smith, E. Coletta, D. Calleri, and M. Hester. 2016. Año Nuevo State Park Seabird Conservation and Habitat Restoration: 2016. Unpublished report.
- Carney, J.M., and W.J. Sydeman. 1999. A review of human disturbance effects on nesting colonial waterbirds. *Waterbirds* **22**: 68-79.
- Carter, H.R. and R.A. Erickson. 1988. Population Status and Conservation Problems of the Marbled Murrelet in California, 1892-1987. Unpublished report. Prepared for California Department of Fish and Game.
- Carter, H.R. and S.G. Sealy. 1987. Inland Records of Downy Young and Fledgling Marbled Murrelets in North America. *The Murrelet* **68**(2): 58-63.
- Carter, H.R., and J.L. Stein. 1985. Molts and plumages in the annual cycle of the marbled Murrelet. In: *Ecology and conservation of the marbled Murrelet* (C.J. Ralph, G.L. Hunt, M.G. Raphael, and J.F. Piatt, eds.) pp99-112 General Technical Report PSW-152, US Forest Service, Pacific Southwest Research Station, Albany, CA.
- Castelein, K. A., D. J. Lauten, K. J. Popper, J. A. Fukuda, and M. A. Stern. 2000a. Snowy Plover distribution and reproductive success along the Oregon Coast -1999. Report to Oregon Department of Fish and Wildlife, Coos Bay BLM, Oregon Dunes National Recreation Area, TMM Co., LTD, and USFWS.
- Castelein, K. A., D. J. Lauten, K. J. Popper, D. C. Bailey, and M. A. Stern. 2000b. The distribution and reproductive success of the Western Snowy Plover along the Oregon Coast - 2000.

References

- Report to Oregon Department of Fish and Wildlife, Coos Bay BLM, Oregon Dunes National Recreation Area, and USFWS.
- Caut, S., E. Angulo, and F. Courchamp. 2008. Discrimination factors ($\Delta^{15}\text{N}$ and $\Delta^{13}\text{C}$) in an omnivorous consumer: effect of diet isotopic ratio. *Functional Ecology* 22:255–263.
- Chamberlain-Auger, J. A., P. J. Auger, and E. G. Strauss. 1990. Breeding biology of American Crows. *Wilson Bulletin* 102:615-622.
- Chesness, R. A., M. M. Nelson, and W. H. Longley. 1968. The effect of predator removal on pheasant reproductive success. *The Journal of Wildlife Management* 32:683-697.
- Christens, E., and H. Blokpoel. 1991. Operational spraying of white mineral oil to prevent hatching of gull eggs. *Wildlife Society Bulletin* 19:423-430.
- Clayton, N.S., T.J. Bussey, and A. Dickinson. 2003. Can Animals Recall the Past and Plan for the Future? *Nature Reviews Neuroscience* 4:685-691.
- Clevenger, A. P., B. Chruszcz, and K. E. Gunson. 2001. Highway mitigation fencing reduces wildlife-vehicle collision. *Wildlife Society Bulletin* 29:646-653.
- Coates, P. S., and D. J. Delehanty. 2004. The effects of raven removal on sage grouse nest success. Pages 17-20 in *Proceedings of the 21st Vertebrate Pest Conference*, U.C. Davis.
- Coates, P. S., and D. J. Delehanty. 2010. Nest predation of greater sage-grouse in relation to microhabitat factors and predators. *Journal of Wildlife Management* 74:240-248.
- Colclazier, E., J. Stumpf and S.W. Singer. 2010. Long-term Monitoring of Marbled Murrelet Populations at Inland Sites in the Santa Cruz Mountains of Central California, 1999-2009. Unpublished report prepared for the Command Trustees Council. Hamer Environmental, L.P. and Steven Singer Environmental & Ecological Services, Santa Cruz, CA.
- Colwell, M. A., T. L. George, and R. T. Golightly. 2009. A predator management strategy to address corvid impacts on productivity of Snowy Plovers (*Charadrius alexandrinus*) and marbled murrelets (*Brachyramphus marmoratus*) in coastal northern California., U. S. Fish and Wildlife Service, Arcata, CA.
- Command Oil Spill FINAL Restoration Plan and Environmental Assessment 2004
- Comfort, E. 2016a. Statistical Analysis of 1998-2015 Marbled Murrelet Surveys at Gazos Mountain Camp. Prepared for Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Comfort, E. 2016b. Statistical Analysis of 2014–2016 Marbled Murrelet Surveys in the Santa Cruz Mountains. Unpublished report prepared for Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Comfort, E. 2017. Statistical Analysis of Annual Marbled Murrelet Surveys at Butano, Portola, and Big Basin. Unpublished report prepared for Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Cornell, H. N., J. M. Marzluff, and S. Pecoraro. 2011. Social learning spreads knowledge about dangerous humans among American Crows. *Proceedings of the Royal Society B: Biological Sciences*.

- Cosco Busan Oil Spill Final Damage Assessment and Restoration Plan/Environmental Assessment 2012
- Cote, I. M., and W. J. Sutherland. 1997. The effectiveness of removing predators to protect bird populations. *Conservation Biology* **11**:395-405.
- Cox, R., S. E. Baker, D. W. MacDonald, and M. Berdoy. 2004. Protecting egg prey from carrion Crows: the potential of aversive conditioning. *Applied Animal Behavior* **87**:325-342.
- Cragg, J.L., A.E. Burger, and J.F. Piatt. 2015. Testing the Effectiveness of Automated Acoustic Sensors for Monitoring Vocal Activity of Marbled Murrelets (*Brachyramphus marmoratus*). *Marine Ornithology* **43**:151-160.
- Crocker, M.J. (ed). 1998. Handbook of acoustics. John Wiley and Sons, NY.
- Cyr, A., and D. LaCombe. 1992. STerilants for managing the populations of red-winged blackbirds (*Agelaius phoeniceus*) in Proceedings of the 15th Vertebrate Pest Conference, U.C. Davis.
- Dawson, W.L. 1923. The Birds of California. Vol. 3: 1484-1488. South Moulton Co. San Diego.
- Day, R. H., K. J. Kuletz, and D. A. Nigro. 1999. Kittlitz's Murrelet (*Brachyramphus brevirostris*).in A. Poole, editor. The Birds of North America, Life Histories for the 21st Century. Cornell Lab of Ornithology, Ithaca.
- DeNiro, M. J., and S. Epstein. 1978. Influence of diet on the distribution of carbon isotopes in animals. *Geochimica et Cosmochimica Acta* **42**:495–506.
- Deutsch, C., A. Ferrel, B. Seibel, H.O. Portner, and R.B. Huey. 2015. Climate change tightens a metabolic constraint on marine habitats. *Science* **348**(6239): 1132-1135.
- Dillingham CP, Miller RC, Webb LO, 1995. Marbled murrelet distribution in the Siskiyou National Forest of southwestern Oregon. *Northwest Naturalist* **76**: 33 - 39.
- Divoky, G.J. and M. Horton. 1995. Breeding and Natal Dispersal, Nest Habitat Loss, and Implications for Marbled Murrelet Populations, in, Ralph, C.J., G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt, editors, Ecology and Conservation of the Marbled Murrelet, PSW-GTR-152, USDA Forest Service Pacific Southwest Research Station, Albany, CA.
- Dooling, R.J. 1992. Hearing in birds. Pp 545-559 in The evolutionary biology of hearing. D.B. Webster, R.R. Fay, and A.N. Popper eds. Springer. NY.
- Dooling, R.J. and A.N. Popper. 2007. The effect of highway noise on birds. California Dept. of Transportation. Sacramento, CA. 74pp.
- Dorn, J. L. 1972. The common Raven in Jackson Hole, Wyoming. Master's Thesis. Univ. of Wyoming, Laramie.
- Duebbert, H. F., and H. A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. *Journal of Wildlife Management* **38**:257-265.
- Duebbert, H. F., and J. T. Lokemoen. 1980. High duck nesting success in a predator-reduced environment. *Journal of Wildlife Management* **44**:428-437.
- Ekanayake, K.B., D.A. Whisson, L.X. L. Tan, and M.A. Weston. 2015. Intense Predation of Non-colonial Ground-nesting Bird Eggs by Corvid and Mammalian Predators. *Wildlife Research* **42**: 518-528.

References

- Ellenberg, U., A.N. Setiawan, A. Cree, D.M. Houston, and P.J. Seddon. 2007. Elevated hormonal stress response in yellow-eyed penguins exposed to unregulated tourism. 2007. *General and Comparative Endocrinology* 152: 54-63.
- Elliot, M.L., R.W. Bradley, D.P. Robinette, and J. Jahncke. 2015. Changes in forage fish community indicated by the diet of Brandt's Cormorant (*Phalacrocorax penicillatus*) in the central California Current. *Journal of Marine Systems* 146: 50-58.
- Engel, K. A. 1989. Spatial and temporal patterns in the diet of common ravens in southwestern Idaho. *Condor* 91:372-378.
- ESA Associates. 2013. Cemex Redwoods Conservation Plan. Unpublished report. Prepared for Conservation Partners. ESA Associates, Sacramento, CA.
- Ettinger, A. O., and J. R. King. 1980. Time and energy budgets of the Willow Flycatcher (*Empidonax traillii*) during the breeding season. *Auk* 97:533-546.
- Evans Mack, D., W.P. Ritchie, S.K. Nelson, E. Kuo-Harrison, P. Harrison, and T.E. Hamer. 2003. Methods for surveying marbled murrelets in forests: a revised protocol for land management and research. Marbled Murrelet Technical Committee, Pacific Seabird Group. 64p.
- Evarts, J. and M. Popper, eds. 2011. Coast Redwood—A Natural and Cultural History. Los Olivos, CA: Cachuma Press.
- Ewald, P. W., and F. L. Carpenter. 1978. Territorial responses to energy manipulations in the Anna hummingbird. *Oecologia* 31:277–292.
- Falxa, G.A., M.G. Raphael, C. Strong, J. Baldwin, M. Lance, D. Lynch, S.F. Pearson, and R.D. Young. 2016. Status and Trend of Marbled Murrelet Populations in the Northwest Forest Plan Area; in, Falxa, G.A. and M.G. Raphael, Tech. Coordinators, Northwest Forest Plan—the First Twenty Years (1994-2013). Gen. Tech. Rpt. PNW-GTR-933. USDA Forest Service, Pacific Northwest Research Station.
- Francis, C.D., and J.R. Barber. 2013. A framework for understanding noise impacts on wildlife: an urgent conservation priority. *Frontiers in Ecology and the Environment*. 11: 305-313.
- Francis, C.D., C.P. Ortega, and A. Cruz. 2009. Noise pollution changes in avian communities and species interactions. *Current Biology* 19: 1415-1419.
- Franklin, J.F., and Spies, T.A. 1991. Composition, Function, and Structure of Old-Growth Douglas-Fir Forests. In: Ruggerio, L.F., Aubry, K.B., Carey, A.B., Huff, M.H., Brookes, M.H., Agee, J.K., Anthony, R.G., Franklin, J.F., Noon, B.R., Raphael, M.G. and others, eds. *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests*. USDA Forest Service Gen. Tech. Rep. PNW-285. Portland, Oregon: US Forest Service, Pacific Northwest Research Station. Pages 71-82.
- Friesen, V. L., A. J. Baker, and J. F. Piatt. 1996. Phylogenetic relationships within the Alcidae (Charadriiformes: Aves) inferred from total molecular evidence. *Molecular Biology and Evolution* 13:359-367.
- Friesen, V.L., T.P. Birt, J.P. Piatt, R.T. Golightly, S.H. Newman, P.N. Hebert, B.C. Congdon, and G. Gissing. 2005. Population Genetic Structure and Conservation of Marbled Murrelets (*Brachyramphus marmoratus*). *Conservation Genetics* 6:607-614.

- Fuller, A.R. G.J. McChesney, J.C. Anderson, R.W. Berger, J.A. Zimmerman, R.J. Potter, B.C. White, J.A. Windsor, and R.T. Golightly. 2015. Restoration and Monitoring of Common Murre Colonies in Central California: Annual Report 2014. US Fish and Wildlife Service, San Francisco Bay NWR, Fremont CA.
- Gabriel, P.O., and R.T. Golightly. 2011. Experimental assessment of taste aversion conditioning on Steller's Jays to provide potential short-term improvement of nest survival of Marbled Murrelets in northern California. Report submitted to National Park Service, Orick, CA. 34 pp.
- Gabriel, P. O., and R. T. Golightly. 2014. Aversive conditioning of Steller's jays to improve marbled murrelet nest survival. *The Journal of Wildlife Management* 78:894–903.
- Gabriel, P.O., P. Halbert, and R.T. Golightly. 2013. Steller's jay conditioned taste aversion treatment in the Santa Cruz mountains in 2012. Report submitted to COSCO BUSAN Trustee Council, California Department of Fish and Game, Office for Oil Spill Prevention and Response, Sacramento, CA.
- Gabriel, P.O., P. Halbert, and R.T. Golightly. 2014. Steller's jay conditioned taste aversion treatment in the Santa Cruz mountains in 2013. Report submitted to COSCO BUSAN Trustee Council, California Department of Fish and Game, Office for Oil Spill Prevention and Response, Sacramento, CA.
- Gabriel, P.O., P. Halbert, and R.T. Golightly. 2015. Steller's jay conditioned taste aversion treatment in the Santa Cruz mountains in 2014. Report submitted to COSCO BUSAN Trustee Council, California Department of Fish and Game, Office for Oil Spill Prevention and Response, Sacramento, CA.
- Gabriel, P.O., P. Halbert, and R.T. Golightly. 2016. Steller's jay aversive conditioning treatment in the Santa Cruz mountains in 2015. Report submitted to COSCO BUSAN Trustee Council, California Department of Fish and Game, Office for Oil Spill Prevention and Response, Sacramento, CA.
- Gaston, A. J., and R. D. Elliot. 1996. Predation by ravens *Corvus corax* on Brunnich's Guillemot *Uria lomvia* eggs and chicks and its possible impact on breeding site selection. *Ibis* **138**:742-748.
- Gerrodette, T. and T. Eguchi. 2011. Precautionary design of a marine protected area based on a habitat model. *Endangered Species Research* 15:159-166.
- Gibble, C.G., and B.A. Hoover. In Press. Interactions between seabirds and harmful algal blooms. In: Shumway, S.E., J.M. Burkholder, and S. Morton, editors. *Harmful Algal Blooms: A compendium desk reference*. Wiley Science Publishers.
- Gill, S.A., J.R. Job, K. Myers, K. Naghshineh, and M.J. Vonhof. 2015. Toward a broader characterization of anthropogenic noise and its effects on wildlife. *Behavioral Ecology* 26:328-333.
- Goldenberg, W. P. 2013. Steller's jay space use and behavior in campground and non-campground sites within Redwood National and State Parks. Humboldt State University.

References

- Goldenberg, W.P., T.L. George, and J.M. Black. 2016. Steller's jay (*Cyanocitta stelleri*) space use and behavior in campground and non-campground sites in coastal redwood forests. *Condor* 118: 532-541.
- Golightly, R.T., and P.O. Gabriel. 2009. Marbled Murrelets. Pages 65-106 in M.A. Colwell, T.L. George, and R.T. Golightly, editors. A predator management strategy to address corvid impacts on productivity of snowy plovers (*Charadrius alexandrinus*) and marbled murrelets (*Brachyramphus marmoratus*) in coastal northern California. Unpublished report, U.S. Fish and Wildlife Service, Arcata, California.
- Golightly, R.T., and S.R. Schneider. 2009. Observations of incubation in year 8 of a long-term monitoring effort at a marbled Murrelet nest in northern California. Dept of Wildlife, Humboldt State University, Arcata, CA. 37pp.
- Golightly, R.T. and S.R. Schneider. 2011. Years 9 and 10 of a Long-term Monitoring Effort at a Marbled Murrelet Nest in northern California. Unpublished report by Dept. of Wildlife, Humboldt State University, Arcata, CA.
- Golightly, R.T., and S.R. Schneider. 2016. Seabird Investigations at Castle Rock National Wildlife Refuge 2006-2012 Report. US Fish and Wildlife Service, Humboldt Bay, Loleta, CA.
- Golightly, R.T., C.D. Hamilton, and P.N. Hébert. 2009. Characteristics of marbled murrelet (*Brachyramphus marmoratus*) habitat in northern California. Unpublished report, National Park Service, Orick, California, and California Department of Fish and Game, Sacramento, California.
- Good, E. E. 1952. The life history of the American Crow, *Corvus brachyrhynchos* Brehm. Ohio State University, Columbus.
- Goodrich, J. M., and S. W. Buskirk. 1995. Control of abundant native vertebrates for conservation of endangered species. *Conservation Biology* 9:1357-1364.
- Gorenzel, W. P., and T. P. Salmon. 1992. Urban crow roosts in California. *in* Proceedings of the 15th Vertebrate Pest Conference.
- Greene, E., W. Davison, and V. R. Muehter. 1998. Steller's jay (*Cyanocitta stelleri*). The Birds of North America Online.
- Greene, M. 2005. Letter to Stacy Martinelli, CDFW dated September 21, 2005. Subject: Gerber Forest Marbled Murrelet Surveys.
- Grinnell, J and A.H. Miller. 1944. The Distribution of the Birds of California. Cooper Ornithological Club, Berkeley, CA.
- Grubb, T.G., L.L. Pater, A.E. Gatto, and D.K. Delaney. 2013. Response of nesting Northern Goshawks to logging truck noise in northern Arizona. *Journal Wildlife Management* 77:1618-1625.
- Gutzwiller, K.J., E.A. Kroese, S.H. Anderson, and C. A. Wilkins. 1997. Does human intrusion alter the seasonal timing of avian song during breeding periods? *Auk* 114: 55-65.
- Habib, L., E.M. Bayne, and S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. *Journal Applied Ecology* 44: 176-184.

- Habitat Restoration Group. 1992. Habitat Use and Occurrence of Marbled Murrelets in the Upper Watershed of Butano Creek, San Mateo County, California. Unpublished report. Prepared for Big Creek Lumber Company.
- Halbert, P. 2015. Summary of 2012 Corvid Monitoring Surveys in the Santa Cruz Mountains (Draft). Unpublished report. California State Parks Department, Felton, CA.
- Halbert, P. 2016. Email Communication Regarding Lethal Control of Corvids in State Parks to W.C. Webb and S.W. Singer.
- Hall, L. A., S. R. Beissinger, P. J. Palsbøll, J. T. Harvey, M. Bérubé, M. G. Raphael, S. K. Nelson, R. T. Golightly, S. Newman, L. McFarlane-Tranquilla, and M. Z. Peery. 2009. Characterizing dispersal patterns of a threatened seabird with limited genetic structure. *Molecular Ecology*. 18:5074–5085.
- Hamer, T.E. and S.K. Nelson. 1995. Nesting chronology of the marbled murrelet. pp 49-56 in Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). *Ecology and conservation of the marbled murrelet*. Gen. Tech. Rep., PSW-GTR-152. US Forest Service, Albany, CA.
- Hamer, T.E., and S.K. Nelson. 1998. Effects of disturbance on nesting marbled murrelets: summary of preliminary results. US Fish and Wildlife Service. Portland, OR. 24 p.
- Hannon, S. J., and S. E. Cotterill. 1998. Nest predation in aspen woodlots in an agricultural area in Alberta: the enemy from within. *Auk* **115**:16-25.
- Harvey and Associates. 2007. Marbled Murrelet Habitat Assessment and Management Recommendations—Phase I—Preliminary Review and Recommendations, Midpeninsula Regional Open Space District. Unpublished report prepared for Midpeninsula Regional Open Space District by H.T. Harvey Associates, Alviso, CA.
- Harris, Larry D. 1984. *The Fragmented Forest*. University of Chicago Press, Chicago.
- Hawkins, Leslie. 1930. Personal journal entry for May 3, 1930.
- Hayward, J. L., G. J. Atkins, A. A. Reichert, and S. M. Henson. 2015. Common Ravens (*Corvus corax*) Prey on Rhinoceros Auklet (*Cerorhinca monocerata*) Eggs, Chicks, and Possibly Adults. *The Wilson Journal of Ornithology* **127**:336-339.
- Hebert, P. N., and R. T. Golightly. 2006. Movements, nesting, and response to anthropogenic disturbance of marbled murrelets (*Brachyramphus marmoratus*) in Redwood National and State Parks, California. Unpublished report, Dept. of Wildlife, Humboldt State University, Arcata California, and California Dept. of Fish and Wildlife Report 2006-02, Sacramento, California.
- Hébert, P.N. and R.T. Golightly. 2007. Observations of predation by corvids at a marbled Murrelet nest. *J. Field Ornithology*. 78: 221-224.
- Hébert, P.N., H.R. Carter, R.T. Golightly, and D.L. Orthmeyer. 2003. Radio Telemetry Evidence of Re-Nesting in the Same Season by the Marbled Murrelet. *Waterbird Society* 26(3): 261-265.
- Hébert, P.N., H.R. Carter, R.T. Golightly, and D.L. Orthmeyer. 2003. Radio-Telemetry Evidence of re-nesting in the same season by the marbled murrelet. *Colonial Waterbirds* 26:261–265.

References

- Heinrich, B. and J.W. Pepper. 1998. Influence of Competitors on Caching Behaviour in the Common Raven, *Corvus corax*. *Animal Behaviour* 56: 1083-1090.
- Helms, J.A., ed. 1998. The Dictionary of Forestry. Society of American Foresters, Bethesda, MD.
- Henkel, L.A. and J.T. Harvey. 2006. Potential prey resources for marbled murrelets in central California. *California Fish and Game* 92: 181-206.
- Henkel, L.A., and M.Z. Peery. 2008. Abundance and productivity of marbled murrelets off central California during the 2007 breeding season. Unpubl. Report, Moss Landing Marine Laboratories, Moss Landing, CA.
- Henkel, L.A., E.E. Burkett, and J.Y. Takekawa. 2004. At-sea activity budget and diving behavior of a radio-tagged marbled murrelet in Central California. *Waterbirds* 27(1):9-12.
- Henry, R.W. and W. B. Tyler. 2016. Abundance and productivity of marbled murrelets off Central California during the 2012-2016 breeding seasons., Report for California State Parks, Half Moon Bay, February 2016.
- Henry, R.W., W. B. Tyler, and M. Z. Peery. 2012. Abundance and productivity of marbled murrelets off Central California during the 2010 and 2011 breeding seasons., Report submitted to California State Parks, Half Moon Bay, October 2012.
- Hester, M., Carle, R., Beck, J., & Calleri, D. (2013). Año Nuevo State Park Seabird Conservation and Habitat Restoration: Report 2013, (415), 1–39.
- Hixon, M. A. 1980. Food Production and Competitor Density as the Determinants of Feeding Territory Size. *The American Naturalist* 115:510–530.
- Hobson K.A. and Clark R.G. 1992. Assessing avian diets using stable isotopes I: turnover of ^{13}C in tissues. *The Condor* 94:181–188.
- Hobson, K. A., and R. G. Clark. 1992. Assessing avian diets using stable isotopes II: factors influencing diet-tissue fractionation. *Condor*:189–197.
- Holt, R. D. 1984. Spatial heterogeneity, indirect interactions and the coexistence of prey species. *American Naturalist* **124**:377-406.
- Holt, A. R., Z. G. Davies, C. Tyler, and S. Staddon. 2008. Metaanalysis of the effects of predation on animal prey abundance: evidence from UK vertebrates. *PLoS ONE* 3:e2400.
- Hothem, R. L., and D. Hatch. 2004. Reproductive success of the Black-crowned Night Heron at Alcatraz Island, San Francisco Bay, California, 1990-2002. *Waterbirds* **27**:112-125.
- Hunt WG, 1988. The natural regulation of peregrine falcon populations. Pp. 667 - 676 in Cade TJ, and Enderson JH, et al. (eds.) *Peregrine Falcon Populations: their management and recovery*. The Peregrine Fund, Boise, Idaho.
- Hunt WG, 1994. Peregrine falcon studies on the Channel Islands. Expert testimony for US, et al. V Montrose, et al.
- Hunt WG, 1998. Raptor floaters at Moffat's Equilibrium. *Oikos* 82: 191 - 197.
- Ivan, J. S., R. K. Murphy, and K. Murphy. 2005. What preys on Piping Plover eggs and chicks? *Wildlife Society Bulletin* **33**:113-119.

- Jahren, A. H., C. Saudek, E. Yeung, W. L. Kao, R. Kraft, and B. Caballero. 2006. An isotopic method for quantifying sweeteners derived from corn and sugar cane. *The American Journal of Clinical Nutrition* 84:1380–1384.
- Jensen, H.A. 1939. Vegetation Types and Forest Conditions of the Santa Cruz Mountains Unit of California. Forest Survey Release No. 1. California Forest and Range Experiment Station, Berkely, CA.
- Jones, I. 2006. Auks, Murres, and Puffins. Pages 280-295 in J. Alderfer, editor. *Complete Birds of North America*. National Geographic Society, Washington, D.C.
- Jones, I.L., F.M. Hunter, and G.J. Robertson. 2002. Annual adult survival of Least Auklets varies with large-scale climatic conditions of the North Pacific Ocean. *Oecologia* 133 (1): 38-44.
- Kelly, J. P. 2005. Factors influencing the nest predatory behaviors of common ravens in heronries. *The Condor* 107:402-415.
- Kelly, J. P., K. L. Etienne, and J. E. Roth. 2005. Factors influencing the nest predatory behaviors of common ravens in heronries. *Condor* 107:402-415.
- Kendall, W. L. 2001. Using models to facilitate complex decisions. Pages 147-170 in T. M. Shenk and A. B. Franklin, editors. *Modeling in natural resource management*. Island Press, Washington, D. C.
- Keppie, D.M. and C.E. Braun. 2000. Band-tailed Pigeon. *The Birds of North America* (A. Poole, Ed.) Ithaca: Cornell Laboratory of Ornithology; Retrieved from the Birds of North America: <https://birdsna.org> (<https://birdsna.org>).
- Kiff L.F., 1980. Historical changes in resident populations of California island raptors. Pp 671 - 673 in *The California Channel Islands: proceedings of a multidisciplinary symposium*, DM Power, editor. Santa Barbara Museum of Natural History, Santa Barbara, California.
- Kight, C.R., and J.P. Swaddle. 2011. How and why environmental noise impacts animals: an integrative, mechanistic review. *Ecology Letters* 14: 1052-1061.
- Kight, C.R., M.S. Saha, and J.P. Swaddle. 2012. Anthropogenic noise is associated with reductions in productivity of breeding eastern bluebirds (*Sialia sialis*). *Ecological applications* 22: 1989-1996.
- Klambach, E. R. 1937. Crow-waterfowl relationships based on preliminary studies on Canadian Breeding Grounds. Circular #433. U.S. Dept. of Agriculture, Washington, D.C.
- Knight, R.L., and K.J. Gutzwiller. 1995. Wildlife and recreationists, coexistence through management and research. Island Press. Covelo, CA.
- Knight, R. L., D. J. Grout, and S. A. Temple. 1987. Nest-defense of the American Crow in urban and rural areas. *Condor* 89:175-177.
- Knopf, F. L., and B. A. Knopf. 1983. Flocking pattern of foraging American Crows in Oklahoma. *Wilson Bulletin* 95:153-154.
- Konyukhov, N. B., and A. S. Kitaysky. 1995. The asian race of the marbled murrelet. Pages 23-32 in C. J. Ralph, J. G. L. Hunt, M. G. Raphael, and J. F. Piatt, editors. *Ecology and Conservation*

References

- of the Marbled Murrelet. Pacific Southwest Research Station, USDA Forest Service, Albany, CA.
- Kristan, W. B., and W. I. Boarman. 2003. Spatial pattern of risk of common raven predation on desert tortoises. *Ecology* **84**:2432-2443.
- Kristan, W. B., and W. I. Boarman. 2007. Effects of anthropogenic developments on common raven nesting biology in the west Mojave desert. *Ecological Applications* **17**:1703-1713.
- Lacey, W.A. 2009. Marbled Murrelet (*Brachyramphus marmoratus*) Five Year Review. US Fish and Wildlife Service.
- Lancia, R. A., C. E. Braun, M. W. Collopy, R. D. Dueser, J. G. Kie, C. J. Martinka, J. D. Nichols, T. D. Nudds, W. R. Porath, and N. G. Tilghman. 1996. ARM! For the future: adaptive management in the wildlife profession. *Wildlife Society Bulletin* **24**:436-442.
- Larivière, S. 1999. Reasons why predators cannot be inferred from nest remains. *Condor*:718–721.
- Larsen, K. H., and J. H. Dietrich. 1970. Reduction of a raven population on lambing grounds with DRC-1339. *J. Wildl. Manage.* **34**:200-204.
- Latta BC, 2012. 2007 Channel Islands peregrine falcon study, final report. Prepared for the US Fish and Wildlife Service, Carlsbad, California, Project No. 9820002.
- Lee, D.E., N. Nur, and W.J. Sydeman. 2007. Climate and demography of the planktivorous Cassin's auklet (*Ptychoramphus aleuticus*) off northern California: implications for population change. *Journal of Animal Ecology* **76**(2): 337-347.
- Leising, A.W., I.D. Schroeder, S.J. Bograd, J. Abell, R. Durazo, G. Gaxiola-Castro, CICESE, E.P. Bjorkstedt, J. Field, K. Sakuma, R.R. Robertson, R. Goericke, W.T. Peterson, R.D. Broedeur, C. Barcelo, T.D Auth, E.A. Daly, R.M. Suryan, A.J. Gladics, J.M. Porquez, S. McClatchie, E.D. Weber, W. Watson, J.A. Santora, W.J. Sydeman, S.R. Melin, F.P. Chavez, R.T. Golightly, S.R. Schneider, J. Fisher, C. Morgan, R. Bradley, and P. Warzybok. 2015. State of the California Current 2014-15: Impacts of the warm-water "blob." *CalCOFI Reports* **56**: 31-69.
- Levy, P. S. and S. Lemeshow. 1991. *Sampling of Populations: Methods and Applications*. 2nd edition. John Wiley and Sons, New York, New York.
- Liebezeit, J. R., and T. L. George. 2002. A summary of predation by Corvids on threatened and endangered species in California and management recommendations to reduce Corvid predation. Species Conservation and Recovery Program report 2002-02. California Department of Fish and Game, Sacramento, CA. 103 pp.
- Lindenmayer, D.B., J.F. Franklin and J. Fischer. 2006. General Management Principles and a Checklist of Strategies to Guide Forest Biodiversity Conservation. *Biological Conservation* **131**: 433-445.
- Linz, G. M., C. E. Knittle, and R. E. Johnson. 1990. Ecology of corvids in the vicinity of the Aliso Creek California Least Tern colony, Camp Pendelton, California. U.S. Dept. of Agric., North Dakota Field Stn., North Dakota State Univ., Fargo.
- Littlefield, C. D. 2003. Sandhill crane nesting success and productivity in relation to predator removal in southeastern Oregon. *The Wilson Bulletin* **115**:263-269.

References

- Littlefield, C. D., and S. P. Thompson. 1987. Greater Sandhill Cranes and Common Ravens on Malheur National Wildlife Refuge. Pages 156-166 in 1985 Crane Workshop. Platte River Whooping Crane Maintenance Trust, Grand Island, Nebraska.
- Long, L. L., Ralph, C. J., & Miller, S. L. (2001). a New Method for Ageing Marbled Murrelets and the Effect on Productivity Estimates. *Pacific Seabirds* 28:82-91.
- Long, L.L., and C.J. Ralph. 1998. Regulation and observations of human disturbance near nesting marbled murrelets. US Forest Service, Pacific Southwest Research Station, Arcata, CA. 36 pp.
- Lorenz, T.J., M.G. Raphael, and T.D. Bloxton, Jr. 2016. Marine habitat selection by marbled murrelets (*Brachyramphus marmoratus*) during the breeding season. *PLoS ONE* 11(9): e0162670.
- Luginbuhl, J. M., J. M. Marzluff, J. E. Bradley, M. G. Raphael, and D. E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. *Journal of Field Ornithology* 72:556-572.
- Lyons, J. E., M. C. Runge, H. P. Laskowski, and W. L. Kendall. 2008. Monitoring in the context of structured decision-making and adaptive management. *The Journal of Wildlife Management* 72:1683-1692.
- M.G. Raphael. 2015. A Review of Marbled Murrelet Research Related to Nesting Habitat Use and Nest Success. Unpublished report prepared for the Oregon Dept. of Forestry, ABR, Inc., Forest Grove, Oregon.
- Madge, S., and H. Burn. 1994. *Crows and Jays*. Princeton University Press, Princeton, NJ.
- Mahringer, E. B. 1970. The population dynamics of the common raven (~*Corvus corax principalis*~ Ridgway) on the Baraga Plains ?Anse, Michigan. Master's Thesis. Michigan Tech. Univ., Houghton.
- Malt, J. and D. Lank. 2007. Temporal Dynamics of Edge Effects on Nest Predation Risk for the Marbled Murrelet. *Biological Conservation* 140: 160-173.
- Malt, J.M. and D.B. Lank. 2009. Marbled Murrelet Nest Predation Risk in Managed Forest Landscapes: Dynamic Fragmentation Effects at Multiple Scales. *Ecological Applications* 19(5):1274-1287.
- Manley, I.A. 1999. Behavior and Habitat Selection of Marbled Murrelets Nesting on the Sunshine Coast. M.Sc. Thesis, Simon Fraser University, Burnaby, B.C.
- Manley, I.A., F.L. Waterhouse, and A.S. Harestad. 1999. Nesting Habitat of Marbled Murrelets on the Sunshine Coast. Forest Research Extension Note. EN-002. Forest Service, British Columbia.
- Marks, D. R. and N. L. Naslund. 1994. Sharp-shinned Hawk Preys on a Marbled Murrelet Nesting in Old-Growth Forest. *Wilson Bulletin* 106(3): 565-567.
- Marr, V., and R. L. Knight. 1982. Raven predation of feral Rock Dove eggs. *Murrelet* 63:25.
- Marschalek, D. A. 2011. California Least Tern Breeding Survey 2010 Season. California Dept. of Fish and Game, Sacramento, CA..

References

- Marshall, D.B., M.G. Hunter, and A.L. Contreras. 2006. Birds of Oregon. Oregon State University Press, Corvallis, OR.
- Martin, T. E. 1993. Nest predation, nest sites, and birds: new perspectives on old patterns. *Bioscience* **43**:523-532.
- Marzluff, J. M. 1988. Do pinyon jays alter nest placement based on prior experience? *Animal Behaviour* **36**:1-10.
- Marzluff, J. M. 2000. Understanding the effects of forest management on avian species. *Wildlife Society Bulletin* **28**:1132-1143.
- Marzluff, J. M. 2001. Worldwide urbanization and its effect on birds. Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Boston.
- Marzluff, J. M., and E. Neatherlin. 2006a. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biological Conservation* **130**:301–314.
- Marzluff, J. M., and E. Neatherlin. 2006b. Corvid response to human settlements and campgrounds: Causes, consequences, and challenges for conservation. *Biological Conservation* **130**:301–314.
- Marzluff, J. M., and M. Restani. 1999. The effects of forest fragmentation on avian nest predation. Pages 155–169 *Forest fragmentation; wildlife and management implications*. eds. J. A. Rochelle, L. A. Lehmann, and J. Wisniewski. Koninklijke Brill NV, Leiden, The Netherlands.
- Marzluff, J. M., R. B. Boone, and G. W. Cox. 1994. Historical changes in populations and perceptions of native pest bird species in the West. *Studies in Avian Biology* **15**:202–220.
- Marzluff, J. M., K. J. McGowan, R. Donnelly, and R. L. Knight. 2001. Causes and consequences of expanding American Crow populations. Pages 331–363 *in* J. M. Marzluff, R. Bowman, and R. Donnelly, editors. *Avian Ecology and Conservation in an Urbanizing World*. Springer US.
- Marzluff, J. M., J. J. Millsbaugh, P. Hurvitz, and M. S. Handcock. 2004. Relating Resources to a Probabilistic Measure of Space Use: Forest Fragments and Steller's jays. *Ecology* **85**:1411–1427.
- Matley, J. K., R. E. Crawford, and T. A. Dick. 2012. Observation of common raven (*Corvus corax*) scavenging Arctic cod (*Boreogadus saida*) from seabirds in the Canadian High Arctic. *Polar Biology* **35**:1119-1122.
- McCall, A.D., W.J. Sydeman, P.C. Davidson, and J.A. Thayer. 2016. Recent collapse of the northern anchovy biomass off California. *Fisheries Research* **175**: 87-94.
- McFarlane Tranquilla, L., R. Bradley, N. Parker, D. Lank, and F. Cooke. 2003. Replacement Laying in the Marbled Murrelet. *Marine Ornithology* **31**:75-81.
- McGregor, R. C. 1901. A list of the land birds if Santa Cruz County, California. *Pacific Coast Avifauna* **2**.

- McKown, M. and A.B. Fleishman. 2015. Acoustic Surveys for Marbled Murrelet and Steller's jay on the San Vicente Redwoods Property–2015. Unpublished report prepared for Peninsula Open Space Trust, Sempervirens Fund, and Hamey Woods.
- McShane, D., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year Status Review of the Marbled Murrelet in Washington, Oregon, and California. Unpublished report. Prepared for the US Fish and Wildlife Service, Portland, Oregon. Prepared by EDAW, Inc. Seattle, Washington. 370 pp.
- Meckstroth, A. M., and A. K. Miles. 2005. Predator removal and nesting waterbird success at San Francisco Bay, California. *Waterbirds* **28**:250-255.
- Miller, S.G., R.L. Knight, and C.K. Miller. 1998. Influence of recreational trails on breeding bird communities. *Ecological Applications* **8**:162-169.
- Montevecchi, W. A. 1978. Predator-prey interactions between ravens and kittiwakes. *Z. Tierpsychol.* **49**:136-141.
- Montevecchi, W. A. 1979. Predator-prey interactions between ravens and kittiwakes. *Z. Tierpsychol.* **49**:136-141.
- Moore, Z. and S.W. Singer. 2014. Discovery of the Tallest Redwoods in the Santa Cruz Mountains–Their Distribution and Ecology. *Journal of Undergraduate Research and Scholarly Excellence* **5**(1): 48-53.
- Morton, M. L., and M. E. Pereyra. 2008. Egg predation at a Golden eagle, *Aquila chrysaetos*, nest. *Canadian Field-Naturalist* **122**:268-269.
- Naef-Daenzer, L. 1983. Scaring of carrion crows (*Corvus carone carone*) by species-specific distress calls and suspended bodies of dead crows. *in* Bird Control Seminars Proceedings. Paper 263.
- Naslund, N. L. 1993a. Breeding Biology and Seasonal Activity Patterns of Marbled Murrelets (*Brachyramphus marmoratus*) Nesting in an Old-Growth Forest. M.S. Thesis. University of California Santa Cruz, CA 146 pp.
- Naslund, N. L. 1993b. Why do marbled murrelets attend old growth forest nesting areas year round? *Auk* **110**: 594-602.
- Naslund, N.L. and B.P. O'Donnell. 1995. Daily Patterns of Marbled Murrelet Activity at Inland Sites. *In* Ralph, C.J., Hunt, G.L. Jr, Raphael, M.G. and Piatt, J.F. (tech. eds.). Ecology and Conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, C: Pacific Southwest Research Station, Forest Service, U.S. Dept. of Agriculture, 420 p.
- National Audubon Society. 2016. The ChristmasBird Counts Historical Results [Online]
- Neatherlin, E. A., and J. M. Marzluff. 2004. Responses of American Crow populations to campgrounds in remote native forest landscapes. *Journal of Wildlife Management* **68**:708-718.
- Nelson, S. K. 1997. Marbled Murrelet. *The Birds of North America* (A.Poole, Ed.). Ithaca: Cornell Laboratory of Ornithology; Retrieved from *The Birds of North America*: <https://birdsna.org> (<https://birdsna.org>).

References

- Nelson, S. K., and T. E. Hamer. 1995. Nest Success and the Effects of Predation on Marbled Murrelets. Pages 89-98 in C. J. Ralph, J. G. L. Hunt, M. G. Raphael, and J. F. Piatt, editors. Ecology and Conservation of the Marbled Murrelet. General Technical Report PSW-152. U.S. Forest Service, Pacific Southwest Research Station, Albany, CA.
- Nelson, S. K., and R. W. Peck. 1995. Behavior of Marbled Murrelets at Nine Nest Sites in Oregon. *Northwestern Naturalist* 76:43–53.
- Newsome, S. D., K. Ralls, C. V. H. Job, M. L. Fogel, and B. L. Cypher. 2010. Stable isotopes evaluate exploitation of anthropogenic foods by the endangered San Joaquin kit fox (*Vulpes macrotis mutica*). *Journal of Mammalogy* 91:1313–1321.
- Newton KM, McKown M, Wolf C, Gellerman H, Coonan T, Richards D, Harvey AL, Holmes N, Howald G, Faulkner K, Tershy BR, Croll DA, 2016. Response of native species 10 years after rat eradication on Anacapa Island, California. *Journal of Fish and Wildlife Management* 7 (1): 72 - 85.
- Newton, I. 1994. Experiments on the limitation of bird breeding densities - a review. *Ibis* **136**:397-411.
- Newton, I. 1998. Population limitation in birds. Academic Press, San Diego, CA.
- Nicolaus, L. K. 1987. Conditioned aversions in a guild of egg predators: implications for aposematism and prey defense mimicry. *American Midland Naturalist* **117**:405-419.
- Nicolaus, L. K., J. F. Cassel, R. B. Carlson, and C. R. Gustavson. 1983. Taste-aversion conditioning of crows to control predation on eggs. *Science* **220**:212-214.
- Nordstrom, M. 2003. Introduced predator in the Baltic Sea: variable effects of feral mink removal on bird and small mammal populations in the outer archipelago. *Annales Universitatis Turkuensis AII*:158.
- Oberski, I. M., and J. D. Wilson. 1991. Territoriality and Site-related Dominance: On Two Related Concepts in Avian Social Organization. *Ethology* **87**:225–236.
- O'Conner, R. J. 1991. Long-term bird population studies in the US. *Ibis* **133**:30-48.
- Orr, R. T. 1942. A study of the birds of the Big Basin region of California. *The American Midland Naturalist* **27**:273-337.
- Orr, R.T. 1990. August 15 letter to Steven Singer re: Marbled Murrelets in Big Basin State Park. California Academy of Sciences, San Francisco, CA.
- Pacific Seabird Group 2010. March 24 letter from Craig Harrison, Pacific Seabird Group to Del Waters, Director, California Department of Forestry and Fire Protection. Subject: Impacts to the Marbled Murrelet from loss of suitable nesting habitat in California.
- Parker, H. 1984. Effect of corvid removal on reproduction of willow ptarmigan and black grouse. *The Journal of Wildlife Management* **48**:1197-1205.
- Pater, L.L., and D.K. Delaney. 2002. Assessment of training noise impacts on the red-cocaded woodpecker. *Journal of the Acoustical Society of America* 112: 2431.
- Pater, L.L., T.G. Grub, and D.K. Delaney. 2009. Recommendations for improved assessment of noise impacts on Wildlife. *J. Wildlife Management* 73: 788-795.

- Paton, P.W.C. and C.J. Ralph. 1990. Distribution of the Marbled Murrelet at Inland Sites in California. *Northwestern Naturalist* 71: 72-84.
- Patricelli, G.L. and J.L. Blickley. 2006. Avian communication in urban noise: causes and consequences of vocal adjustment. *Auk* 123: 639-649.
- Peery, M. Z. and R. W. Henry. 2010a. Abundance and productivity of marbled murrelets off Central California during the 2009 breeding season., Report submitted to California State Parks, Half Moon Bay, Feb 2010.
- Peery M. Z., and R.W. Henry. 2010b. Recovering marbled murrelets via corvid management: a population viability analysis approach. *Biological Conservation* 143: 2414 - 2424.
- Peery, M. Z., B.H. Becker, and S.R. Beissinger. 2006a. Combining Demographic and Count-based Approaches to Identify Source-Sink Dynamics for a Threatened Seabird. *Ecological Applications* 16:1516-1528.
- Peery, M. Z., B. H. Becker, and S. R. Beissinger. 2007. Age ratios as estimators of productivity: testing assumptions on a threatened seabird, the marbled murrelet. *Auk*.124:224-240.
- Peery M. Z., Beissinger SR, Burkett E, Newman SH, 2006. Local survival of marbled murrelets in central California: roles of oceanographic processes, sex, and radiotagging. *Journal of Wildlife Management* 70 (1) 78 - 88.
- Peery, M. Z., S. H. Newman, C.D. Storlazzi, and SR. Beissinger. 2009. Meeting Reproductive Demands in a Dynamic Upwelling System: Foraging Strategies of a Pursuit-Diving Seabird, the Marbled Murrelet. *The Condor* 111(1): 120134.
- Peery, M. Z., S. R. Beissinger, S. H. Newman, E. B. Burkett, and T. D. Williams. 2004a. Applying the Declining Population Paradigm: Diagnosing Causes of Poor Reproduction in the Marbled Murrelet. *Conservation Biology* **18**:1088-1098.
- Peery, M. Z., S. R. Beissinger, S.H. Newman, B.H. Becker, E. Burkett, and T.D. Williams. 2004b. Individual and temporal variation in inland flight behavior of marbled murrelets: Implications for population monitoring. *Condor* 106: 344-353.
- Peery, M. Z., S. R. Beissinger, R. F. House, M. Berube, L. A. Hall, A. Sellas, and P. J. Palsboll. 2008a. Characterizing source-sink dynamics with genetic parentage assignments. *Ecology* **89**:2746-2759.
- Peery, M. Z., L. A. Henkel, B.H. Becker, S.H. Newman, J.T. Harvey, C. Thompson, and S.R. Beissinger. 2008b. Effects of rapid flight-feather molt on post-breeding dispersal in a pursuit-diving seabird. *Auk* 125:113-123
- Peery, M. Z., L. A. Hall, A. Sellas, S.R. Beissinger, C. Moritz, M. Berube, M.G. Raphael, S.K. Nelson, R.T. Golightly, L. McFarlane Tranquilla, S. Newman, and P.J. Palsboll. 2010. Genetic Analysis of Historic and Modern Marbled Murrelets Suggest Decoupling of Migration and Gene Flow After Habitat Fragmentation. *Proc. Royal Society B*. 277: 697-706.
- Peterson, S. A., and M. A. Colwell. 2014. Experimental evidence that scare tactics and effigies reduce corvid occurrence. *Northwestern Naturalist* **95**:103-112.

References

- Phillips, D. L., S. D. Newsome, and J. W. Gregg. 2005. Combining sources in stable isotope mixing models: alternative methods. *Oecologia* 144:520–527.
- Piatt, J.F., B.D. Roberts, W.W. Lidster, J.L. Wells, and S.A. Hatch. 1990. Effects of human disturbance on breeding least and crested auklets at St. Lawrence Island, Alaska. *Auk* 107: 342-350.
- Piatt, J.F., K.J. Kuletz, A.E. Burger, S.A. Hatch, V.L. Friesen, T.P. Brit, M.L. Arimitsu, G.S. Drew, A.M.A. Harding, and K.S. Bixler. 2007. Status review of the marbled murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia. USGS Open File Report 2006-1387, USGS, Reston, VA.
- Plissner, J.H., B.A. Cooper, R.H. Day, P.M. Sanzenbacher, A.E. Burger, and M.G. Raphael. 2015. A Review of Marbled Murrelet Research Related to Nesting Habitat Use and Nest Success. Unpublished report prepared for the Oregon Dept. of Forestry, ABR, Inc., Forest Grove, Oregon.
- Pochop, P. A., J. L. Cummings, C. A. Yoder, and J. E. Steuber. 1998. Comparison of white mineral oil and corn oil to reduce hatchability in ring-billed gull eggs.*in* Proceedings of the eighteenth vertebrate pest conference.
- Potts, G. R. 1986. The partridge: pesticides, predation and conservation. Collins, London, UK.
- Powell, A. N. 2001. Habitat characteristics and nest success of snowy plover associated with California least tern colonies. *The Condor* **103**:785-792.
- Quinlan, S. E. and J. H. Hughes. 1990. Location and Description of a Marbled Murrelet Tree Nest Site in Alaska. 92:1068-1073.
- R. Carle, J. Beck, N. Smith, E. Coletta, D. Calleri, and M. Hester. 2016. Año Nuevo State Park Seabird Conservation and Habitat Restoration: 2016. Unpublished Report to California Dept. of Parks and Recreation, Año Nuevo State Park.
- Radeloff, V. C., E. Nelson, A. J. Plantinga, D. J. Lewis, D. Helmers, J. J. Lawler, J. C. Withey, F. Beaudry, S. Martinuzzi, V. Butsic, and others. 2012. Economic-based projections of future land use in the conterminous United States under alternative policy scenarios. *Ecological Applications* 22:1036–1049.
- Rado, T. 1993. Results of the 1989 pilot raven control program. Pages 266-272 Proceedings of the 1987-1991 Desert Tortoise Council Symposia. Desert Tortoise Council, San Bernardino, CA.
- Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. Pac. Southwest Res. Station, Forest Service, U.S.D.A.
- Ralph, C.J., Miller, S.L. 1995 Offshore population estimates of marbled murrelets in California, p. 353-360. In Ralph C.J, Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.E. [eds.], Ecology and conservation of the marbled murrelet. USDA Forest Serv. Gen. Tech. Rep. PSW-GTR 152.
- Raphael, M. G.; Shirk, A. J.; Falxa, G. A.; Pearson, S. F. 2015. Habitat associations of marbled murrelets during the nesting season in nearshore waters along the Washington to California coast. *Journal of Marine Systems* 146:17-25.

- Raphael, M. G., D. Evans Mack, J. M. Marzluff, and J. Luginbuhl. 2002. Effects of Forest Fragmentation on Populations of the Marbled Murrelet. *Studies in Avian Biology* **25**: 221-235.
- Raphael, M. G.; A. J. Shirk; G. A. Falxa; D. Lynch; S. K. Nelson; S. F. Pearson; C. Strong, R. D. Young. 2016. Factors Influencing Status and Trend of Marbled Murrelet Populations: An Integrated Perspective. Pages 95-120 in Falxa and Raphael (tech. coords.). Northwest Forest Plan—the first 20 years (1994-2013): status and trend of marbled murrelet populations and nesting habitat. Gen. Tech. Rep. PNW-GTR-933. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 132 p.
- Ray, M. S. 1909. Birds of Big Basin. *The Condor* **11**:18-22.
- Restani, M., J. M. Marzluff, and R. E. Yates. 2001. Effects of anthropogenic food sources on movements, survivorship, and sociality of common ravens in the arctic. *The Condor* **103**:399–404.
- Reynolds, J. C., and S. C. Tapper. 1996. Control of mammalian predators in game management and conservation. *Mammal Review* **26**:127-155.
- Richards, G. L. 1971. The Common Crow, *Corvus brachyrhynchos*, in the Great Basin. *Condor* **73**:116-118.
- Richardson, D. S., and G. M. Bolen. 1999. A nesting association between semi-colonial Bullock's orioles and yellow-billed magpies: evidence for the predator protection hypothesis. *Behavioral Ecology and Sociobiology* **46**:373-380.
- RNSP (Redwood National and State Parks). 2007. Redwood national and state parks auditory disturbance guidelines for projects in suitable spotted owl and marbled Murrelet nesting habitat during the breeding season. Unpublished report, RNSP, Orick, CA. 6p.
- Robinson, S. K., F. R. T. III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* **268**:1987-1990.
- Rodger, J. C. 2003. Reproductive science and integrated conservation. Pages 281-290 in W. V. Holt, A. R. Pickard, J. C. Rodger, and D. E. Wildt, editors. *Conservation Biology* 8. Cambridge University Press.
- Rodway, M.S., W.A. Montevecchi, and J.W. Chardine. 1996 Effects of investigator disturbance on breeding success of Atlantic puffins *Fratercula arctica*. *Biological Conservation* **76**: 311-319.
- Rojek, N.A., M.W. Parker, H.R. Carter, and G.J. McChesney. 2007. Aircraft and vessel disturbance to common murres at breeding colonies in central California 1997—1999. *Marine Ornithology* **35**:21-28.
- Rominger, A.J. 2010. Report on the Statistical Analysis of Marbled Murrelet Detections: 1998-2010. Unpublished report prepared for Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Roth, J. E., J. P. Kelly, W. J. Sydeman, and M. A. Colwell. 2004. Sex differences in space use of breeding common ravens in western Marin County, California. *Condor* **106**:529-539.
- Ryan, P. G., & Cooper, J. 1989. Observer precision and bird conspicuousness during counts of birds at sea. *South African Journal of Marine Science*. **8**: 271-276.

References

- Sanzenbacher, P. M., B. A. Cooper, J. H. Plissner, and J. Bond. 2014. Intra-annual Patterns of Passage Rates and Flight Altitudes of Marbled Murrelets *Brachyramphus marmoratus* at Inland Sites in Northern California. *Marine Ornithology* 42: 169-174.
- Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, J. D. J. Ziolkowski, and W. A. Link. 2014. The North American Breeding Bird Survey, Results and Analysis 1966 - 2013. Version 01.30.2015. USGS Patuxent Wildlife Research Center, Laurel, MD.
- Scarpignato, A. L., and T. L. George. 2013. Space use by common ravens in marbled murrelet nesting habitat in Northern California. *Journal of Field Ornithology* 84:147-159.
- Schafer, E. W., Jr. 1984. Potential primary and secondary hazards of avicides, in *Proceedings of the Eleventh Vertebrate Pest Conference*, UC Davis.
- Schmidt, A.E., K.E. Dybala, L.W. Botsford, J.M. Eadie, R.W. Bradley, and J. Jahncke. 2015. Shifting effects of ocean conditions on survival and breeding probability of a long-lived seabird. *PLoS ONE* 10(7): e0132372.
- Schneider, M. F. 2001. Habitat loss, fragmentation and predator impact: spatial implications for prey conservation. *Journal of Applied Ecology* 38:720-735.
- Schoener, T. W. 1983. Simple Models of Optimal Feeding-Territory Size: A Reconciliation. *The American Naturalist* 121:608–629.
- Schwan, M. W., and D. D. Williams. 1978. Temperature regulation in the common raven of interior Alaska. *Comp. Biochem. Physiol.* 60:31-36.
- Scientific Panel on Restoration of Marbled Murrelet Habitat. 2003. Managing Second-Growth Forests in the Redwood Region to Enhance Marbled Murrelet Habitat. Unpublished report. Unattributed.
- Sempervirens Fund. 2012. Santa Cruz Mountains Redwoods Conceptual Area Protection Plan. Unpublished report prepared for the California Wildlife Conservation Board. Sempervirens Fund, Los Altos, CA.
- Sergio, F., F. F. Rizzolli, L. Marchesi, and P. Pedrini. 2004. The importance of interspecific interactions for breeding-site selection: peregrine falcons seek proximity to raven nests. *Ecography* 27:818-826.
- Sharpe PB, 2015. Peregrine falcon monitoring on the California Channel Islands, California, 2014. Unpublished report prepared by The Institute for Wildlife Studies, Arcata, California for Montrose Settlements Restoration Program.
- Shaw, B. 2011. Summary of 2011 Marbled Murrelet Monitoring Surveys in the Santa Cruz Mountains. Unpublished report prepared for the California Department of Parks and Recreation.
- Shields, T. 2016. Raven and subsidy management technology: lasers, Techno tortoise models, drones and rovers. Raven Workshop, PalmSprings, CA.
- Shochat, E., S. B. Lerman, M. Katti, and D. B. Lewis. 2004. Linking Optimal Foraging Behavior to Bird Community Structure in an Urban-Desert Landscape: Field Experiments with Artificial Food Patches. *The American Naturalist* 164:232–243.

- Shwiff, S. A., R. T. Sterner, J. W. Turman, and B. D. Foster. 2005. Ex post economic analysis of reproduction-monitoring and predator-removal variables associated with protection of the endangered California least tern. *Ecological Economics* 53:277-287.
- Sibly, R. M., C. C. Witt, N. A. Wright, C. Vendittid, W. Jetze, and J. H. Brown. 2012. Energetics, lifestyle, and reproduction in birds. *Proceedings of the National Academy of Sciences* 109:10937–10941.
- Silvergieter, M.P. and D.B. Lank. 2011. Marbled Murrelets Select Distinctive Nest Trees within Old-Growth Forest Patches. *Avian Conservation and Ecology* 6(2): 3.
- Simpson, G. 1972. Some approaches to control depredations by crows and jays in Tulare County. Pages 112-117 in *Proceedings of the Fifth Vertebrate Pest Conference*, UC Davis.
- Singer, M.T., and C.G. Lorimer. 1997. Crown release as a potential old-growth restoration approach in northern hardwoods. *Canadian Journal of Forest Research* 27: 1222-1232.
- Singer, S.W. 1999. Marbled Murrelet Monitoring Program for Gazos Mountain Camp and the Gazos Creek Watershed. Unpublished report for the Apex Houston Trustees Council and The Sempervirens Fund. Prepared by Steven Singer E & E Services, Santa Cruz, CA.
- Singer, S.W. 2001. Unpublished data sheet. Purisima Open Space Preserve Audio-Visual Survey, July 20.
- Singer, S.W. 2003. Old-growth Forest Stands in the Santa Cruz Mountains. Unpublished report prepared for Save the Redwoods League by Steven Singer E & E Services, Santa Cruz.
- Singer, S.W. 2010. Results of Marbled Murrelet Audio-Visual Surveys at Gazos Mountain Camp 1998-2010. Unpublished report for the Apex Houston Trustees Council and The Sempervirens Fund. Prepared by Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Singer, S.W. 2013. Results of 2013 Marbled Murrelet Surveys at Gazos Mountain Camp and Other Sites. Unpublished report. Prepared by Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Singer, S.W. 2014. The Marbled Murrelet–Flagship Species of Our Old-growth Forests. In Robinson, L., ed., *Redwood Logging and Conservation in the Santa Cruz Mountains—A Split History*. *Santa Cruz History Journal* 7:213-219.
- Singer, S.W. 2015a. 2015 Forest Survey Results - Marbled Murrelets in the Santa Cruz Mountains. Unpublished report prepared for California State Parks Department. Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Singer, S.W. 2015b. 2014 Forest Survey Results–Marbled Murrelets in the Santa Cruz Mountains. Unpublished report prepared for California State Parks Department. Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Singer, S. W. 2016. 2016 Forest Survey Results–Marbled Murrelets in the Santa Cruz Mountains. Unpublished report prepared for the California State Parks Department. Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Singer, S.W. and D.R. Verardo. 1975. The Murrelet’s Nest Discovered. *Pacific Discovery* 28(4): 18-21.

References

- Singer, S.W. and H.R. Carter. 1992. Restoration of the Central California Population of the Marbled Murrelet after Injuries from the Apex Houston Oil Spill. Unpublished report. Prepared for U.S. Dept. of Justice.
- Singer, S. W. and P. L. Fiedler. 1994. Breeding Distribution of the Marbled Murrelet *Brachyramphus marmoratus* in the Santa Cruz Mountains.
- Singer, S. W. and T. E. Hamer. 1998. Use of Radar to Monitor Marbled Murrelets in Gazos Creek and Adjoining Watersheds in the Santa Cruz Mountains. Unpublished report prepared for Apex Houston Trustee Council. Steven Singer E & E Services, Santa Cruz, CA.
- Singer, S. W., and D. L. Suddjian. 1995. The common raven in the Santa Cruz Mountains - its historic occurrence, numbers, and impact on nesting murrelets. Unpublished report. Santa Cruz Mountains Murrelet Group, Santa Cruz, CA.
- Singer, S. W. and T. E. Hamer. 1999a. Gazos Creek Marbled Murrelet Monitoring Program–1999 Annual Report. Unpublished report prepared for The Sempervirens Fund and The Apex Houston Trustees Council. Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Singer, S. W. and T. E. Hamer. 1999b. Use of Radar to Monitor Marbled Murrelets in the Santa Cruz Mountains, California. Abstract, Proceedings of the 26th annual PSG meeting, Blaine, Washington. Pacific Seabirds 26 (1): 45.
- Singer, S.W. and E. Colclazier. 2010. Results of Marbled Murrelet Radar Surveys in the Gazos Creek Watershed 2000-2010. Unpublished report. Prepared for the Apex Houston Trustees Council and The Sempervirens Fund. Steven Singer Environmental and Ecological Services and Hamer Environmental, LP.
- Singer, S.W. and D. Houston. 2006. An evaluation of potential noise disturbance to the marbled Murrelet–sewer work at Big Basin State Park. Unpublished report prepared for California State Parks Department by Steven Singer E & E Services, Santa Cruz.
- Singer, S.W. and D. Houston. 2012. Investigation and mitigation of construction noise impacts on the Marbled Murrelet–facilities upgrade at Big Basin Redwoods State Park. Unpublished report prepared for California State Parks Dept.by Steven Singer E & E Services, Santa Cruz, CA.
- Singer, S. W., D .L. Suddjian and S.A. Singer. 1995. Fledging Behavior, Flight Patterns, and Forest Characteristics at Marbled Murrelet Tree Nests in California. Northwestern Naturalist 76: 54-62.
- Singer, S.W., N.L. Naslund, S.A. Singer, and C.J. Ralph. 1991. Discovery and observations of two tree nests of the marbled Murrelet. Condor 93: 330-339.
- Slabbekoorn, H., and E.A. Ripmeester 2008. Birdsong and anthropogenic noise: implications and applications for conservation. Molecular Ecology 17: 72-83.
- Small, A. 1994. Status and Distribution of California Birds. Ibis Publishing Co., Vista, CA.
- Smith, R. K., A. S. Pullin, G. B. Stewart, and W. J. Sutherland. 2010. Effectiveness of predator removal for enhancing bird populations. Conservation Biology 24:820-829.

- Sonerud, G. A., and P. E. Fjeld. 1987. Long-term memory in egg predators: an experiment with a hooded crow. *Ornis Scandinavica* **18**:323-325.
- Sonerud, G. A. and P.E. Fjeld. 1987. Long-term Memory in Egg Predators: An Experiment with a Hooded Crow. *Ornis Scandinavica* **18**(4): 323-325.
- Soule, M. E. 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. *Conservation Biology* **2**:75-92.
- Spear, L.B., N. Nur, and D.G. Ainley. 1992. Estimating absolute densities of flying seabirds using analyses of relative movement. *Auk* **109**(2): 385-389.
- Spickler, J. C. and W.C. Webb. 1996. Site Assessment and Results of Intensive Marbled Murrelet Surveys in West Waddell State Wilderness. Unpublished report.
- S.S. Jacob Luckenbach and Associated Mystery Oil Spills FINAL Damage Assessment and Restoration Plan/Environmental Assessment 2006.
- Stahler, D., B. Heinrich, and D. Smith. 2002. Common ravens, *Corvus corax*, preferentially associate with grey wolves, *Canis lupus*, as a foraging strategy in winter. *Animal Behaviour* **64**:283-290.
- Steen, J. B., and O. A. Haugvold. 2009. Cause of death in willow ptarmigan *Lagopus l. lagopus* chicks and the effect of intensive, local predator control on chick production. *Wildlife Biology* **15**:53-59.
- Stiehl, R. B. 1978a. Aspects of the ecology of the common raven in Harney Basin, Oregon. Phd Thesis. Portland State Univ., Portland, OR.
- Strong, C.S. 1998. Techniques for Marbled Murrelet age determination in the field. *Pacific Seabirds* **25**(1): 6-8.
- Struthers, K., and P. Ryan. 2005. Predator control for the protection of the federally endangered Great Lakes Piping Plover (*Charadrius melodus*) at Dimmick's Point, North Manitou Island. *in* Proceedings of the 11th Wildlife Damage Management Conference.
- Stumpf, J. 2010. A Continued Statistical Review of Gazos Creek Murrelet Radar Data. Unpublished report. Prepared for Steven Singer Environmental and Ecological Services, Santa Cruz, CA.
- Suddjian, D. L. 1996. October 10 letter to Steve Singer Re: Marbled Murrelet Breeding Records from my Study Areas. David L. Suddjian Biological Consulting Services, Capitola, CA.
- Suddjian, D. L. 2003a. Ten Years of Monitoring Marbled Murrelets at the South Fork of Butano Creek, San Mateo County, California, 1992-2001. Unpublished report. Prepared for Big Creek Lumber Company.
- Suddjian, D. L. 2003b. Summary of 2002 Marbled Murrelet Monitoring Surveys at Big Basin and Portola State Parks.
- Suddjian, D. L. 2003c. April 22 letter to Esther Burkett, California Department of Fish and Game Re: Summary of 2002 Marbled Murrelet Monitoring Surveys at Big Basin and Portola State Parks.

References

- Suddjian, D. L. 2003d. Summary of 2003 Department of Fish and Game Marbled Murrelet Monitoring Surveys at Big Basin and Portola Redwoods State Parks. Unpublished report. Prepared for California Dept. of Fish and Game.
- Suddjian, D. L. 2005a. Summary of 2005 Corvid Monitoring Surveys in the Santa Cruz Mountains. Unpublished report prepared for the Command Oil Spill Trustees Council.
- Suddjian, D. L. 2005b. Summary of 2004 Marbled Murrelet Monitoring Surveys in the Santa Cruz Mountains. Unpublished report. Prepared for Command Oil Spill Trustees Council.
- Suddjian, D. L. 2006. Summary of 2005 Marbled Murrelet Monitoring Surveys in the Santa Cruz Mountains. Unpublished report. Prepared for the Command Oil Spill Trustees Council.
- Suddjian, D. L. 2009a. Summary of 2008 Marbled Murrelet Monitoring Surveys in the Santa Cruz Mountains. Unpublished report. Prepared for Command Oil Spill Trustees Council.
- Suddjian, D. L. 2009b. Summary of 2008 Corvid Monitoring Surveys in the Santa Cruz Mountains. Unpublished report prepared for the Command Oil spill Trustees Council.
- Suddjian, D. L. 2009c. Summary of 2009 corvid monitoring surveys in the Santa Cruz Mountains. Unpublished report prepared for the Command Oil Spill Trustee Council.
- Suddjian, D. L. 2010a. Summary of 2009 Marbled Murrelet Monitoring Surveys in the Santa Cruz Mountains (Draft). Unpublished report prepared for the Command Oil Spill Trustees Council.
- Suddjian, D. L. 2010b. Summary of 2009 corvid monitoring surveys in the Santa Cruz Mountains.
- Sugden, L. G. and G. W. Beyersbergen. 1986. Effect of density and concealment on American Crow predation of simulated duck nests. *Journal of Wildlife Management* 50: 9-14.
- Sugihara, N. G., J.W. VanWagtendonk, K.E. Schaffer, J. Fites-Kaufman, and A.E. Thode. 2006. *Fire in California's Ecosystems*. Univ. of California Press, Berkeley, CA.
- Swarthout, E. C. H., and R. J. Steidl. 2001. Flush responses of Mexican spotted owls to recreationists. *Journal Wildlife Management* 65: 312-317.
- Swift, K. N., and J. M. Marzluff. 2015. Wild American crows gather around their dead to learn about danger. *Animal Behavior* **109**:187-197.
- Sydeman, W. J., K. L. Mills, J. A. Santora, S. A. Thompson, D. F. Bertram, K. H. Morgan, B. K. Wells, J. M. Hipfner, and S. G. Wolf. 2009. Seabirds and climate in the California Current—A synthesis of change. *CalCOFI Reports* 50: 82-104.
- Sydeman, W. J., M. Garcia-Reyes, D. S. Schoeman, R. R. Rykaczewski, S. A. Thompson, B. A. Black, and S. J. Bograd. 2014. Climate change and wind intensification in coastal upwelling ecosystems. *Science* 345(6192): 77-80.
- Sydeman, W. J., S. A. Thompson, M. Garcia-Reyes, M. Kahru, W. T. Peterson, and J. L. Largier. 2014. Multivariate ocean-climate indicators (MOCI) for the central California Current: Environmental change, 1990-2010. *Progress in Oceanography* 120: 352-369.
- Temple, S. A. 1974. Winter food habits of ravens on the arctic slope of Alaska. *Arctic* **27**:41-46.

- Thayer, J. A., and W. J. Sydeman. 2007. Spatio-temporal variability in prey harvest and reproductive ecology of a piscivorous seabird, *Cerorhinca monocerata*, in an upwelling system. *Marine Ecology Progress Series* 329: 253-265.
- Thompson, W. L., G. C. White, and C. Gowan. 1998. *Monitoring Vertebrate Populations*. Academic Press, Santa Diego, California.
- Truett, J. C., M. E. Miller, and K. Kertell. 1997. Effects of Arctic Alaska Oil Development on Brant and Snow Geese. *Arctic* 50:138-146.
- Tucker, V. A. 1973. Bird metabolism during flight: evaluation of a theory. *Journal of Experimental Biology* 58: 689-709.
- U.S. Fish and Wildlife Service. 1995. Proposed Designation of Critical Habitat for the Marbled Murrelet. *Federal Register* 60 (154): 40892-40954.
- U.S. Fish and Wildlife Service. 1997. Recovery Plan for the Threatened Marbled Murrelet in Washington, Oregon, and California. Unpublished report. Portland, Oregon, 203 pp.
- U.S. Fish and Wildlife Service. 2006. Estimating the effects of auditory and visual disturbance to northern spotted owls and marbled murrelets in northwestern California. Arcata Field Office, Arcata, CA. 12 pp.
- U.S. Fish and Wildlife Service 2007. Recovery plan for the Pacific coast population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). Page 751, Sacramento, CA.
- U.S. Fish and Wildlife Service, 2009. Final 5 - year review for the marbled murrelet. Washington Fish and Wildlife Office, Lacey, Washington.
- U.S. Fish and Wildlife Service. 2012. Report on Marbled Murrelet Recovery Implementation Team Meeting and Stakeholder Workshop. Unpublished report.
- Valkama, J., E. Korpimäki, B. Arroyo, P. Beja, V. Bretagnolle, E. Bro, R. Kenward, S. Manosa, S. M. Redpath, S. Thirgood, and V. Javier. 2005. Birds of prey as limiting factors of gamebird populations in Europe: a review. *Biological Reviews* 80:171-203.
- van Kempen, G. M. P. and L. J. van Vliet. 2000. Mean and variance of ratio estimators used in fluorescence imaging. *Cytometry* 39: 300-305.
- Vas, E., A. Lescoel, O. Duriez, G. Boguszewski, and D. Gremillet. 2015. Approaching birds with drones: first experiments and ethical guidelines. *Biology Letters* 11: 20140764.
- Vásquez-Carrillo, C., R.W. Henry, L. Henkel, and M.Z. Peery. 2013. Integrating population and genetic monitoring to understand changes in the abundance of a threatened seabird. *Biological Conservation* 167: 173-178.
- Verbeek, N. A. M., and C. Caffrey. 2002. American Crow (*Corvus brachyrhynchos*). Pages 1-36 in A. Poole and F. Gill, editors. *Birds of North America*. The American Ornithologists Union, Washington, D.C.
- Verschuyt, J. 2008. A Statistical Review of Gazos Creek Murrelet Radar Data. Unpublished report for Steven Singer Environmental and Ecological Services. Hamer Environmental, Mt. Vernon, WA.

References

- Vigallon, S. M., and J. M. Marzluff. 2005a. Abundance, nest sites, and nesting success of Steller's jays along a gradient of urbanization in western Washington. *Northwest science* 79:22.
- Vigallon, S. M., and J. M. Marzluff. 2005b. Is nest predation by Steller's jays (*Cyanocitta stelleri*) incidental or the result of a specialized search strategy? *The Auk* 122:36–49.
- Walker, L. E., and J. M. Marzluff. 2015. Recreation changes the use of a wild landscape by corvids. *The Condor* 117:262–283.
- Walker, B.G., P.D. Boersma and J.C. Wingfield. 2006. Habituation of adult magellanic penguins to human visitation as expressed through behavior and corticosterone secretion. *Conservation Biology* 20: 146-154.
- Wallen, R., J. Gordon, and C. Arguello. 1998. Abundance of corvids in old-growth forest habitats in Redwood National and State Parks. Annual report of Redwood National and State Parks.
- Wallen, R., C. Arguello, J. Friedman, and D. Baldwin. 1999. The corvids of Redwood National and State Parks: What is their relative abundance and how does abundance vary relative to human activities in the forest? Annual progress report for Redwood National and State Parks.
- Warburton, B., and B. G. Nelson. 2009. Towards a knowledge-based ethic for lethal control of nuisance wildlife. *The Journal of Wildlife Management* 73:158-164.
- Ward, C. 2011. Evaluation of Communication Strategies to Mitigate Visitor Use Impacts On Marbled Murrelets.
- Warzybok, P. M and R. W. Bradley. 2009. Status of Seabirds on Southeast Farallon Island During the 2009 Breeding Season. Unpublished report to the US Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1707.
- Webb, W. C. 2010. Demography, gene flow and nest predatory behavior of the common raven (*Corvus corax*) in a temperate rainforest. University of Washington.
- Webb, W. C., W. I. Boarman, and J. T. Rotenberry. 2004. Common raven juvenile survival in a human-augmented landscape. *Condor* 106:517-528.
- Webb, W. C., W. I. Boarman, and J. T. Rotenberry. 2009. Movements of Juvenile Common Ravens in an Arid Landscape. *Journal of Wildlife Management* 73:72-81.
- Webb, W. C., J. M. Marzluff, and J. Hepinstall-Cymerman. 2011. Linking resource use with demography in a synanthropic population of common ravens. *Biological Conservation* 144:2264–2273.
- Webb, W. C., J. M. Marzluff, and J. Hepinstall-Cymerman. 2012. Differences in Space Use by Common Ravens in Relation to Sex, Breeding Status, and Kinship. *The Condor* 114:584-594.
- West, E. H., W.A. Henry, W. Goldenberg, and M. Z. Peery. 2016. Influence of Food Subsidies on the Foraging Ecology of a Synanthropic Species in Protected Areas. *Ecosphere* 7(10): 1-15
- Western Ecological Services Company. 1983. Natural resources management program for Pescadero Creek County Park, San Mateo County, California. Unpublished report prepared for San Mateo Co. Parks Dept. by WESCO, Novato, CA.
- Whidden, S.E., C.T. Williams, A.R. Breton, and C.L. Buck. 2007. Effects of Transmitters on the Reproductive Success of Tufted Puffins. *Journal of Field Ornithology* 78:206-212.

- Wildlife Services. 2001. Egg oil: an avian population control tool. Technical bulletin. US Dept. of Agriculture, Animal and Plant Health Inspection Service, Washington, D. C.
- Willebrand, T., and V. Marcstrom. 1988. On the Danger of Using Dummy Nests to Study Predation. *Auk* **105**:378-379.
- Wilson, J.S., and C.D. Oliver. 2000. Stability and density management in Douglas-fir plantations. *Canadian Journal of Forest Research* 30:910-920.
- Wong, S. N. P., R. A. Ronconi, A. E. Burger, and B. Hansen. 2008. Marine distribution and behavior of juvenile and adult marbled murrelets off southwest Vancouver Island, British Columbia: Applications for monitoring. *Condor* **110**:306-315.
- Wonn, H.T., and K.L. O'Hara. 2001. Height:diameter ratios and stability relationships for four northern Rocky Mountain tree species. *Western Journal of Applied Forestry* 16(2):87-94.
- Wood, E. M., A. M. Pidgeon, V. C. Radeloff, D. Helmers, P. D. Culbert, N. S. Keuler, and C. H. Flather. 2014. Housing development erodes avian community structure in U.S. protected areas. *Ecological Applications* 24:1445–1462.
- Wright, M.D., P. Goodman, and T.C. Cameron. 2010. Exploring behavioral responses of shorebirds to impulsive noise. *Wildfowl* 60: 150-167.
- Yom-Tov, Y. 1974. The effect of food and predation on breeding density and success, clutch size and laying date of the crow (*Corvus corone*). *Journal of Animal Ecology* **43**:479-498.

APPENDICIES

APPENDIX A—HISTORIC OCCURRENCES OF MURRELETS IN THE SANTA CRUZ MOUNTAINS

Prepared by Steven W. Singer, M.S., Consulting Forest Biologist

HISTORIC OCCURRENCES OF MURRELETS IN THE SANTA CRUZ MOUNTAINS

Originally the Santa Cruz Mountains is reported to have contained about 157,000 acres of old-growth redwood-Douglas-fir, and Douglas-fir forest (Jensen 1939)—likely all being suitable habitat for murrelets. Logging of old-growth forest began in the 1850s and continues to this day although logging of old-growth stands used by murrelets has been prohibited since 1992 (Calif. Dept. of Forestry 2012). Today there are only about 10,000 acres of old-growth forest remaining (Singer, 2003). As the old-growth forest dwindled in size, it is believed that the local murrelet population shrank proportionately (Paton and Ralph 1990).

Throughout its brief recorded history in the Santa Cruz Mountains, the marbled murrelet has been an elusive bird. The first record of a murrelet detected inland in Zone 6 was by Joseph Grinnell in 1904 (Grinnell and Miller 1944). On August 24 he detected a bird inland near Pescadero Creek. Grinnell believed that murrelets nested in the forest, but not in trees, instead preferring to nest on the ground, under logs or in mammal burrows in spongy ground. The next recorded inland detections were on May 18 and 19, 1914 by William Dawson. While camped somewhere along Big Creek, he saw five birds on one morning and six birds the next, all going straight down the valley toward the ocean (Dawson 1923).

There is an undocumented report that Dawson may have found a nest or perhaps seen murrelet flight behavior indicative of nesting at the confluence of Big Creek and Deadman Gulch (CDFW 2016). Unless his field notes can be found and examined, this report of an historic nest site should be rejected. Dawson was well aware of the mystery surrounding the nesting of the marbled murrelet and if he had found a nest or even seen a murrelet flying below the treetops he would have certainly reported it in the species account in his book. Being an avid egg-collector, he would no doubt have made an extraordinary effort to try to find the nest so that he could collect a murrelet egg. He makes no mention of doing so.

There is a surprising paucity of reports of murrelets being seen inland in the Santa Cruz Mountains after 1914. In 1930, Leslie Hawkins, a visiting birdwatcher from the East, was birding along the San Lorenzo River below Big Trees (now Henry Cowell State Park). In the early morning of May 3, 1930, he heard and saw two murrelets flying overhead (Hawkins 1930).

During the period of 1931 through 1935, a study was made of the occurrence and distribution of birds in the Big Basin Region (Orr 1942). The region was defined broadly to include the lower part of the Pescadero Creek Watershed (east as far as the Jones Gulch YMCA camp); south from there along Butano Ridge and China Grade Road to a point east of Eagle Rock ; and from Eagle Rock in a straight line to Greyhound Rock on the coast. This area includes all of Big Basin, Butano, and Memorial parks, and also the entire Butano Creek, Gazos Creek, and Waddell Creek watersheds. There was still a relative abundance of old-growth murrelet habitat within this region at that time. However the study did not detect the occurrence of any marbled murrelets. Years later, Dr. Orr was asked why he didn't observe any murrelets. In a letter, he said that much of his work in Big Basin "did not involve observations at pre- and early post dawn hours of the morning. Looking back now, I wish I had." (Orr, 1990).

Appendix A—Historic Occurrences of Murrelets in the Santa Cruz Mountains

In May of 1956, Eleanor Pugh, a naturalist and bird-watcher who was capable of identifying murrelet vocalizations, moved to Portola State Park with her husband who was a park attendant for the state. On July 4, 1956, she detected 6–10 murrelets flying and calling over the park in the early morning. (California State Parks 1984). Apparently she was the first person at a local state park who was capable of identifying marbled murrelets while they were flying and calling over the park.

On June 15, 1957, a visitor brought her a juvenile murrelet that had been found floating on Pescadero Creek (Anderson 1972). This was the first confirming evidence that murrelets were nesting in the old-growth forest in Zone 6. She made other observations of murrelets in the park until she and her husband transferred to Big Basin in March 1957. Once there she continued to see and hear murrelets. Before being transferred out of the Basin, she passed her identification skills on to other park staff. On August 18, 1960, shortly after she had left, a grounded fledgling murrelet was found there (California State Parks 1984).

As the first identified grounded fledglings began to appear and be recorded in the old-growth state and county parks, their remaining habitat in Zone 6 was being rapidly destroyed. There was still a large stand of old growth in the Butano Creek watershed, but it was the only stand of trees left that was comparable in size to Big Basin. It was 3000 acres of virgin trees, many reported to be the equal in size and grandeur to those protected in Big Basin State Park. It was called the Butano Forest, and it was owned by the Pacific Lumber Company (Singer 2014).

When Pacific Lumber announced that they would soon begin logging this stand, a campaign was organized by a coalition of conservation groups to raise money to acquire the property. They raised over \$1 million in matching funds for acquisition, and pushed a Butano Forest acquisition bill that was passed by the state legislature in 1955. Unfortunately, Governor Knight vetoed the bill. The Pacific Lumber Company with its partner, the Santa Cruz Lumber Company, commenced clear-cutting on the very next day. By doing so, they destroyed nesting habitat likely used by hundreds of murrelets. Although no one was surveying for murrelets at the time, murrelets typically re-use the same stands for nesting, and some murrelets still nest in the remnants of this stand left just outside the Pacific Lumber Company's property line in Butano State Park.

This remaining sliver of the Butano Forest is now known as the North Slope stand and it, along with the even-aged regenerating stand formerly owned by Pacific Lumber Company and now owned by Big Creek Lumber Company was the focus of an extensive A-V survey effort from 1998 to 2009. Murrelets were found to be nesting on the state park stand and not nesting on the harvested stand (Suddjian 2003a). Butano State Park was created in 1961 as a sort of consolation prize for the conservation community, with a much smaller area and a lower quality of old-growth trees (Singer 2014).

In 1974, the world's first marbled murrelet tree nest was found in an old-growth Douglas-fir tree in Big Basin State Park (Binford et al 1975, Singer and Verardo 1975). It was located in a campground not far from Park Headquarters. It was discovered accidentally by a tree pruner doing a safety prune 45 meters (147 feet) up in the tree. He came upon a bird that he had never seen before sitting on a branch. It was a downy chick of the marbled murrelet. The chick was taken from the nest, and when it died later, was preserved as a specimen at the California Academy of Sciences. Later the segment of branch containing

Appendix A—Historic Occurrences of Murrelets in the Santa Cruz Mountains

the nest was also removed, and it also is archived at the Academy of Sciences. The mystery of where murrelets nested had finally been solved.

The second North American tree nest was found in 1984 in southeast Alaska using radio telemetry. A bird captured and tagged in Kelp Bay was tracked to a nest site in an old-growth mountain hemlock tree (Quinlan and Hughes 1990).

The third and fourth North American murrelet tree nests were found in Big Basin State park in 1989 (Singer et al. 1991). Both nests were in old-growth Douglas-firs, and both failed due to predation—the first during the egg stage to a common raven, and the second during the nestling stage to Steller’s jays. The first nest to be found in a redwood, which was also the first nest where successful fledging was observed live, was also in Big Basin State Park. This occurred in 1991 in the Father Tree which is one of the largest trees in the park and is located along the most heavily used trail in the park. This tree had two different nest sites within it and was used for nesting for at least four consecutive years, with three years known to have been successful (Singer, Suddjian, and Singer 1995).

In 1987, Carter and Erickson compiled all the available information on the distribution of the murrelet in California, including the Santa Cruz Mountains, for the California Department of Fish and Game (Carter and Erickson 1988). Information from this work is included in Table 2-4 (Chapter 2, this Plan) along with other evidence of nesting occurrences.

In 1988 and 1989, the U.S. Forest Service conducted 170 transect surveys from the Oregon border south to Monterey County. Twenty-two transects were surveyed within the breeding range of the murrelet in Zone 6. Each transect consisted of 8–12 spaced stations with a 10 minute count done at each station. The purpose was to determine the distribution of the murrelet and both old-growth stands and second-growth stands were surveyed (Paton and Ralph 1990).

The parks located north of Santa Cruz that contained transects were Butano, Heritage Grove, Memorial Park, Pescadero Creek County Park, Portola, and Henry Cowell State Park. All except Henry Cowell had detections. The greatest number of detections occurred at Iverson Trail in Portola State Park, with high numbers also being reported from Big Basin Headquarters, Waddell Creek, Lodge Road in Big Basin, Gazos Creek, and the haul road in Pescadero Creek County Park. No transects were done at the Fall Creek Unit of Henry Cowell State Park or on private timberlands. A transect was also run along a forested section of Highway #84 in the San Gregorio watershed, but had no detections (Paton and Ralph 1990).

APPENDIX B—MURRELET HABITAT DISTRIBUTION BY WATERSHED IN ZONE 6

by Steven W. Singer, M.S., Consulting Forest Biologist

(Note: Stand identifier codes, such as FE-4 or BIBA-7, refer to the digital map of old-growth and older second-growth stands found in the Santa Cruz Mountains that is available from the editor.)

Watersheds in Zone 6 with occupied behavior sites are presented in sequence from south-most to north-most.

FALL CREEK SUB-WATERSHED OF THE SAN LORENZO RIVER WATERSHED

The Fall Creek sub-watershed contains 3,148 acres, and its upper two-thirds is located almost entirely within Henry Cowell Redwoods State Park. In 2001 David Suddjian discovered a stand of old-growth and older second-growth forest on the Fall Creek Truck Trail. It is about 190 acres in size in two disconnected but close groves and extends over both state and private lands, although it is mostly within the state park (FE-4).

During two early morning surveys for forest birds he observed marbled murrelets, including occupied behavior. The current status of this local breeding area is unknown, as no recent surveys have been done in this area. This location represents the southern-most breeding area in Zone 6, and the only occupied murrelet site in the San Lorenzo River Watershed.

LAGUNA CREEK WATERSHED

Two areas of suitable habitat have been mapped within the Laguna Creek watershed totaling about 100 acres (FE-1/DA-7; FE-2/DA-8). This area was monitored with an acoustic recording unit in the summers of 2013 and 2015 and murrelet vocalizations were detected in both years in the southern stand (McKown and Fleishman 2015). No other information is available on this watershed and the CDFW database (CDFW 2016) has no information about it. Should it be that murrelets are breeding here, this would be the southernmost breeding locality in Zone 6, replacing Fall Creek which is 3.5 miles to the north.

SAN VICENTE CREEK WATERSHED

The San Vicente Creek watershed is 10,233 acres in size. Much of the watershed was formerly owned by the Cemex Corporation which operated a limestone quarry, a cement factory, and timber lands managed for wood production. Recently it was purchased by a consortium of local land conservancies and has been renamed San Vicente Redwoods. The property will be managed in separate units, some to be preserved and others to provide on-going timber harvesting.

There appears to be one small stand of old-growth on the property in the Mill Creek area, but it has not been surveyed. There definitely are 5 stands of older second-growth forest, totaling about 200 acres. A-V surveys were done in the largest of these stands in 2007 and 2008 and found no detections. Acoustic recorder units were deployed at 5 of the most promising locations, including Mill Creek, in 2015, but no detections were recorded. The CDFW Murrelet Database (CDFW 2016) shows no presence and no occupied behaviors found within this watershed.

SCOTT CREEK WATERSHED

The Scott Creek watershed is one of the larger watersheds in Zone 6 totaling 20,477 acres. Shortly before Scott Creek enters the ocean at a southeast heading its alignment changes to northwest to southeast. It runs roughly parallel to the coastline for about 3.5 miles until turning inland (to the northeast) after passing the confluence with Lair Gulch. Because of this peculiar alignment, several large sub-watersheds exist that drain the land up to the summit divide. From south to north these are Little Creek, Big Creek, and Mill Creek sub-watersheds. These sub-watersheds are remote, undeveloped, and have not suffered from the habitat fragmentation associated with human land use as is common throughout much of Zone 6.

The Lockheed Martin Corporation owns a large portion of the Big Creek and Mill Creek watersheds. The 2008 Lockheed Fire burned much of the Scott Creek Watershed including the sub-watersheds of Little Creek, Big Creek, and Mill Creek. Fortunately Lair Gulch and the main stem above Lair Gulch were largely spared. Fire intensity was geo-spatially variable. Its impact on the previously mapped stands of suitable habitat, primarily older second-growth with residuals, is unknown, although old-growth Douglas-fir trees would likely be highly vulnerable to destruction by fire. So when "suitable habitat" is mentioned in the following discussions about Scotts Creek sub-watersheds, it should be understood that if the habitat area lies within the burn perimeter, it might now be degraded in acreage or quality.

The Little Creek watershed is 4,469 acres in size. Little Creek contains no old-growth and only one stand of older second-growth with residuals (DA-19, 35 acres). This stand was surveyed 10 times in 2002, 10 times in 2003, 5 times in 2009, 5 times in 2010, and 5 times in 2015. In every case there were no detections. The 2009 Lockheed fire burned through this property and its effects were noted by 2015 A-V surveyor Mike Duffy, who said, "...it significantly altered the stand, killing off many Douglas-fir and pine trees. The overstory and understory canopies were reduced." He went on to say ".the loss of habitat from Douglas-fir mortality has diminished the stand's potential for murrelet occupancy."

Big Creek is the largest of the watersheds draining into Scott Creek but has received very little survey effort. Its 7,205 acres includes three prominent sub-watersheds, Berry Creek, Boyer Creek and Deadman Gulch. Potentially suitable murrelet habitat is scarce in the Deadman Gulch watershed, and there are no records of occupied behavior.

The Boyer Creek watershed has about 130 acres of potentially suitable habitat in one unprotected and fairly big stand (DA-5), but it has not been surveyed. The California Department of Fish and Wildlife has called this and other nearby habitat stands "some of the best [murrelet] habitat in the Santa Cruz Mountains." It is likely that nesting is occurring in this stand as surveys done in 1999 and 2000 by John Bulger near Big Creek Falls, which is well downstream, show murrelets flying upstream onto the Lockheed- Martin property, and this stand provides the best upstream habitat. Also upstream of the Falls is the Berry Creek sub-watershed which has two stands of potentially suitable habitat totaling 33 acres. Surveys were done at the larger parcel (DA-1, 27 acres) known as the General Smith stand. There were surveys done in 2002, 2003, 2010, and 2011. The only detections made were two distant detections in 2002, and the stand is not considered to be occupied.

The main stem of Big Creek has three identified stands of potentially suitable habitat totaling 42 acres. Surveys were done in 1999 and 2000 on the BCL property below Big Creek Falls, and two below-canopy detections were observed. However the observer, John Bulger, believes these were only birds flying

Appendix B—Murrelet Habitat Distribution by Watershed in Zone 6

through the property as it lacks habitat (Bulger, pers. comm.) He believes this site is on the flyway birds use to move from the ocean to upper Big Creek and Boyer Creek.

Murrelet activity in the Mill Creek Sub-watershed is poorly known. The Watershed is 8,800 acres in size but has only about 185 acres of older second-growth forest habitat. There apparently have been no A-V surveys done in the Mill Creek watershed. The CDFW database shows no sites with presence or occupied behaviors. **Murrelet A-V surveys are needed in this watershed to determine if murrelets are nesting there.**

A majority of the murrelet activity known from the Scott Creek Watershed is believed to occur in Lair Gulch and the main stem above Lair Gulch. The area from Lair Gulch to the Locatelli property upstream (BIBA-7) has been mapped as an Important Murrelet Area (Figure 2-16, Table 2-8). Lair Gulch (PO-2) is 184 acres of older second-growth with residuals owned by Big Creek Lumber and has been mapped as occupied habitat by the CDFW. A nest was found here in 1997 by tracking a murrelet that was caught and radio- tagged at sea. The nest failed (Baker et al. 2006).

The main stem of Scott Creek above Lair Gulch has slightly less than 300 acres of suitable habitat (all privately owned and not otherwise protected) in one piece divided between two owners. North of the property line is the Locatelli old-growth parcel of 38 acres (BIBA-7) which abuts two stand of older second-growth (BI-10, BI-11) totaling 57 acres. A nest was found here in 2001 by radio-tagging a bird at sea and tracking it inland. The nest failed (Baker et al. 2006).

On the south side of the property line, on Big Creek Lumber property, is a 115-acre old-growth stand (BIBA-5/DAVE-1) with occupied behavior.

About 3,000 feet further downstream is a 25 acre stand of older second- growth forest with residuals (DA-17). With two nests documented, and no nearby human developments or recreational improvements, this portion of the main stem plus Lair Gulch has been listed as an Important Murrelet Area (Figure 2-16, Table 2-8 , Chapter 2 – this Plan). Unfortunately, upstream of the Locatelli property there is little or no suitable habitat.

WADDELL CREEK WATERSHED

The Waddell Creek watershed contains Big Basin Redwoods State Park which has 4,400 acres of old-growth, approximately 40% of all the remaining old-growth in the Santa Cruz Mountains. With this much potentially suitable habitat it is not surprising that the Waddell watershed has historically been the stronghold of murrelet activity in Zone 6. A large portion of the watershed has been mapped as an Important Murrelet Area (Figure 2-16, Table 2-8, Chapter 2 – this Plan). Murrelets detected in this area have been shown to use a flyway that runs up Waddell Creek Canyon, starting near the creek mouth at Ano Nuevo Bay and extending upstream into the state park. Ano Nuevo Bay is known to be an important overnight murrelet staging area for murrelets nesting in the watershed (see Chapter 7 –this Plan). Because the canyon runs all the way to the coast with no intervening coastal plain, this is the only murrelet flyway that begins on the immediate coastline.

A threat to murrelets nesting in this watershed is the presence of a peregrine falcon nest located along the Waddell Creek Flyway. Peregrines are important murrelet predators, and this nesting pair may take 5 – 15 murrelets each season (see Chapter 4 – this Plan).

Much of the murrelet activity in the park has been recorded in the upper watershed of the east fork of Waddell Creek within a one mile radius of park headquarters. Fourteen murrelet nests have been found within this relatively small area, starting with the world's first Marbled Murrelet tree nest in 1974, and the most recent documented nest which was found in 2002 which failed due to raven predation (Baker et al. 2006; Binford, Elliott, and Singer 1975; Suddjian 2003). Nesting activity has also been documented by the occurrence of grounded fledglings found in the park. Between the years 1960 to 1996, a period of 37 years, 15 grounded fledglings have been found within the same area (Table 2-4, Chapter 2 – this Plan). Records of grounded fledglings are mostly missing from 1997 on, but this was the period of a greatly elevated raven presence in the park, and the number of chicks that would survive long enough to attempt fledging was probably much lower.

The Redwood Meadow survey station in Big Basin is one of only five long- term monitoring sites active to this day, and has data going back to 1991.

The data reveal a dramatic decline in murrelet activity (both total detections and occupied behavior) during the period 1998 to 2002, with activity levels after that date remaining low (Figure 2-11, Chapter 2 – this Plan). A-V surveys in the park have traditionally be done at several stations in the developed portion of the park east of Middle ridge, and all these areas have also had a similar collapse in murrelet numbers.

Corvid surveys have found there to be much higher than normal levels of these species in the park (Suddjian 2009b), which has many campgrounds, picnic areas, and other day-use areas where food scraps from park visitors provide a bonanza food source. In 2002, David Suddjian found there to be four raven nests located within 1 kilometer of park headquarters (Suddjian 2003). This is the same area in which many murrelet nests had been found in the past. The State Parks Department has implemented a Crumb Clean public education program, and several other programs to eliminate the corvid food subsidies provided by human food wastes, hoping to reduce corvid numbers and thereby increase murrelet numbers, but as of yet, murrelet activity levels have not increased.

Although the eastern, developed portion of the park has received a fairly regular A-V survey effort, the western part of the park, i.e., the West Waddell Wilderness Area located west of Middle Ridge, has received little survey effort. This western part of the park seems to have about as much old-growth forest habitat as the eastern portion, but only one nest has been found here. That nest was located near Berry Creek Falls and was found by tracking the location of a bird that was radio-tagged at sea in 2001. Old-growth in the western part of the park does not extend south of the confluence of Henry Creek and Berry Creek except for two stands located east and southeast of Chalks Mountain.

Only two A-V surveys are known to exist within this area. Both were done June of 1996—one on West Berry Creek above its confluence with East Berry Creek and one on West Waddell Creek near its confluence with Berry Creek. The first site had 41 total detections including 18 subcanopy flights. The second site had 29 total detections including 24 subcanopy flights (Spickler and Webb, 1996). **There is a great need for more surveys in this area of old-growth and should include the drainages of Berry Creek, Kelly Creek, Timms Creek, and West Waddell Creek within the park boundary.**

Old-growth forest does not extend further downstream along West Waddell Creek below the Berry Creek confluence, but second-growth forest that often contains some suitable nest trees is present. Several

Appendix B—Murrelet Habitat Distribution by Watershed in Zone 6

surveys in this area, included 9 surveys per year in both 2009 and 2010 have found presence but not occupied behavior. The observers felt that the detections they saw were associated with flyway flights. Radar surveys conducted near the mouth of Waddell Creek in several years spread between 1998 and 2009 (Figure 2-9 page 19, Chapter 2 – this Plan) confirmed that this is a murrelet flyway and that it was used by birds commuting from the ocean to Big Basin State Park.

CASCADE CREEK WATERSHED

The Cascade Creek watershed is a small watershed of about 2,000 acres. Suitable habitat is found on a 581 acre parcel owned by the Holmes family and surrounded on three sides by state park land. It is known to contain 260 acres of old-growth forest (Singer and Carter 1992). Although no A-V surveys have been done on the property, two observations from the state park land looking into the Holmes parcel in 1988 detected subcanopy flight, making this an occupied site. In 1990 another observation found "presence" on the Holmes old-growth parcel. The most recent observation was by David Suddjian in 2002. He recorded five detections of murrelets flying up and down the canyon at the property line. There have been no observations since then, and new surveys are needed to see if this site is still being used.

This parcel is of special interest for two reasons. In 1992, the U.S. Fish and Wildlife Service thought highly enough of its habitat quality to recommend that it be acquired as a protected reserve for Marbled Murrelets (Singer and Carter, 1992). It was intended as compensation for murrelets killed in the Apex Houston oil spill of 1986, and to be purchased using oil spill mitigation funds. Although the funds became available, the property owner was not willing to sell, so the acquisition never occurred.

This parcel is also of interest since a logging operation in 1987–1988 removed all the old residual Douglas-fir from an upland Douglas-fir stand that bordered the two other stands mentioned above. This was probably one of the last occupied habitats to be logged in the Santa Cruz Mountains. It was reported that murrelets could be seen circling and flying over the site at the same time as trees were being felled (Naslund, pers. comm.).

WHITEHOUSE CREEK WATERSHED

The Whitehouse Creek watershed is a small watershed of less than 3,000 acres. It contains about 50 acres of potential habitat divided between two stands of older second-growth with residuals. Occupied behavior has been detected only at the stand at the head of the creek (FR-15, 32 acres) which was purchased a few years ago by the Sempervirens Fund and is now part of Big Basin State Park. The other stand is in Skylark Ranch owned by the Girl Scouts of Northern California, and its potentially suitable habitat is protected by a conservation easement that prohibits logging.

GAZOS CREEK WATERSHED

The Gazos Creek Watershed is a moderately small watershed of 7,472 acres. Gazos Creek begins just outside the northwest corner of Big Basin Redwood State Park and enters the ocean at a point about half-way between Pigeon Point and Franklin Point. Along with Waddell Creek, it is one of the least developed watersheds in the Santa Cruz Mountains, and also lacks the campgrounds and picnic areas found in the Waddell Watershed. However it does have two small areas of widely-space rural homesites, on Old Womans Creek and on the South Fork of Gazos Creek. Ownership of the forested portion of the Watershed is primarily Redwood Empire Timber Company, Big Creek Lumber Company, the Ainsley

Family Trust, and the State Parks Department. Logging has been a major activity in this area and continues to this day. Only three stands of old-growth are present – a 10 acre stand on a steep hillside at Gazos Mountain Camp (FRPO-10), the Bryan Grove (FAPO-1), which is 70 acres, has had some early-day minor tree cutting, and is part of Big Basin State Park, and a 42-acre stand with two sub-units owned by Big Creek Lumber (FRPO-7). There are also nine stands of older second-growth with residuals, on private land. These range in size from about 10 to 100 acres, totaling 330 acres, and provide nesting habitat for murrelets.

For such a heavily logged watershed, there is a surprising amount of murrelet activity. A-V surveys have been conducted at Gazos Mountain Camp, a unit of Butano Redwoods State Park, almost every year since 1998; and in 2010 through 2012 a large number of A-V surveys were conducted on Redwood Empire lands east of Gazos Mountain Camp for several different timber harvest proposals. Overall, the upper Gazos Creek Watershed probably ranks third of the most intensely surveyed areas in Zone 6, following Butano South Fork, and Big Basin State Park. These survey results suggest that birds flying upstream do not continue beyond the Redwood Empire property and thus do not cross over the ridge to enter the Opal Creek Watershed in Big Basin State Park. Thus the Gazos Creek Flyway does not appear to be a murrelet "commute" route between the ocean and Big Basin State Park.

The watershed lands further inland of the junction of Barranca Knolls Road are almost all managed for timber production. They have been subject to selective harvest logging over the last 45 years. Many large and deformed trees, probably unsuitable for the mill, yet suitable for murrelet use, were left in place, and these residuals are applying the nesting sites for today's population of murrelets. Murrelet persistence in this watershed has no doubt been aided by the fact that this type of land use has kept residential, agricultural, and improved recreational uses from occurring and modifying the landscape in such a way as to increase corvid numbers.

Suitable nesting habitat in the Gazos Creek Watershed is close to habitat in the Butano Creek Watershed, and portions of each have been combined and mapped as Important Murrelet Area #2 (Figure 2-16, Table 2-8).

BUTANO CREEK WATERSHED

Butano Creek is a large watershed (about 12,000 acres) with three major sub-watersheds, Little Butano Creek, South Fork, and North Fork, all of which have occupied behavior. Within the forested part of the watershed, the only human developments are the state park (which has a campground and a picnic area) and, on the main stem of Butano Creek, the small gated residential community of Butano Park Colony, located just downstream of Butano Falls.

The main stem of Butano Creek also has two stands of old-growth with occupied behavior – the Girl Scout Creek stand (FRPO-6, 53 acres) and the Big Creek Lumber Conservation Easement Stand (Butano Falls, FRPO-8, 70 acres). Also adjoining these is one stand of older second-growth forest (FR-

1) consisting of 128 acres on or near the Butano Girl Scout Camp. Taken together, these areas comprise a suitable habitat patch of 250 acres in size.

This complex is divided by Canyon Road which ends at the Butano Colony. The Butano Falls property (actually located downstream of both the Colony and the actual waterfall) has a conservation easement

Appendix B—Murrelet Habitat Distribution by Watershed in Zone 6

held by the Pacific Forest Trust that protects the trees from logging. Occupied behavior was found here by David Suddjian in 1991 (Suddjian, pers. comm.). A number of A-V surveys were performed at the stand during several years between 2002 and 2011. The results are summarized in Table 2-4 (Chapter 2 – this Plan).

Little Butano Creek sub-watershed contains Butano Redwoods State Park which has an estimated 625 acres of old-growth and likely more than 100 acres of older second-growth that has not been delineated, but provides suitable nesting habitat. The old-growth forest is in 3 stands, two in the western half of the park, the Little Butano Stand, totaling 320 acres and one in the eastern part, the North Slope stand, totaling 280 acres, however most of this is in the South Fork of Butano Creek Sub-watershed.

The Little Butano stand has the highest current murrelet activity level of any site in the Santa Cruz Mountains (Table 2-5, Chapter 2 – this Plan). Sub-canopy flights and wing sounds (up to 28 wing sound detections in a single morning) are common here. The station itself is located in a patch of older second-growth with residuals, but large stands of old-growth exist in both the up canyon and down canyon directions. Few ravens are detected during the dawn A-V murrelet surveys.

The South Fork Sub-watershed is an undeveloped forest landscape with its only human development being Camp Cutter, a boy scout camp, located on a ridge at its very headwaters. The South Fork contains harvested lands of the Big Creek Lumber Company as well as the Butano State Park North Slope grove of old-growth, about 260 acres in size. This area was the subject of the most intensive murrelet monitoring efforts ever undertaken in the Santa Cruz Mountains (Habitat Restoration Group 1992, Suddjian 2003). From 1990 to 2001, over 1000 A-V surveys were conducted at over 40 different survey stations. These surveys found that murrelets were nesting in the North Slope stand and that murrelets were not nesting on Big Creek Lumber lands. They also found that murrelets were using the Big Creek land as flyways to approach the North Slope stand, were performing social flights over the BCL land, and also that murrelets using the North Slope stand did not approach it from the Little Butano Creek Watershed. This last finding suggests that murrelets nesting in the Little Butano Stand are a separate group of birds from those using the North Slope stand.

Activity levels in the North Slope stand in the South Fork sub-watershed were fairly high with occupied behavior regular, and conclusive evidence of nesting was found in the form of a nest (found in 2000), 2 eggshell finds, and 2 grounded fledglings found (Table 2-2, Chapter 2 – this Plan). This would seem to be an important murrelet breeding site, however no surveys have been done since 2001, and its current status is unknown. New A-V surveys are needed, especially in light of the fact that a peregrine falcon nest is known to exist near the North Slope old-growth stand.

David Suddjian found a peregrine nest along the South Fork Flyway near the North Slope murrelet nesting area. During the period 1997 – 2003, the only time in which A-V surveys were conducted along the flyway, peregrines were observed to attack 13 murrelets, with 5 sure kills (Suddjian 2003; Chapter 4 – this Plan).

The North Butano sub-watershed is the largest sub-watershed and is currently used only for timber harvesting. Big Creek Lumber and Redtree Properties own a large component of it. One exception is the 160-acre Sinnott parcel owned by the Sempervirens Fund not far from the Butano Colony. The Sinnott parcel contains a portion of an 57-acre older second-growth stand (2 groves) (FR-4) that is shared with

Appendix B—Murrelet Habitat Distribution by Watershed in Zone 6

Big Creek Lumber property on the south side. A-V surveys were done in 2005 and 2006, and found murrelets to be present, but no occupied behavior was seen. Only one stand of suitable habitat (with 4 sub-units) (BIBA-6, 32 acres) is located in the upper end of the sub-watershed, and has occupied behavior. A small 40-acre parcel of Pescadero Creek County Park extends south from Butano Ridge into Butano North Fork Sub-watershed. It has 20 acres of old-growth with occupied behavior. Despite the limited amount of suitable habitat in the middle and upper watershed, "presence" has been documented throughout its entire length.

PESCADERO CREEK WATERSHED

The Pescadero Watershed is the second-largest watershed in the Santa Cruz Mountains (38,143 acres) and encompasses a wide variety of different land uses including rural residential, timber production, small scale agriculture, youth camps, and park lands. In terms of existing murrelet habitat, this watershed contains about 4,000 acres, a figure which is second only to the amount of habitat in the Waddell Creek Watershed.

In addition to the large amount of habitat available, another favorable aspect of this watershed for murrelets is that there are no peregrine falcon nests located along the Pescadero Creek Flyway (29) and the only peregrine nest (not confirmed yet) is in the Devil's Canyon area at the headwaters of Peters Creek, which is inland from any known murrelet nesting areas.

Habitat lands include almost 3,200 acres of old-growth divided among eight stands ranging in size from 25 acres to 974 acres in size. Seven of the eight stands have shown occupied behavior and the eighth stand, although never surveyed, is located close to a stand with occupied behavior. Habitat also includes 14 stands of older second-growth on private lands totaling 800 plus acres, and ranging in size from 6 acres to 430 acres. Few of these stands have been surveyed, and only one is known to have occupied behavior. Also part of the 4,000 acre total is an estimated 400 acres of undelineated second-growth with residuals found in Pescadero Creek County Park and Portola State Park. Within Pescadero Creek County Park, occupied behavior has been detected on parts of the undelineated older second-growth forest containing residuals.

One stand located just outside the watershed, in the San Gregorio watershed to the north, is closely associated with older second-growth stands of the Jones Gulch YMCA Camp. It is the Sam McDonald County Park stand consisting of 24 acres of occupied old-growth forest (LAHO-3). This stand occupies the ridge separating the two watersheds and the north-facing slope. It is likely that birds approach it from the Pescadero Watershed. No surveys have been done there since the pioneering work of Carter and Erickson (1988) in 1987.

Most of the potential nesting habitat in the Pescadero Watershed can be found in two large clusters each containing small areas of non-habitat mixed within. The first cluster, called the Lower Pescadero Creek Cluster, begins about 4 miles from the coast with the Michelsen stand of old-growth stand of Douglas-fir (LAHO-8, Dearborn Park) protected from cutting by a conservation easement from POST. No murrelet surveys have been done on this property. This cluster continues upstream with the Big Creek Lumber property (LAHO-8 and LA-7) that contains Hidden Gulch and Dearborn Valley. Adjoining these stands are 430 acres of older second-growth (FR- 14, LA-7). Nearby to the east is a 56 acre of older second-growth (LA-5) which in turn touches on the corner of Memorial County Park (LAHO-5). This cluster,

Appendix B—Murrelet Habitat Distribution by Watershed in Zone 6

which has been mapped as Important Murrelet Area #1 (Table 2-8, Figure 2-16, Chapter 2 – this Plan,) ends with Memorial County Park. This Important Murrelet Area contains about 2,600 acres of which 1,110 acres (43%) are potentially suitable habitat.

In a long-term A-V monitoring effort from 2003 to 2014 (Shaw 2011, Singer 2015), Memorial County Park consistently had the lowest number of total detections of the five parks surveyed each year – Big Basin, Butano, Gazos, Portola, and Memorial . Memorial and Big Basin consistently had the fewest detections. Memorial and Big Basin are similar in that they both have heavy recreational use and a high density of resident corvids (Halbert 2015).

Although no early survey records from Memorial are available, it is believed to have once supported higher numbers of murrelets. A total of five grounded fledglings have been found in the park or in Loma Mar next door, but they were all found before 1989 (Table 2-2, Chapter 2 – this Plan). The dense packing of campsites and other recreational facilities in the park has led over the year to a fairly thorough safety pruning of trees that removed many suitable murrelet nest platforms from the trees (Singer, pers. obs.). At the same time that habitat was being degraded, it is likely that raven numbers were increasing, and the combination of the two likely created a severe blow to murrelets that were trying to nest successfully in the park.

The other landscape cluster, called Middle Pescadero – Portola, has been designated as Important Murrelet Area #5 with a total area of about 7,200 acres (Figure 2-16, Table 2-8, Chapter 2 – this Plan). It begins with Pescadero Creek County Park and extends in the upstream direction. Included in the park are several old- growth stands (LAHO-7 and MIHI-5). Other habitat in this cluster is the Valley of the Giants stand on the Jones Gulch YMCA camp (LAHO-6, LA- 2), Portola State Park old-growth (MIHI-4), the Middleton Tract old-growth now part of the park (MIHI-3), Portola older second-growth (MI-2), and Pescadero Creek – Bear Creek older second-growth (MI-1). All together, this cluster contains about 1,860 acres of potential nesting habitat, about half of which is in Portola State Park. However, the actual amount of habitat in this cluster is likely to be significantly larger since older second-growth forest habitat in Pescadero County Park has not been delineated and is sure to be 200 acres or more.

The Upper Pescadero Watershed upstream of Portola State Park contains very little habitat. It is almost entirely managed second-growth timberland, mostly owned by Redtree Properties. One notable stand of older second- growth with residuals is Water Tank Creek (BI-9) which encompasses 40 acres. Occupied behavior was observed there in 2007 by John Bulger.

Isolated peripheral and minimally occupied sites like this might serve as an indicator of how the population as a whole is doing. If the overall population is declining, these marginal and peripheral sites might be expected to blink out first.

SAN GREGORIO CREEK WATERSHED

San Gregorio is one of the three largest watersheds in the Santa Cruz Mountains (33,322 acres), but has only about 260 acres of old-growth forest and about 135 acres of older second-growth forest, with most of this habitat being found inside the El Corte de Madera Sub-watershed. It was not part of the CAPP project area, so the amount of older second-growth forest present is unknown. However, older second growth forest suitable for nesting has been found on the El Corte de Madera Open Space Preserve (135 acres in two stands with three subunits each) by H.T. Harvey and Associates (2007) and on the Gerber Forest

property (WOOD-2, Young) located south of the open space preserve and containing 48 acres of younger old-growth forest.

Publicly-owned old-growth forest is found at Heritage Grove (MIHI-1, 29 acres), at McDonald County Park (LAHO-3, 24 acres), and at the old Woodhaven Camp (LAHO-10, 26 acres). Privately owned old-growth is found at Lower Mindego Creek (LAHO-2, 24 acres), at Redwood Terrace (LAHO-12, 17 acres), and at stands located on Lower and Middle El Corte de Madera Creek (LAHO-1, 68 acres, LAHO-4 and WOOD-2, 45 acres). It should be noted that only one of the private sites have been “ground-truthed”, and some of the mapped old-growth may have been logged since it was mapped.

There are relatively few records of murrelet activity in this watershed. Occupied behavior is known from the McDonald County Park and Lower Mindego Creek sites, and presence only is known from El Corte de Madera Open Space Preserve (a few sightings) and the Gerber Forest property (a.k.a., Young) just south of it. The largest old-growth stand in the Watershed is the 68 acre stand on lower El Corte de Madera Creek, which was surveyed three times in 1993 and had no detections (Singer and Fiedler 1994).

Although no occupied behavior or other evidence of nesting has been recorded for El Corte de Madera Open Space Preserve, it is believed to be used for nesting. Surveys were done as part of a THP proposal for the adjoining Gerber Forest (WOOD-2) in 2004 and 2005. Twenty-one A-V surveys were done by Matt Greene at various stations and 9 detections of birds were noted and no occupied behaviors. He considered the Gerber property to be marginal habitat. In all but one case, the birds were flying downstream suggested to the surveyor that the Gerber Stand was in a flyway used by birds nesting in the El Corte de Madera Preserve (Greene 2005).

Since the Preserve provides the only habitat further upstream, this would seem to be the case. **A-V surveys are needed within the Preserve to confirm that nesting is occurring.**

TUNITAS CREEK WATERSHED

The Tunitas Creek Watershed (7,886 acres) is a moderate to small sized watershed that lies between the large San Gregorio Watershed and the small Lobitos Creek Watershed. It is mostly managed timber lands with little residential development. It contains no park or open space preserves.

It contains only 13 acres of old-growth divided among two sub-units near the creek (mapped as one stand, WOOD-4). The amount of older second- growth forest containing residuals is unknown, as it was not part of the CAPP project in which such stands were identified. The CDFW database (2016) contains no records of murrelet occupied behavior, and it is assumed to not be breeding habitat.

PURISIMA AND LOBITOS CREEK WATERSHEDS

These two watersheds together comprise 9,700 acres. There is very little suitable murrelet habitat in this area, yet murrelet occupied behaviors have been observed here, although no recent surveys have been done. The only available habitat is in the Purisima Creek Open Space Preserve. It contains 61 acres of mapped old-growth in three stands with five sub-units (WOOD- 1, WOOD-5, and WOOD-6) mapped by H. T. Harvey and Associates (2007). Some additional older second-growth with widely-spaced residuals is also present, but has not been mapped. A small, but typical, portion of the Preserve's second-growth at the confluence of Grabtown Gulch and Purisima Creek was assessed by eye in 2001 and found to have only one potentially suitable nest tree per every 14 acres (Singer, 2001).

Appendix B—Murrelet Habitat Distribution by Watershed in Zone 6

Murrelet presence has been documented by A-V surveys on Purisima Creek at different stations in 1992 (3 surveys), 1994 (5 surveys), 1996 (4 surveys), and 2001 (1 survey). One radar survey was done in 2001, on the hillside above Purisima Creek, and recorded 8 detections. None of the stations were in or adjacent to suitable nesting habitat, instead being found near to the type of habitat to that is described above, i.e., a stand containing a very few widely scattered potentially suitable nest trees.

A total of 71 occupied behaviors have been observed. All but one of these occurred on two days. Forty-eight (48) occurred on July 10, 1994, being made by what seemed to be only one or two birds repeatedly doing landings and brief “touch-downs” in one specific tree which lacked any suitable nesting platforms. On July 12, 1996, 23 subcanopy detections were made by what appeared to be two birds repeatedly zooming between the same group of trees bordering the creek.

On July 20, 2001, while doing an A-V survey on the hillside above the stations mentioned previously, only four murrelets detected, but 24 ravens were seen flying out of the canyon and more were heard calling. On the drive in to site it was noted that the canyon was occupied by a large roost of ravens, an estimated 30 – 60 individuals. This may explain why so few murrelets were detected.

In 2002, on August 30, a grounded fledgling murrelet was found at a location intermediate between the two stations where all the occupied behaviors had been seen.

There have been no recent surveys, and new surveys are needed to verify that nesting is still occurring here.

PILARCITOS CREEK WATERSHED

The Pilarcitos Creek Watershed extends from the ocean near Half Moon Bay to Pilarcitos Lake in the San Francisco City Watershed lands, encompassing about 1,650 acres. Most of this watershed is a highly fragmented landscape with many residential, commercial, and agricultural land uses in place and a major highway that parallels the creek, used by workers who commute from Half Moon Bay to the San Francisco Bay area.

In contrast, the extreme upper end of the watershed is undeveloped and largely off-limit to human entry. The San Francisco Public Utility District owns a large acreage that includes the second-largest old-growth stand (MOMO-1, 1,138 acres) remaining in the Santa Cruz Mountains. Murrelet use, including occupied behavior, has been documented in this area since 2005, although only in the downstream lowland area of the stand. A-V surveys have been conducted annually since then, and it is one of only five locations that are surveyed each year. Murrelet activity levels are relatively low (Table 2-2, Chapter 2 – this Plan) in the surveyed area, however the majority of the old-growth stand is difficult to access and has never been surveyed.

Surprisingly, beyond the regular detections of occupied behavior, there has been no other evidence of nesting, although it can assumed to be occurring.

This site is the northern-most murrelet breeding area in Zone 6, and is separated from the next closest breeding area to the south, which is Purisima Redwoods Open Space Preserve, by about six miles, and there is no potentially suitable nesting habitat found between the two sites.

Appendix B—Murrelet Habitat Distribution by Watershed in Zone 6

The greatest threat to this breeding area is wildfire. This stand is dominated by mature Douglas-fir trees with no redwoods present. Douglas-fir forests are more susceptible to damaging crown fires than are redwood-Douglas-fir forests, and individual Douglas-fir trees are much more likely to die from wildfire than individual redwood trees (Sugihara, et al, 2006).

The Upper Pilarcitos Old-growth Stand has been designated as Important Murrelet Area #7 (Figure 2-16, Table 2-8, Chapter 2—this Plan). There are no known peregrine falcon nests within this Area or along the likely route, Pilarcitos Creek Canyon, that murrelets would take flying from this site to the ocean and back.

APPENDIX C—ADDITIONAL RECOMMENDATIONS FROM INDIVIDUAL CHAPTERS

Data gaps, information needs, research or monitoring efforts advocated by the authors, if not included in their chapters, are included in this appendix.

CHAPTER 2. MURRELET INLAND DISTRIBUTION AND DETECTION NUMBERS IN ZONE 6

—Prepared by Steven W. Singer, M.S., Consulting Forest Biologist

High Priority Recommendations:

1. Continue pre-harvest inspections by the California Department of Fish and Wildlife (CDFW) and the requirement to do A-V surveys on timber lands that contain suitable murrelet habitat. Mitigation measures proposed by CDFW should be rigorously enforced.
2. Encourage the protection, through acquisition or easement, of all privately-owned important murrelet stands. These include: Scott Creek–Locatelli, Scott Creek-Big Creek Lumber (BCL), Hidden Gulch-BCL, Dearborn Valley-BCL, Cascade Creek, and the Middle Gazos Creek Grove on the Redwood Empire property.
3. Prevent increased human disturbance on all publicly-owned occupied murrelet stands that are otherwise distant from sources of anthropogenic disturbance. Apply management actions or use restrictions to these areas: Little Butano Creek old-growth stand east of campground, North Slope old-growth stand in Butano State Park, Gazos Mountain Camp of Butano State Park, Pescadero Creek County Park, and the Peters Creek Grove in Portola State Park.
4. Focus conservation and recovery efforts within the mapped Important Murrelet Areas (Figure 2-16 page 29). Protecting occupied stands within these areas should be the highest priority along with protecting and enhancing the buffer or future habitat value of intervening non-habitat lands. This applies to all the following recommendations as well.

Other Recommendations:

1. Continue the annual A-V surveys at three or more of the long-term survey stations including Big Basin. Detection analysis should include the metric, single silent birds below one canopy.
2. Curtail new developments or activities on publicly-owned murrelet habitat that would increase human use or disturbance.
3. Establish buffer areas, preferably of non-habitat forestland, around important murrelet breeding stands through acquisition, easement, or land use regulations.
4. Expand the public education program on garbage control and the prohibition of wildlife feeding to all lands within or bordering the Important Murrelet Areas, especially youth camps, farms, recreational sites, and residential/commercial sites. Hire a public education specialist to work with the local community in an expanded “Crumb Clean” campaign.
5. Create a secure internet site to archive all marbled murrelet research and monitoring information for Zone 6. Collaborators could be State Parks, San Mateo County Parks, Midpeninsula Regional Open Space District, the San Francisco Public Utilities District, and the Santa Cruz Mountains Bioregional Council. The California Department of Fish and Wildlife and the U.S. Fish and

Wildlife Service would also be invited to participate. The purpose would be to archive research and monitoring information and make it available to government agencies, land managers and researchers.

CHAPTER 3. CORVID PREDATION OF MURRELETS IN ZONE 6

Subchapter—Management of Crows and Ravens, prepared by William C. Webb, PhD.

Suggestions for Future Research

The following are research suggestions for an improved understanding of the distribution, behavior and life histories of corvid populations in the Santa Cruz Mountains. The goals of pursuing this knowledge is to reduce knowledge gaps in support of management actions that reduce the risk of nest predation of murrelets by crows and ravens in the Santa Cruz Mountains.

1. Quantify the abundance and distribution of crows and ravens at multiple scales (*e.g.* forest stand, management unit (park level), watershed, and regionally). Using geospatial analyses, compare spatial variation in relative abundance with land cover and land use patterns to quantify the relative importance of land cover and land use patterns to corvid populations. The results of these analyses can be used to develop predictive models of crow and raven abundance throughout the Santa Cruz Mountains, compare abundance with murrelet habitat and identify areas with the greatest need for corvid management.
2. Identify point subsidies (landfills, ranches, agricultural fields, etc.) attracting and potentially sustaining large, regional numbers of surplus individuals in the Santa Cruz Mountains and nearby areas. This can be accomplished using corvid census techniques or radio-tagging nonbreeding individuals. These individuals serve as potential immigrants to vacancies created by territory holders in murrelet nesting habitat that die from natural causes or are subject to lethal removal.
3. Using radio-tagged individuals, identify land cover and land use patterns in the Santa Cruz Mountains which influence crow and raven survival and reproduction.
4. Conduct behavioral experiments using simulated nests to investigate factors associated with nest predatory behavior of crows and ravens. Results from these types of behavioral experiments lend insight into ecological conditions that increase the risk of nest predation. Predictor variables for investigation could include relative abundance of crows and ravens in addition to habitat characteristics such as habitat composition and configuration. Experimental results can be extrapolated to larger spatial scales to generate spatial models of the relative risk of nest predation by crows and ravens in murrelet nesting habitat. Note that simulated nests need not mimic murrelet nests to be informative.
5. Investigate crow and raven foraging behavior and diet composition in murrelet nesting habitat. This could be accomplished in conjunction with corvid census techniques, examining stomach contents of dead birds, or by following radio-tagged individuals.
6. Experiment with the use of reproductive control techniques, including sterilants and egg oiling.
7. Determine to what degree effigies alter the behavior of crows and ravens, especially to what degree they change the habitat use of territory holders within their home ranges. Effigies can be

Appendix C—Additional Recommendations from Individual Chapters

obtained from individuals killed through lethal removal or obtained from birds euthanized at wildlife rehabilitation centers.

8. Develop demographic models of crow and raven populations in the Santa Cruz Mountains. The models can be populated using life history data collected elsewhere, or from future data collected in the Santa Cruz Mountains. Demographic models can be used to project future population growth of crows and ravens and be combined with distribution data to generate spatial models of the relative risk of nest predation to murrelets across the Santa Cruz Mountains. The models can be manipulated to project the effects of different management actions on crow and raven population growth and can also be used to predict spatial variation in the relative risk of nest predation to murrelets under different management actions.

Subchapter—Management of Steller’s Jays, prepared by Elena H. West, PhD Candidate

1. Expand on the Crumb Clean Campaign to broaden outreach and effectiveness. Require all park visitors to sign forms saying they understand it is illegal to feed wildlife or leave food and toiletries out in campsites.
2. Improve enforcement of park policies by hiring additional staff to patrol campsites and picnic areas.
3. Experiment with effigies and hazing techniques targeted at jays in campgrounds in order to behaviorally “de-condition” them from exploring picnic tables and campsites for food.
4. Monitor Steller’s jay diet composition to determine if trash management and visitor education efforts have reduced the proportion of anthropogenic food subsidies to jays in campgrounds; compare results to findings from West et al. (2016).
5. Continue monitoring Steller’s jay abundance in Big Basin Redwoods (and potentially others) to determine if trash management and visitor education efforts have reduced jay densities in campgrounds; compare results to findings from West et al. (2016).
6. Conduct research to identify the nest predator community in key marbled murrelet nesting areas (i.e. Big Basin Redwoods and Butano state parks), which should improve the ability to relate nesting success to nest predator occurrence. Campground areas in these parks have a suite of potential predators, including mammalian predators that have become habituated to human activity and anthropogenic food in these areas. Understanding the role of these predators in murrelet nest predation, by studies of real or artificial nests would provide land managers with a more complete understanding of which predators are of greatest concern.
7. All corvid management activities should be conducted in parallel with effectiveness monitoring studies.

CHAPTER 4. PEREGRINE FALCON PREDATION OF MURRELETS IN ZONE 6

—Prepared by Craig Himmelwright, DVM, Biologist and Consultant

Specific Recommendations

1. For the next three years conduct an occupancy and breeding surveys for peregrine nesting territories located near local murrelet nesting groves and flyways. Several are already known, and suitable nesting substrate (cliffs) can be checked for new sites. The purpose would be to find active nest sites, confirm seasonal timing of egg lay, hatching, and failure or fledging, numbers of fledged young if successful, and dispersal timing of falcons post-breeding. In addition, early morning foraging observations can be conducted, preferably in May, June and July. Findings will also allow comparison of murrelet detection surveys between marbled murrelet nesting areas and flyways subject to potential predation by peregrine nesting pairs, and areas that no such pressure may be present. At least three years of search are needed because Peregrines don't breed every year.
2. If artificial nesting sites are present, they should be removed or exclusion barriers placed to prevent access. In addition, any artificial structure that provides hunting perches over areas of murrelet activity should likewise be removed or fitted with deterrent devices. While this is unlikely in the Zone 6 management area, it must be considered, as peregrines frequently utilize anthropogenic substrates and structures when available.
3. When active nests are found, these sites would then be climbed to collect prey remains and fecal material from nests, prey caches, "plucking ledges". The prey remains would then be targeted for analysis including DNA sequencing to determine peregrine diet.
4. If foraging observations or collection of prey remains confirm some predation on murrelets, but at only a minor level, first consider decreasing overall predation pressure by increasing management of corvids at murrelet nesting areas. This can be done with any nesting area, or specifically with nesting areas and flyways not impacted by peregrines.
5. If it is determined that peregrines are taking numbers of murrelets that are demographically significant according to best available models, then more direct management can be taken to reduce the number of peregrines and shorten their breeding season.
 - The easiest technique, involving only one climb, is to remove the nestlings early, and release them through hacking at a distant location. This results immediately in lower predation pressure, and can shorten the time period the adult peregrines stay in the nesting area.
 - Another technique is that a nest can also be climbed earlier in the incubation phase, eggs removed and hybrid or falconry
 - bred chicks placed in the nest for 12-14 days, then removed. This shortens the breeding season even more dramatically, and insures the female will likely not lay a second set of eggs, and the young do not have to be hacked, which is expensive. However, this technique requires a take permit for the eggs, and two climbs.

In either case, there is the potential to remove or dramatically reduce localized peregrine predation by the month of May, or possibly earlier. As the majority of observed predation events

upon murrelets at Butano Creek occurred in June or July (9 of 13) it may be possible to reduce peregrine predation on murrelets by more than 50%.

6. It is not recommended to perform simple egg set removal or addling, as pairs frequently re-nest, and can stay a prolonged period in the area before laying a second egg set. Further, peregrines often re-nest at an alternate cliff site when available in the breeding territory, making field logistics and observations potentially more difficult and less predictable. Nor is trapping of breeding pairs recommended for the purpose of either translocation, or holding captive during murrelet breeding season. There are currently too many “floater” adult peregrines available to reoccupy vacant nest sites.

CHAPTER 5. EVALUATION OF NOISE IMPACTS ON MURRELETS IN ZONE 6

—Prepared by Richard T. Golightly, Dept. of Wildlife, Humboldt State University

1. Marbled Murrelet biology suggests that the risk of impact from noise varies with the hour of the day, the phase of nesting, and throughout the year.
2. The appropriate measurement of noise amplitude (loudness) and character (frequency, duration, time to maximum amplitude) is at the location of the individual marbled murrelet and it's nest, rather than the source. Measurement of sound should occur either at the nest site, the nest tree, or be calculated based on distances from the source (for examples see USFWS 2006, Singer and Houston 2012).
3. Because noise varies considerably through space, noise and associated impacts should be assessed on a case-by-case, project-by-project basis.
4. Project planners should strive to characterize the type of sound and not work simply with the loudness (amplitude). Additional characteristics that should be considered include duration, injection of new sound, background levels, sudden sounds, and very low frequency sound (which is poorly understood).
5. Project managers need to overtly distinguish between projects that are within nesting stands and those that are external to the nesting stands in each analysis and take care that the measurements and assumptions are appropriate to each situation.
6. Project planning should consider noise minimizations and equipment attributes specific to that project. These should be monitored for consistency and compliance. Very loud noise production should be limited to short durations when near a nest or in nesting habitat.
7. Loud impulsive noise that quickly reaches maximum amplitude (e.g. gun shots, explosions, felling of large trees) should be completely avoided at any time during the actual nesting season, and year-round for 1 hour before to 1.5 hours after sunrise.
8. Equipment can be extremely variable in noise production (from machine to machine, and based on task) and empirical measures should be made to ensure that they operate within planned guidance. Amplitude can be measured with sound meters (and for consistency reported in dB, C-weighted)
9. Efforts should be made to ensure that corvids are not trained by the association of specific noises with food rewards.

10. Any noise that causes flushing, or that could cause flushing, should be considered harmful. Generally, sudden noise, novel noise, or noise that is very loud (+90 dB) should be considered as having the potential to cause flushing.
11. Thresholds for chronic noise, changes in background noise, or changes in frequency to cause damage are unclear. However, at all times during the nesting season and year-round from 1 hour before sunrise to 1.5 hours after sunrise should have additional noise restrictions to include any chronic noise production or new noise that is 30-35 dB above background. These noises should be carefully evaluated, and to the extent possible minimized.
12. It is reasonable to consider the adjustments to the timing of noise restrictions to match the timing of greatest risk. Research conducted since the original establishment of recommendations for noise restrictions suggests that there is need to reconsider the exact dates and timing of imposing restrictions, as well as the level of acceptable noise during those periods of noise restriction. Improved match of risk could allow projects or other activities to occur later in the spring or earlier in the fall, as well as provide additional protections that do not presently exist. This potential to adjust the timing of restrictions requires additional information on the current timing of inward flying murrelets, possibly using radar techniques, and subsequent discussion between researchers, land managers, and the regulatory agencies.

CHAPTER 7. MURRELET AT SEA ABUNDANCE, PRODUCTIVITY, AND PREY RESOURCES IN ZONE 6

—Prepared by R. William Henry, PhD, Principal, Integrated Ecology

Research Recommendations

1. Continue at-sea monitoring as it is the most effective method for monitoring the entire Zone 6 murrelet population, recognizing that population estimates will likely vary considerably from year to year due to movements of murrelets in and out of the survey area.
 - Analyze existing data on at-sea populations, at sea distribution, and reproductive success (based on at sea ratios) in relation to ocean conditions, distance from shore, depth, measures of prey availability and other continuous variables.
2. Investigate the connection between at-sea prey base and murrelet population dynamics.
 - Collect background prey base metrics from static stations or vessel born instruments.
 - Continue to investigate prey resources used in Zone 6 through DNA analysis of feces
 - Complete mass balance analyses of regional impact of fisheries, especially that of the market squid. Include trophic transfer to other species that consume squid are or produce murrelet prey.
 - Evaluate the impact of Año Nuevo Marine Reserve on murrelet prey.
 - Consider use of “proxy” species with similar diets locally but for which monitoring of reproductive success would be easier (e.g., Pelagic Cormorant)
3. Assess at-sea distribution during the non-breeding season. This would be extremely challenging given large area and predicted densities of wintering murrelets.
4. Investigate how at-sea and terrestrial distribution change over time.
 - Model of at-sea distribution over time with random effects of SST, upwelling, and other at sea variables.

Appendix C—Additional Recommendations from Individual Chapters

- Examine at-sea distribution in relation to watershed-based polygons and compare with historic records of inland distribution and/or multiple inland survey locations (via observer or remote acoustic sensing).

Management Recommendations

1. Deploy 2-3 automatic continuous-recording radar tracking devices to independently monitor trends at multiple murrelet flyways

APPENDIX D-KEY FINDINGS FROM INDIVIDUAL CHAPTERS

Key Findings on Murrelet Inland Distribution and Detection Numbers (Chapter 2)

--Prepared by Steven W. Singer, M.S., Consulting Forest Biologist

1. Breeding range of the murrelet in Zone 6 is confined to the Santa Cruz Mountains west of the summit and extends from Stone Dam Reservoir on the San Francisco Public Utility District land at the north end to Fall Creek State Park at the south end.
2. Total potentially suitable murrelet nesting habitat within Zone 6 consists of about 10,000 acres of old-growth forest and a significant additional amount of older second-growth forest with old-growth residual trees. About 60% of the old-growth acreage is found in 3 state parks-Big Basin, Portola, and Butano. The other old-growth occurs on a mix of public and private lands.
3. There are 109 stands or stand complexes with potentially suitable habitat occurring on a mix of public and private lands. Of these, 39 have had occupied behavior documented or some other evidence of nesting. Thirteen stands have areas of concentrated breeding activity.
4. Most of the remaining suitable habitat is found in 7 watersheds, in order of decreasing habitat acreage, these are: Waddell, Pescadero, Pilarcitos, Butano (including Little Butano Creek), Scott Creek, and Gazos Creek.
5. Four major murrelet flyways, from nesting areas to the ocean or coastal plain, have been identified within the breeding range and confirmed by radar monitoring. These are Waddell Creek, Gazos Creek, Pescadero Creek, and Butano Creek.
6. Two moderately large stands of suitable habitat exist that have never been surveyed for murrelet presence – one in the Pescadero Creek Watershed and one in the Big Creek Watershed.
7. Stands as small as 7 acres in size have been used for nesting as evidenced by occupied behaviors.
8. There have been 63 records of documented nesting my murrelets in the Santa Cruz Mountains but only 20 nests have been found to date. Most of these were from Big Basin State Park, but nesting has also occurred on other lands both public and private.
9. Long-term monitoring records (A-V surveys) exist for Big Basin (started 1991), Portola (started 1992), and Gazos Mountain Camp (started 1998). Results indicate that numbers at Big Basin have dropped dramatically, while total detection numbers at the other sites have shown no statistically significant trend.
10. Radar surveys at Gazos (2000-2010) also suggest that activity levels there have been stable. Detection numbers at Big Basin from 2007 to present suggest that numbers may have stabilized, but the results are not yet statistically significant.
11. Seven important sites of concentrated murrelet activity have not been surveyed for over 10 years. New A-V or ARU surveys are needed to confirm continued use of these areas.

Appendix D-Key Findings from Individual Chapters

12. Threats to the remaining potentially suitable nesting habitat include logging, increased development within the forest matrix surrounding habitat stands (which could increase predation risk), and loss of residual Douglas-fir trees (and their suitable nest platforms) through old age, disease, windfall, or wildfire.
13. Efforts to conserve murrelets in Zone 6 have been hindered by the lack of coordination and collaboration of research, monitoring, and management efforts. Also lacking is any sort of information clearinghouse (where data could be shared) and a mechanism or institution that would provide long-term storage for murrelet research findings, monitoring results, and management tools.

Key Findings on Corvid Predation of Murrelet Nests (Chapter 3)

Management of Crows and Ravens to Reduce the Risk of Nest Predation on Marbled Murrelets in the Santa Cruz Mountains

Prepared by William C. Webb, PhD.

1. Nest predation likely prevents successful recovery of murrelets throughout their range.
2. Murrelets show very low nest success in the Santa Cruz Mountains. Only three of 19 nests located in the Santa Cruz Mountains successfully fledged young and the cause of failure was reasonably determined for nine nests. Nest predation was the predominate cause of failure, and ravens were implicated in half (3/6) of these cases.
3. There are several species of birds and mammals which are known or suspected murrelet nest predators. However, corvids are the most commonly-documented and suspected murrelet nest predators.
4. Ravens were implicated in 35% of real and simulated murrelet nests depredated by corvids in British Columbia, California, Oregon and Washington. Ravens and jays were no more likely to depredate murrelet nests.
5. Crows are suspected predators of some artificial murrelet nests and are considered potential predators of real murrelet nests. However, there are no confirmed records of crows depredating murrelet nests.
6. Nest predation by ravens increases with raven abundance, the presence of large communal food resources (food bonanzas), and reduced vegetative structure.
7. The landscape scale is the most appropriate for understanding the relationship between the abundance of crows and ravens and the risk of nest predation to murrelets. Corvid management within murrelet habitat alone is insufficient to affect crow and raven populations.
8. Landscape factors associated with elevated risk of predation for murrelet nests include hard edges, nest proximity to forest edges, forest fragmentation and increased forest complexity.
9. Elevated numbers of ravens and crows occur more frequently near human settlements and recreation sites, in fragmented landscapes, and along forest edges. Their increased

Appendix D-Key Findings from Individual Chapters

abundance likely results in an elevated risk of nest predation to murrelets in the Santa Cruz Mountains.

10. The abundance of ravens in the Santa Cruz Mountains has increased sharply over the past several decades. The number of ravens has declined since peaks from 2003-9, but remain elevated.
11. Raven numbers are not evenly distributed throughout the forested areas that murrelets use for nesting. Corvid surveys show that raven density is significantly higher in campgrounds compared to control sites.
12. Crows are currently not residents in most of the redwood forests in the Santa Cruz Mountains. Although significantly less numerous than ravens, crow abundance has increased over the past ten years in the Santa Cruz Mountains.
13. The raven population in the Santa Cruz Mountains requires intensive management to aid in the recovery of murrelets. Since crows are potential murrelet nest predators, the growing crow population in the Santa Cruz Mountains should be closely monitored.
14. Corvid control efforts initiated in 2005 had no effect on the density of ravens in the four parks. Corvid surveys show the density of ravens did not significantly change after implementation of corvid control efforts.
15. Key information about our local ravens, their diets, foraging behavior, nesting ecology, and their interactions with other murrelet nest predators is lacking. New research using raven nest cams, radio-tagging and tracking of birds, and other techniques could be immensely helpful in selecting control strategies that would be effective.
16. Lethal control is rarely effective, and did not reduce the density of ravens in parks. Other techniques such as Conditioned Taste Aversion (CTA), effigy use, sterilant use, or egg oiling warrant further investigation as they might be more effective.
17. Lethal control is effective in limited circumstances. It is most effective on islands or when prey is concentrated. Its effectiveness is reduced by factors such as immigration, when prey is widely dispersed, by mesopredator release and compensatory predation.
18. It is vital to establish a robust monitoring program to evaluate the effectiveness of corvid control. Corvid surveys last conducted in 2012 should be re-initiated using distance sampling techniques.

[Management of Steller's Jays to Reduce the Risk of Nest Predation on Marbled Murrelets](#)

Prepared by Elena H. West, PhD. Candidate (Findings based on data collected from 2011– 2014)

1. Steller's jay populations have increased dramatically in the Santa Cruz Mountains over the last several decades, which may be due to the expansion of exurban development, increases in human activities, and associated food resources within parks and recreation areas in this region. Steller's jay densities remain very high in state park campgrounds.
2. Steller's jays may account for as much as 20% of predation events on Marbled Murrelets in the Santa Cruz Mountains (source: Peery et al. 2004; note that only one predation event was confirmed as a jay in the Santa Cruz Mountains but the predation rate appears

Appendix D-Key Findings from Individual Chapters

- to be higher in other regions; source: Chapter 3–Subchapter on Crows and Ravens (this Plan).
3. West et al. (2016) showed that the anthropogenic food comprised a large portion of the diet of Steller’s jays in state park campgrounds studied; more than half of the diet of campground jays in Big Basin, 37% of the diet of jays in Jedediah Smith Redwoods and Redwood State and National Park, and 35% of the diet of jays in Butano State Park.
 4. West and Peery (in review) determined that Steller’s jay abundance was six times greater in Big Basin campgrounds ($4.33 \text{ jays/ha} \pm 0.91$) compared to forest sites ($0.70 \text{ jays/ha} \pm 0.22$; $F_{1,17} = 855.58$, $P < 0.01$), presumably because of the presence of abundant anthropogenic food subsidies in these areas (2011 – 2013 data).
 5. Steller’s jays in campgrounds appear to exhibit a functional response by consuming an increasing proportion of human-derived foods as park visitation increases. Park visitation peaks in July and August and coincides with the jay fledgling period such that food subsidies are likely most prevalent during the energetically expensive nestling and fledgling provisioning stages. Of note, breeding jays in Big Basin appeared to preferentially feed their juveniles anthropogenic food in campgrounds as juveniles were more enriched in anthropogenic food than adults.
 6. West and Peery (in review) found that jays subsidized by anthropogenic food were also in better body condition, which in turn, appeared to promote higher reproductive output compared to putatively unsubsidized jays at nearby forest sites.
 7. Annual survival rates for juvenile and adult jays in campgrounds were also higher than expected based on previous findings of corvid survival rates.
 8. In a separate study, 60% of radio-marked juvenile jays ($n = 40$) produced in campgrounds dispersed into murrelet nesting habitat during their hatch year (EHW, unpubl. data)
 9. Collectively, these findings suggest that campgrounds in Big Basin Redwoods State Park serve as “source” habitats for Steller’s jays on the landscape, which ultimately impact murrelets and may result in negative impacts to other species through spillover predation.
 10. Given the risk that abundant Steller’s jay populations pose to nesting murrelets, jay populations in the Santa Cruz Mountains require targeted management in order to reduce predation and recover murrelet populations over the long-term.

Key Findings on Peregrine Falcon Predation of Marbled Murrelets in the S.C. Mountains (Chapter 4)

--Prepared by Craig Himmelwright, DVM

1. There is minimal information available about interactions between marbled murrelets and peregrine falcons. However, several instances of take of murrelets by peregrines have been observed in the Santa Cruz Mountains.
2. Peregrine falcon predation on alcids is common and has the potential to impact the demographics of prey populations.

Appendix D-Key Findings from Individual Chapters

3. Between 1994 and 2001, murrelet audio-visual surveys in South Butano Creek Canyon documented 14 attacks by peregrines on murrelets with at least 6 being successful.
4. Peregrine nesting territories exist in the Santa Cruz Mountains along the South Butano Creek murrelet flyway and the Waddell Creek murrelet flyway, and possibly at one other significant location.
5. A reasonable and conservative estimate of murrelet kills from peregrines associated with these nest territories could be 5 -15 birds per flyway each season, which assumes that <5% percent of probable kills during a successful nesting season are murrelets.
6. Field investigation is necessary to determine the level of peregrine take – if any - and to collect information on how and where mitigation activities might be initiated.
7. Two direct management measures may be employed to reduce peregrine predation of murrelets. In the first instance, peregrine chicks can be removed from the nest early and released through hacking at a distant location. In the second, an egg set can be removed early in the incubation phase, and a falconry bred peregrine or hybrid can be placed in the nest, which is then removed in 1-2 weeks. The goal for both techniques is to significantly shorten the nesting season and peregrine presence in the territory. This is because during a typical 40-day nestling period and subsequent post-fledging period there is often a dramatic increase in the number of kills made by the peregrines.

Key Findings on Noise Impacts On Murrelets In Zone 6 (Chapter 5)

--Prepared by Richard T. Golightly, Dept. of Wildlife, Humboldt State University

1. Marbled murrelet biology suggests that the risk of impact from noise varies with the hour of the day, the phase of nesting, and throughout the year.
2. The appropriate measurement of noise amplitude (loudness) and character (frequency, duration, time to maximum amplitude) is at the location of the individual marbled murrelet and the nest, rather than the noise source.
3. Because noise varies considerably through space, noise and associated impacts should be assessed on a case-by-case, project-by-project basis considering vegetation and topography at a site, existing noise levels, distance to potential nest trees, the character and loudness of the noise, and the potential to dampen or minimize the noise.
4. Characteristics of sound that should be considered by managers include amplitude (loudness), duration, injection of new sound, background levels, sudden sounds, and very low frequency sound (which is poorly understood).
5. Project managers need to overtly distinguish between projects that are within potential nesting stands and those that are external to the nesting stands in each analysis.
6. Any noise that causes flushing, or that could cause flushing, should be considered harmful. Generally, sudden noise, novel noise, or noise that is very loud (+90 dB) should be considered as having the potential to cause flushing.
7. Loud impulsive noise that quickly reaches maximum amplitude (e.g. gun shots, explosions, felling of large trees) has potential to cause flushing and should be

Appendix D-Key Findings from Individual Chapters

- completely avoided at any time during the nesting season, and year-round for 1 hour before to 1.5 hours after sunrise.
8. Equipment that makes noise in or adjacent to murrelet habitat can be extremely variable in producing noise (from machine to machine, even those machines of the same type, and based on different tasks performed by that same machinery). Empirical measures should be made to ensure that this equipment operates within planned guidance. Amplitude can be measured with sound meters (and for consistency reported in dB, C-weighted).
 9. Corvids can be inadvertently trained to associate specific noises with food rewards, which should be avoided.
 10. Thresholds for chronic noise, changes in background noise, or changes in frequency that may cause damage are unclear.
 11. It is reasonable to consider adjustments to the timing of noise restrictions in order to match the timing of greatest risk. Research conducted since the original establishment of recommendations for noise restrictions suggests that there may be need to reconsider the exact dates and timing of imposing restrictions, as well as the level of acceptable noise during those periods of noise restriction.

Key Findings on Murrelet At-Sea Abundance, Productivity, And Prey Resources (Chapter 7)

--Prepared by R. William Henry, PhD., Integrated Ecology

1. At-sea surveys from 1999-2016 provide a measure of murrelet abundance and juvenile ratios in the Santa Cruz Mountains of Zone 6.
2. At-sea monitoring is our best tool for monitoring abundance and productivity of marbled murrelets for the entirety of Zone 6. This technique has limited ability to detect small changes in murrelet abundance likely resulting from inter-annual variability and multiple sources of error. At-sea surveys are particularly important for monitoring juvenile ratios. We recommend continuation of at-sea surveys to estimate abundance and productivity until positive population growth and rising population numbers are consistently documented. If this were to occur, we recommend ongoing periodic monitoring to document sustained recovery.
3. The trend for abundance estimates from 1999 to 2016 using transects drawn from the North, our longest running dataset, is negative and significant at the $p=0.1$ level ($F(1,13)=3.152$, $p=0.09924$, $R^2 = 0.1332$). The trend for results using estimates from 2001 to 2016 using transects drawn from both directions is also negative but not significant. ($F(1,11)=1.644$, $p=0.2262$, $R^2 = 0.13$).
4. We have not witnessed an increase in population estimates since corvid control measures were implemented, with abundance estimates for transects drawn from the North remaining significantly lower after corvid control (2009-2016, $\bar{x}=409.75$, $SD=98.3$) than before (1999-2003, $\bar{x}= 572.6$, $SD=74.5$), ($t(10) = 3.39$, $p = 0.006$).
5. Abundance estimates could be improved by re-analysis of historical and future survey data using techniques that incorporate co-factors (e.g., distance from shore, bottom type, and depth).

Appendix D-Key Findings from Individual Chapters

1. Autonomous continuous-recording radar monitoring at the mouth of key watersheds could be a good tool for detecting change in murrelet abundance. This would allow for ongoing comparisons across time and between watersheds that differ in both conservation actions and threats.
2. Juvenile ratio estimates have remained low from 1996 to 2016 ($\bar{x}=0.05048$, $sd=0.030513$, from Table 7-2) and remain well below levels thought to support positive population growth.
3. Juvenile ratios show an increasing trend across all years, 1996-2016 ($F(1,16)=10.25$, $p=0.006$, $R^2 = 0.3904$) and corrected juvenile ratio estimates are significantly higher following corvid control (2009-2016, $\bar{x}= 0.070$, $SD=0.028$) than prior to corvid control (1996-2008, $\bar{x}=0.035$, $SD=0.022$), ($t(13.2) = -2.90$, $p = 0.012$).
4. Murrelet observations were highest in the nearshore waters from Franklin Point to just south of Waddell Creek, the area adjacent prime old-growth breeding habitat in Big Basin.
5. Murrelet density was consistently low in the Southern portion of the survey area where adjacent old growth habitat is sparse and the rural/urban footprint is large.
6. The zonal relative abundance analyses suggest an increase in relative abundance in the Northern portions and decline in the Southern portions of the study area. A linear regression for each Zone shows a marginally significant increasing trend proportion of birds in the North over the survey years ($F(1,120)=3.629$, $p=0.059$), adjusted $R^2 = 0.021$), no trend in the Central Zone ($F(1,120)=0.177$, $p=0.674$), adjusted $R^2 = -0.007$), and a significant decreasing trend in the South ($F(1,120)=4.538$, $p=0.035$), adjusted $R^2 = 0.028$).
7. The market squid fleet removes large amounts of biomass from this system. Research on the impact of the squid fleet via direct and indirect resource competition as well as disturbance is warranted.
8. Information on ocean conditions, diet, and how prey resources influence murrelet abundance and productivity is lacking. Research including diet of other seabirds in Zone 6 and next gen sequencing can help inform this important aspect of murrelet ecology.
9. Data on patterns of recruitment and distribution of nearshore rockfish (*Sebastes spp*), market squid (*Loligo opalescens*), and other prey including northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax caerulea*), and Pacific sand lance (*Ammodytes hexapterus*) could help shed light on the connection between local prey availability and murrelet population dynamics. Such data could be collected through partnerships with the University of California at Santa Cruz and/or NOAA.

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Initial Floristic Response to High Severity Wildfire in an Old-Growth Coast Redwood (*Sequoia sempervirens* (D. Don) Endl.) Forest

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Article

Initial Floristic Response to High Severity Wildfire in an Old-Growth Coast Redwood (*Sequoia sempervirens* (D. Don) Endl.) Forest

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Abstract: Climate driven increases in fire frequency and severity are predicted for Mediterranean climatic zones, including the Pacific coast of California. A recent high severity wildfire that burned in the Santa Cruz Mountains affected a variety of vegetation types, including ancient coast redwood (*Sequoia sempervirens* (D. Don) Endl.) stands. The purpose of this study was to characterize the survival and initial recovery of vegetation approximately six months after the fire. We sampled thirty randomly selected points in an old-growth coast redwood forest to examine and compare survival, crown retention, and post fire regeneration of trees by species, and the recovery of associated understory plant species. *Sequoia sempervirens* exhibited the highest post-fire survival (95%), with lower survival rates for subcanopy hardwood associates including tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos) (88%), coast live oak (*Quercus agrifolia* Nee.) (93%), Pacific wax myrtle (*Myrica californica* (Cham. & Schltdl.) Wilbur) (75%), Pacific madrone (*Arbutus menziesii* Pursh) (71%), and the lowest survival recorded for the canopy codominant Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) (15%). Canopy retention and post fire regeneration were also highest for *S. sempervirens* and lowest for *P. menziesii*, indicating that *S. sempervirens* had a competitive advantage over *P. menziesii* following high severity crown fire. Both canopy survival and regeneration were greater for larger height and diameter trees; and basal sprouting was positively associated with tree height and diameter for *S. sempervirens* and *N. densiflorus*. Observed recovery of understory species was modest but included the reemergence of coast redwood associated herbaceous species. The robust nature of survival and recovery of *S. sempervirens* following this extreme fire event suggest that the removal of scorched, and the seeding or planting of trees, following this type of fire is contraindicated. The decline of *P. menziesii* is of concern, however, and suggests that repeated high severity fires driven by climate change could eventually lead to vegetation type conversion.



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Keywords: coast redwood; *Sequoia sempervirens*; *Pseudotsuga menziesii*; succession; post fire

1. Introduction

Forests in Mediterranean systems are at risk due to the effects of climate driven weather patterns and a history of resource exploitation [1,2]. Fire frequency and severity are projected to increase as a result [3,4], leading to shifts in forest composition and structure [5]. In California, a century of systematic fire suppression coupled with prolonged drought conditions have led to extensive tree mortality and record fires in recent years [6,7]. The coast redwood forest, dominated by the iconic tree species *Sequoia sempervirens* (D. Don) Endl., is of particular interest due to its inherent resilience to fire coupled with a dependence on a cool and moist marine layer originating from the Pacific Ocean [8].

The history of natural fire in the coast redwood forest has been one of predominantly infrequent and low severity disturbance [9,10]. Natural ignitions occur from lightning strikes, and storms generally occur during the rainy season when fuels have high relative humidity. The occurrence of lightning storms in the dry season, as those that preceded the

CZU Lightning Complex Fire, are historically rare but can have a significant impact when they occur.

Indigenous burning was initiated approximately 13,000 years ago in California [11,12], generally increasing fire frequencies in coast redwood forests. Intentional burning continued into the early European-settlement period as a result of grazing practices and post-logging slash burning. Systematic fire suppression beginning in the early part of the 20th century led to a significant fire regime shift and increased overall fuel load in the region [13,14]. Widespread timber harvesting in the coast redwood forest over the past centuries has also altered forest structure resulting in an increase in the abundance of fine fuels, fuel continuity, and the potential for high severity crown fires. In addition, fire frequency and severity are increasing throughout the western United States as a result of land use changes and climate driven drought severity [15,16], which could lead to undesirable ecosystem changes [5].

Coast redwood is adapted to withstand fire, with a high crown, thick fibrous insulative bark, and vigorous clonal sprouting ability [17]. Trees that appear severely damaged following crown fire, and have lost all foliar tissue, can begin to replace canopy within a few months through epicormic sprouting [18]. However, the loss of the structural components of crown may limit the ability of the canopy to provide habitat for rare and endangered species such as the marbled murrelet and the northern spotted owl, though some have argued that this risk has been overestimated [19]. The loss of canopy can also affect the diversity and abundance of understory plant species, particularly those coast redwood associates that are adapted to a moist, shady environment. In addition, invasive species can take advantage of gaps created by high severity crown fire further impacting redwood forest endemics [18]. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is often a co-dominant canopy species with *S. sempervirens*. Mature *P. menziesii* have relatively thick insulating bark which enables them to withstand fire [20]; however, they lack the ability for post-fire sprouting and rely on regeneration from seed. *Pseudotsuga menziesii* seedlings have the potential for rapid initial growth post fire, but this potential may be limited following high severity fire. Tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos) is the most abundant subcanopy species in the central and southern range of the coast redwood forest [21]. This shade-tolerant evergreen tree can sprout vigorously post fire even when top killed [22]. However, some research suggests that its relative response to fire is under-studied [23]. Other common associate redwood species are California bay (*Umbellularia California* (Hook. & Arn.) Nutt.), Pacific madrone (*Arbutus menziesii* Pursh), and a variety of hybridizing oak species (*Quercus*, sp.), which have little fire resistance but do have the ability to sprout following fire [18].

Fire behavior in the coast redwood forest is unpredictable and tends to result in a patchwork of mixed intensities on the landscape [24,25]. Historically, high intensity crown fires have been rare in this forest type but may be increasing in frequency as a result of human induced climate change [26]. It is imperative, therefore, to examine the influence of such crown fires on mature coast redwood communities. The goal of this study was to estimate survival and recovery of *S. sempervirens* and its associated tree and understory species following a high severity fire, and to determine if severe fire gives a successional advantage to particular species.

2. Materials and Methods

2.1. Site Description

Big Basin Redwoods State Park is located in the heart of the Santa Cruz Mountains (37.42° N/122.05° W), and is the oldest State Park in California, having been established in 1902. The Park is 10 km from the ocean with elevations ranging from sea level to over 600 m. Average daily temperatures range between 12.7 °C to 23.3 °C, and the site receives an average of 549 mm of precipitation annually mostly during the wet winter months. During the summer, the forest receives most of its moisture from marine fog, which is absorbed by the foliar tissue of *S. sempervirens* and some of its understory associates [27]. Big Basin is home to the largest continuous stand of old-growth coast redwoods south of San Francisco.

S. sempervirens and *P. menziesii* dominate the upper canopy while *N. densiflorus*, *Quercus* sp., *Umbellularia californica* and *A. menziesii* dominate the subcanopy. In 2020, a massive wildfire caused by dry lightning and exacerbated by drought conditions and windstorms swept through the Santa Cruz Mountains. The CZU Lightning Complex Fire burned 350 km² in Santa Cruz and San Mateo Counties between 16 August 2020 to 22 September 2020, affecting 97% of the acreage in Big Basin State Park.

2.2. Sampling Design and Measurements

We randomly selected thirty sample points within an approximately 20 ha area in the central old-growth section of Big Basin State Park with a minimum of 20 m between plots. Data collected at each point included, aspect measured with a handheld compass, slope collected with a clinometer, and percent canopy cover estimated with a spherical densiometer. We recorded all trees > 4 cm in diameter within a 10 m radius of the sample point and designated them as living or dead based on the existence of live crown or sprouts emerging from the bole. Trees of < 4 cm in diameter were recorded as saplings. We noted the following metrics for each individual tree: species; height measured with a laser rangefinder; diameter at breast height; ocular assessment of live canopy; ocular estimates of epicormic sprouting; the number of saplings, and seedlings by species; and the number of basal sprouts. In addition, basal sprouts were divided by height classes, defined as small (0.0–0.5 m), medium (>0.5–1 m), and large (>1 m). Species and percent cover were recorded for all understory plants occurring on plots, and observations were made regarding understory vegetation occurring within the study area.

2.3. Data Analysis

We employed the Shapiro-Wilk test of normality for each variable prior to the following analysis. Pearson's correlation coefficient analysis was used to examine plot data for the following variables: residual live canopy, regenerated canopy, tree density, mean height and diameter, mean basal sprouting, and the percent cover of all understory species. Survival of trees with regard to size (height and diameter) was compared between species using two sample *t*-tests for unequal variance. The relationship between the number of basal sprouts and tree size (height and diameter) was explored with linear regression analysis for all species combined, and for those species with a sufficient sample size and that exhibited normal data distributions. The number of basal sprouts was compared between species using one-way ANOVA with subsequent Tukey post-hoc analysis. We used R package version 2.7-1 (R Foundation for Statistical Computing, Vienna, Austria.) and Microsoft Excel version 16.49 (Microsoft Corporation, Minneapolis, NM, USA) for analysis and graphing.

3. Results

3.1. Post Fire Survival

A total of 487 individual trees of six species were recorded within the sample plots including two coniferous canopy species (*S. sempervirens* and *P. menziesii*), and four hardwood subcanopy species (*N. densiflorus*, *Quercus agrifolia* Nee., *Myrica californica* (Cham. & Schltdl.) Wilbur, and *A. menziesii*). Eighty-five percent of the trees sampled survived the fire based on the presence of live canopy or basal sprouting. *Sequoia sempervirens* exhibited the highest overall survival and *P. menziesii* the lowest (Figure 1). *Quercus agrifolia* and *N. densiflorus* exhibited the highest survival rate among the hardwood species, with *M. californica* and *A. menziesii* lower. Coniferous trees that survived had significantly higher measures of diameter and height than those that did not survive: *S. sempervirens* ($t = 4.150, p < 0.001$; $t = 2.632, p = 0.022$), and *P. menziesii* ($t = 2.843, p < 0.013$; $t = 4.890, p < 0.001$).

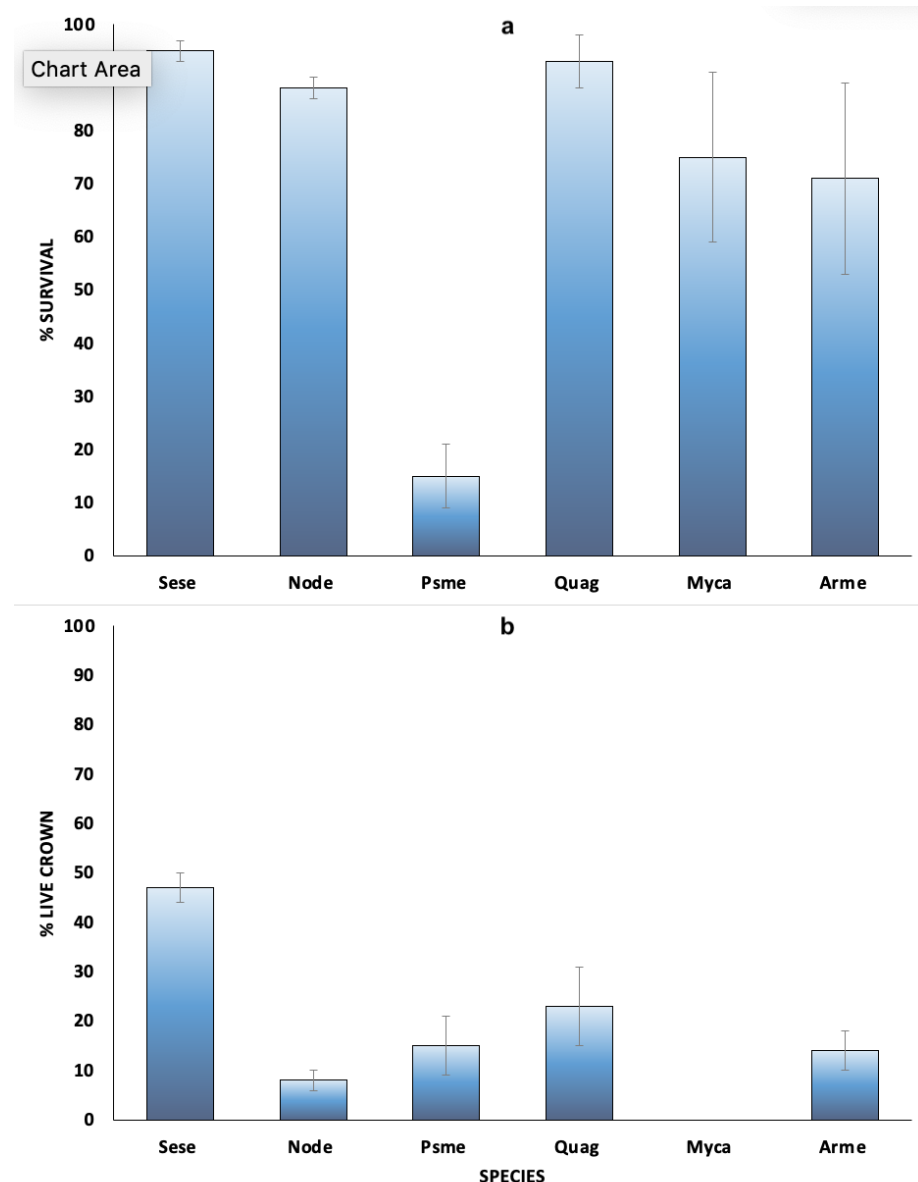


Figure 1. Percent survival (a); and percent trees exhibiting crown retention (b); following a high severity crown fire in Big Basin Redwoods State Park, California. Sese = *Sequoia sempervirens* (D. Don) Endl.; Node = *Notholithocarpus densiflorus* (Hook. & Arn.) Manos; Psme = *Pseudotsuga menziesii* (Mirb.) Franco; Quag = *Quercus agrifolia* Nee.; Myca = *Myrica californica* (Cham. & Schltdl.) Wilbur; Arme = *Arbutus menziesii* Pursh. Error bars indicate standard error.

Live crown retention was generally low following the fire, but significant variation was evident among species with *S. sempervirens* exhibiting the highest percent of trees with crown retention, and *P. menziesii* the lowest (Figure 1). *Quercus agrifolia* had the next highest measure of trees with retained live crown after *S. sempervirens*, while no live crown was observed for *M. californica*. Percent cover of residual live canopy was positively associated with tree height and diameter for all tree species combined ($r = 0.648$; $r = 0.565$), and crown retention was positively correlated with the density of *S. sempervirens* ($r = 0.575$).

3.2. Post Fire Recovery of Trees

Vigorous sprouting in response to fire was observed for all tree species, with the exception of *P. menziesii* which does not have the ability to produce clonal sprouts (Figure 2). The highest average number of basal sprouts per individual tree was found for *S. sempervirens* ($F = 5.05$; p

< 0.01), (31.9, SE = 3.6), followed by *N. densiflorus* (16.6, SE = 1.2), *Q. agrifolia* (15.5, SE = 2.9), *A. menziesii* (9.6, SE = 5.0), and *M. californica* (3.6, SE = 1.8).

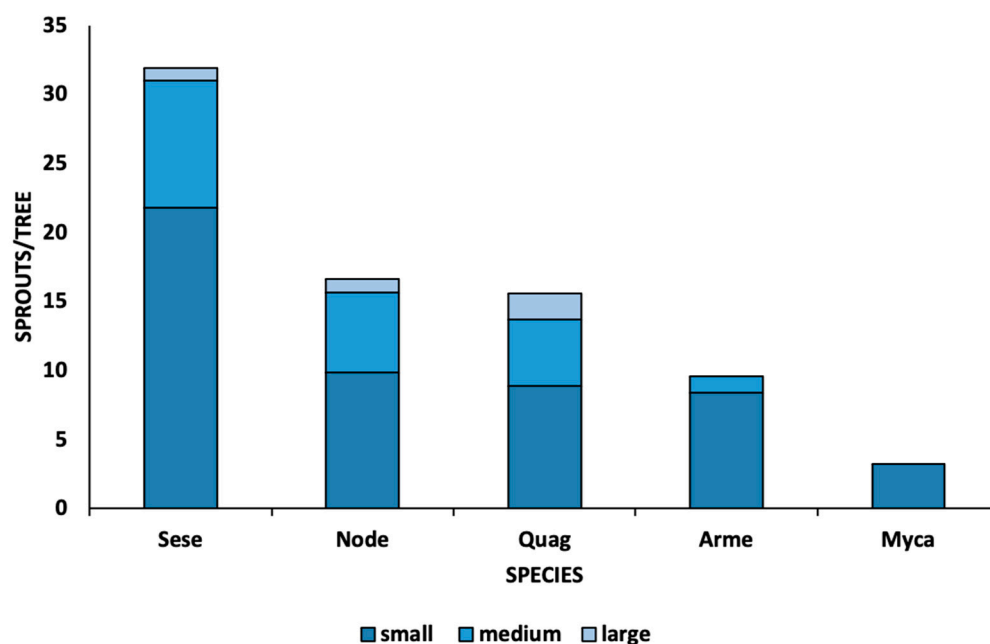


Figure 2. Post fire sprouting by size-class following a high severity crown fire in Big Basin Redwoods State Park, California. Sese = *Sequoia sempervirens* (D. Don) Endl.; Node = *Notholithocarpus densiflorus* (Hook. & Arn.) Manos; Psme = *Pseudotsuga menziesii* (Mirb.) Franco; Quag = *Quercus agrifolia* Nee.; Myca = *Myrica californica* (Cham. & Schltdl.) Wilbur; Arme = *Arbutus menziesii* Pursh. Height classes were defined as small (0.0–0.5 m), medium (>0.5–1 m), and large (>1 m).

We observed positive associations between mean percent post fire canopy regeneration and both tree diameter and tree height ($r = 0.278$; $r = 0.355$). Very little regeneration through seedlings was observed for any species with only fourteen *S. sempervirens* and seven *N. densiflorus* seedlings observed within plots. The lack of *P. menziesii* seedlings was a particularly critical finding, as conal regeneration is not possible for this species. However, though there were no *P. menziesii* seedlings recorded within the plots, there were patches of seedlings observed in other areas in the Park that appeared not to have burned as intensely and some *P. menziesii* canopy had been maintained.

The number of basal sprouts, for all species sprouting combined as a dependent variable, exhibited a positive linear relationship with both tree height and tree diameter as independent variables ($R^2 = 0.373$; $p < 0.001$; $R^2 = 0.199$; $p < 0.001$) (Figure 3). Linear relationships were also observed for *Sequoia sempervirens* ($R^2 = 0.287$, $p < 0.001$; $R^2 = 0.142$; $p < 0.001$) and *N. densiflorus* ($R^2 = 0.293$, $p < 0.001$; $R^2 = 0.261$; $p < 0.001$) between basal sprouting and tree height and tree diameter; while no relationship was observed for *Q. agrifolia*, *M. californica*, and *A. menziesii*. In addition to basal regeneration, the scorched boles of many redwood trees survived the fire and responded by sprouting epicormically (Figure 4).

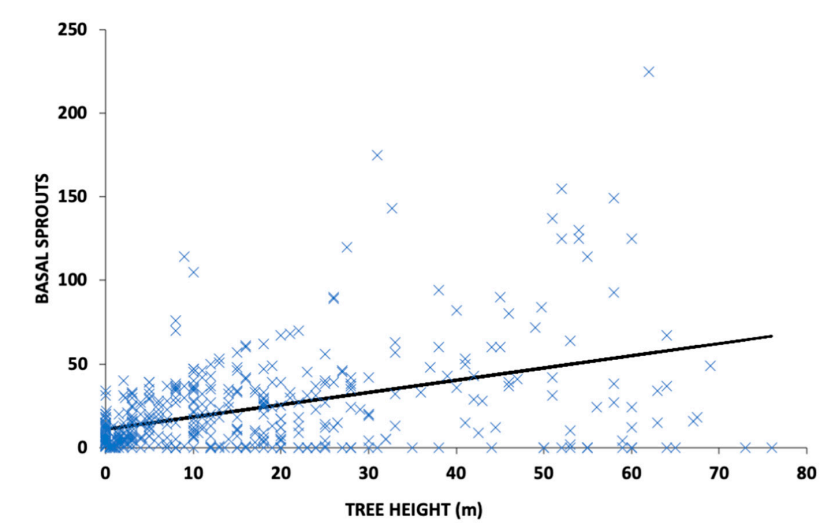


Figure 3. Scatter plot of the number of post-fire basal sprouts combined for *Sequoia sempervirens* (D. Don) Endl.; *Notholithocarpus densiflorus* (Hook. & Arn.) Manos; *Quercus agrifolia* Nee.; *Myrica californica* (Cham. & Schltdl.) Wilbur; and *Arbutus menziesii* Pursh), in relation to tree height produced in response to a high severity crown fire in Big Basin Redwoods State Park, California.



Figure 4. Epicormic sprouting in response to high severity crown fire on a group of *Sequoia. Sempervirens* (D. Don) Endl. in Big Basin Redwoods State Park, California.

3.3. Reestablishment of Understory Species

Recovery of understory species following the fire, from both sprouts and seeds, was modest with an average of slightly less than 4% total cover across the samples; however,

sixteen species were recorded on the burned plots, with the sprouting shrub, *Vaccinium ovatum* Pursh., being the most prevalent (Table 1). Understory recovery appears to be related to overstory conditions, as understory cover was associated with canopy retention ($r = 0.402$), especially for *V. ovatum* ($r = 0.354$). *Trillium ovatum* Pursh was also found to be associated with canopy regeneration and was the only understory species found to be associated with *S. sempervirens* density ($r = 0.491$; $r = 0.563$) (Figure 5). All of the species observed on the sample plots were native coast redwood forest associates, however *Genista monspessulana* (L.) L. A. S. Johnson a highly invasive non-native species was observed in the area.

Table 1. Percent cover of sixteen recovering understory species recorded following a high severity wildfire in Big Basin Redwood State Park in the Santa Cruz Mountains, California.

Species	Mean% Cover ($\pm$ SE)
All species combined	3.97 ($\pm$ 1.6)
<i>Vaccinium ovatum</i> Pursh.	2.79 ($\pm$ 1.4)
<i>Equisetum arvense</i> L.	0.67 ($\pm$ 0.67)
<i>Polystichum munitum</i> (Kaulf.) C. Presl.	0.31 ($\pm$ 0.30)
<i>Viola sempervirens</i> Greene	0.31 ($\pm$ 0.30)
<i>Stachys bullata</i> Benth.	0.30 ($\pm$ 0.30)
<i>Oxalis oregana</i> Nutt.	0.20 ($\pm$ 0.17)
<i>Galium</i> spp.	0.17 ($\pm$ 0.17)
<i>Cardamine californica</i> (Nutt.) Greene	0.04 ($\pm$ 0.33)
<i>Trillium ovatum</i> Pursh	0.02 ($\pm$ 0.01)
<i>Pteridium aquilinum</i> (L.) Kuhn	0.01 ($\pm$ 0.01)
<i>Lysimachia latifolia</i> (Hook.) Cholewa	0.01 ($\pm$ 0.01)
<i>Toxicoscordion fremontii</i> (Torr.) Rydb.	0.01 ($\pm$ 0.01)
<i>Rubus ursinus</i> Cham. & Schltdl.	0.01 ($\pm$ 0.01)
<i>Adenocaulon bicolor</i> Hook.	0.01 ($\pm$ 0.01)
<i>Viola cuneate</i> S. Watson	0.01 ($\pm$ 0.01)
<i>Prosartes hookeri</i> Torr.	0.01 ($\pm$ 0.01)



Figure 5. Perennial herb *Trillium ovatum* Pursh sprouting through charred fuel following a high severity crown fire.

4. Discussion

Fire frequency and severity are projected to increase due to human induced climate change in California, and in Mediterranean systems as a whole, resulting in significant shifts in vegetation patterns [28,29]. Coast redwood forests have generally been considered to be both resistant to fire and resilient following disturbance [18], however recent fires of unprecedented magnitude have presented opportunities to study response of this forest type under extreme fire conditions.

Analysis of initial recovery suggests a successional advantage for *S. sempervirens* over its coniferous codominant *P. menziesii*. Tree size, both height and diameter, were also correlated with survival and recovery metrics including canopy retention, canopy regeneration, and basal sprouting. Recovery was variable among hardwood subcanopy and herbaceous understory species, but generally robust. These findings support previous research that suggests a post-fire advantage for *S. sempervirens* compared to co-occurring tree species, as well as a relationship between tree size and survival [18]. However, the level of mortality recorded for *P. menziesii* in this study exceeded that found in the literature. Ordinarily *P. menziesii* is considered resistant to low and moderate fire intensity and can attain canopy dominance in the presence of occasional fire. In this case, many of the largest *P. menziesii* succumbed to fire, suggesting that high burn severity could initiate a species shift in dominance toward *S. sempervirens*. Many of the trees associated with the coast redwood forest are able to regenerate clonally, but the recovery of *P. menziesii* will depend on seed availability and germination over time. Six months post fire, no *P. menziesii* seedlings were recorded in the sample plots, where fire appeared to have been intense and very little canopy had been retained. The observation of *P. menziesii* seedlings in other areas of the park was encouraging, however. A general lack of tree seedlings of any species was evident in the study area and may be linked to altered physical and chemical properties of the soil and an accumulation of a thick layer of ash on the forest floor [30]. Prolonged drought in the region may have affected, and may continue to affect, the recruitment of seedlings as well. Additional sampling will be necessary to determine if *P. menziesii* recruitment will expand in the coming seasons.

Basal sprouting, epicormic sprouting was vigorous on *S. sempervirens* trees, and was positively correlated with tree diameter and height. This supports research indicating that bud dormancy release responds to stressors such as fire [31] and drought [32] and is related to tree architecture [33] and tree vigor [34]. Subcanopy hardwood species were able to survive high severity fire primarily through basal sprouting, as the majority were top-killed. Species with more vigorous basal sprouting will likely gain greater relative dominance, and the post-fire sprouting pattern can be considered as a key determinant of future stand composition [23]. In this case, *N. densiflorus* and *Q. agrifolia* exhibited the most prolific basal sprouting suggesting that they may have a greater competitive advantage under a high severity fire regime.

The post-fire recovery of understory cover, at approximately 4%, was quite low [35]. Though cover and richness were reduced due to conditions created by the fire, it was encouraging that many of the species commonly associated with coast redwood forests, such as *Oxalis oregana*, *T. ovatum*, *Viola sempervirens*, and *Prosartes hookeri* were present [36]. The most abundant understory species observed was *V. ovatum*, which was able to regenerate vigorously from basal sprouts and underground rhizomes. While no invasive non-native species were recorded within plots, the observation of *Genista monspessulana* in the area is concerning as it can spread quickly and is adapted to post fire conditions. Further reduction of canopy through hazard tree removal could exacerbate this situation.

It will likely be many years before the influence of this fire on the forest community will be fully understood, and the specter of climate change and continuing drought may stimulate additional fires that will further influence successional patterns. *Sequoia sempervirens* is extraordinarily resilient, and even what can appear to be a lifeless blackened stump will often recover if given the chance to do so; suggesting that post-fire planting, seeding, and post-fire removal of scorched trees is counterproductive in this forest type.

Unfortunately, the post-hoc nature of this study limits the ability to assess the impact of this fire on the ecological community as a whole. For example, the loss of crown structure and the wildlife habitat that it provides is critical [19], yet quantifying this loss following a fire is challenging. In addition, long-term increases in fire intensity and frequency driven by climate change could eventually inhibit the recovery of even the most resilient species, leading to vegetation type conversion on a regional scale.

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References

1. Keeley, J.E. Fire in Mediterranean climate ecosystems—A comparative overview. *J. Ecol. Evol.* **2012**, *58*, 123–135.
2. Peñuelas, J.; Sardans, J. Global change and forest disturbances in the Mediterranean basin: Breakthroughs, knowledge gaps, and recommendations. *Forests* **2021**, *12*, 603. [\[CrossRef\]](#)
3. Keeley, J.E. Fire intensity, fire severity and burn severity: A brief review and suggested usage. *Int. J. Wildland Fire* **2009**, *18*, 116–126. [\[CrossRef\]](#)
4. Bedia, J.; Herrera, S.; Camia, A.; Moreno, J.M.; Gutiérrez, J.M. Forest fire danger projections in the Mediterranean using ENSEMBLES regional climate change scenarios. *Clim. Chang.* **2014**, *122*, 185–199. [\[CrossRef\]](#)
5. Stephens, S.L.; Agee, J.K.; Fule, P.Z.; North, M.P.; Romme, W.H.; Swetnam, T.W.; Turner, M.G. Managing forests and fire in changing climates. *Science* **2013**, *342*, 41–42. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Stephens, S.L.; Collins, B.M.; Fettig, C.J.; Finney, M.A.; Hoffman, C.M.; Knapp, E.E.; North, M.P.; Safford, H.; Wayman, R.B. Drought, tree mortality, and wildfire in forests adapted to frequent fire. *BioScience* **2018**, *68*, 77–88. [\[CrossRef\]](#)
7. Steel, Z.L.; Safford, H.D.; Viers, J.H. The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere* **2015**, *6*, 1–23. [\[CrossRef\]](#)
8. Johnstone, J.A.; Dawson, T.E. Climatic context and ecological implications of summer fog decline in the coast redwood region. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 4533–4538. [\[CrossRef\]](#)
9. Carroll, A.L.; Sillett, S.C.; Van Pelt, R. Tree-ring indicators of fire in two old-growth coast redwood forests. *Fire Ecol.* **2018**, *14*, 85–105. [\[CrossRef\]](#)
10. Brown, P.M.; Baxter, W.T. Fire history in coast redwood forests of the Mendocino Coast, California. *Northwest Sci.* **2003**, *77*, 147–158.
11. Greenlee, J.M.; Langenheim, J.H. Historic fire regimes and their relation to vegetation patterns in the Monterey Bay area of California. *Am. Midl. Nat.* **1990**, *124*, 239–253. [\[CrossRef\]](#)
12. Jones, G.; Russell, W. Approximation of fire-return intervals with point samples in the southern range of the coast redwood forest, California, USA. *Fire Ecol.* **2015**, *11*, 80–94. [\[CrossRef\]](#)
13. Lorimer, C.G.; Porter, D.J.; Madej, M.A.; Stuart, J.D.; Veirs, S.D.; Norman, S.P.; O'Hara, K.L.; Libby, W.J. Presettlement and modern disturbance regimes in coast redwood forests: Implications for the conservation of old-growth stands. *For. Ecol. Manag.* **2009**, *258*, 1038–1054. [\[CrossRef\]](#)
14. Stephens, S.L.; Fry, D.L. Fire history in coast redwood stands in the northeastern Santa Cruz Mountains, California. *Fire Ecol.* **2005**, *1*, 2–19. [\[CrossRef\]](#)
15. Brendan, R.M.; Neilson, R.P.; Drapek, R.; Lenihan, J.M.; Wells, J.R.; Bachelet, D.; Law, B.E. Impacts of climate change on fire regimes and carbon stocks of the U.S. Pacific Northwest. *J. Geophys. Res. Biogeosci.* **2011**, *116*, G3.
16. Dennison, P.E.; Brewer, S.C.; Arnold, J.D.; Moritz, M.A. Large wildfire trends in the western United States, 1984–2011. *Geophys. Res. Lett.* **2014**, *41*, 2928–2933. [\[CrossRef\]](#)
17. Berrill, J.; O'Hara, K.L.; Kichas, N.E. Bark thickness in coast redwood (*Sequoia Sempervirens* (D. Don) Endl.) varies according to tree- and crown size, stand structure, altitude and genotype. *Forests* **2020**, *11*, 637. [\[CrossRef\]](#)
18. Lazzeri-Aerts, R.; Russell, W. Survival and recovery following wildfire in the southern range of the coast redwood forest. *Fire Ecol.* **2014**, *10*, 43–55. [\[CrossRef\]](#)

19. Hanson, C.T.; Odion, D.C.; DellaSala, D.A.; Baker, W.L. Overestimation of fire risk in the Northern Spotted Owl Recovery Plan. *Conserv. Biol.* **2009**, *23*, 1314–1319. [[CrossRef](#)]
20. Ganio, L.M.; Progar, R.A. Mortality predictions of fire-injured large Douglas-fir and ponderosa pine in Oregon and Washington, USA. *For. Ecol. Manag.* **2017**, *390*, 47–67. [[CrossRef](#)]
21. Tappeiner, J.C., II; McDonald, P.M. Development of tanoak understories in conifer stands. *Can. J. For. Res.* **1984**, *14*, 271–277. [[CrossRef](#)]
22. Kauffman, J.B.; Martin, R.E. Sprouting shrub response to different seasons and fuel consumption levels of prescribed fire in Sierra Nevada mixed conifer ecosystems. *For. Sci.* **1990**, *36*, 748–764.
23. Ramage, B.S.; O'Hara, K.L.; Caldwell, B.T. The role of fire in the competitive dynamics of coast redwood forests. *Ecosphere* **2010**, *1*, 1–18. [[CrossRef](#)]
24. Oneal, C.B.; Stuart, J.D.; Steinberg, S.J.; Fox, L. Geographic analysis of natural fire rotation in the California redwood forest during the suppression era. *Fire Ecol.* **2006**, *2*, 73–99. [[CrossRef](#)]
25. Bishop, B.D.; Dietterick, B.C.; White, R.A.; Mastin, T.B. Classification of plot-level fire-caused tree mortality in a redwood forest using digital orthophotography and LiDAR. *Remote. Sens.* **2014**, *6*, 1954–1972. [[CrossRef](#)]
26. Torn, M.S.; Fried, J.S. Predicting the impacts of global warming on wildland fire. *Clim. Chang.* **1992**, *21*, 257–274. [[CrossRef](#)]
27. Limm, E.B.; Dawson, T.E. *Polystichum munitum* (Dryopteridaceae) varies geographically in its capacity to absorb fog water by foliar uptake within the redwood forest ecosystem. *Am. J. Bot.* **2010**, *97*, 1121–1128. [[CrossRef](#)]
28. Moriondo, M.; Good, P.; Durao, R.; Bindi, M.; Giannakopoulos, C.; Corte-Real, J. Potential impact of climate change on fire risk in the Mediterranean area. *Clim. Res.* **2006**, *31*, 85–95. [[CrossRef](#)]
29. Lenihan, J.M.; Bachelet, D.; Neilson, R.P.; Drapek, R. Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. *Clim. Chang.* **2008**, *87*, 215–230. [[CrossRef](#)]
30. Woodward, B.D.; Romme, W.H.; Evangelista, P.H. Early postfire response of a northern range margin coast redwood forest community. *For. Ecol. Manag.* **2020**, *462*, 117966. [[CrossRef](#)]
31. Burrows, G.E. Syncarpia and Tristaniopsis (Myrtaceae) possess specialized fire-resistant epicormic structures. *Aust. J. Bot.* **2008**, *56*, 254–264. [[CrossRef](#)]
32. Burrows, G.E. Epicormic strand structure in Angophora, Eucalyptus and Lophostemon (Myrtaceae)-implications for fire resistance and recovery. *New Phytol.* **2002**, *153*, 111–131. [[CrossRef](#)]
33. Van Pelt, R.; Sillett, S.C. Crown development of coastal *Pseudotsuga menziesii*, including a conceptual model for tall conifers. *Ecol. Monogr.* **2008**, *78*, 283–311. [[CrossRef](#)]
34. O'Hara, K.L.; Valappil, N.I. Epicormic sprouting of pruned western larch. *Can. J. For. Res.* **2000**, *30*, 324–328. [[CrossRef](#)]
35. Cowman, D.; Russell, W. Fuel load, stand structure, and understory species composition following prescribed fire in an old-growth coast redwood (*Sequoia sempervirens*) forest. *Fire Ecol.* **2021**, *17*, 1–13. [[CrossRef](#)]
36. Russell, W. Herbaceous understory indicators of post-harvest recovery in coast redwood (*Sequoia sempervirens*) forests. *Open J. For.* **2020**, *10*, 204–216.

**TERRESTRIAL HABITAT MANAGEMENT RECOMMENDATIONS FOR
MARBLED MURRELETS**

Compiled and edited by:

The Marbled Murrelet Habitat Management Team

**Pacific Seabird Group
Marbled Murrelet Technical Committee**

January 2024



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TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii
GLOSSARY	iv
INTRODUCTION	1
HABITAT MANAGEMENT RECOMMENDATIONS	4
Selecting Habitat and Conducting Surveys.....	4
Application of Survey Results to Designate Occupied Areas	5
Delineating Occupied Areas	5
Delineating Not Occupied Areas	9
How Long Do Survey Results Apply?.....	9
Data Sharing and Coordination with Adjacent Land Managers	9
Maintaining and Managing Occupied Areas and the Integrity of the Landscape.....	10
Protecting and Managing Residual Old-growth within Second-growth Forests	12
Developing New Habitat.....	12
Minimizing Edge Effects Through Buffers	14
Managing and Reducing Threats of Megafires.....	17
Reducing Impacts from Recreation and Other Human Activities	19
Hazard trees	21
Construction and Maintenance of Power Lines, Roads, and Inland Wind Power Developments	23
Minimizing Disturbance and Disruption	24
LITERATURE CITED	26

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GLOSSARY

Words and terms that appear in bold caps at first mention in this document (not including headers) are included in this glossary. The majority of these definitions are derived from *A Revised Protocol for Surveying Marbled Murrelets in Forests* (PSG Technical Publication 6, <https://pacificseabirdgroup.org/psg-publications/technical-publications/>; hereafter referred to as the *2024 Inland Survey Protocol*). It may help to refer to the *2024 Inland Survey Protocol* for additional details for some terms.

Audio-Visual Survey: The required method for determining murrelet use or occupancy in relation to proposed projects that may negatively impact murrelets or their terrestrial **Habitat (Nesting Habitat)**, primarily timber harvest-related projects. Audio-visual surveys can also be useful for monitoring murrelet activity levels, locating nests, establishing murrelet use patterns, or for research purposes such as characterizing habitat.

Breeding Season: the portion of the calendar year defined by the earliest known nesting and latest known fledging dates. The breeding season extends 24 March – 15 September in California, 1 April – 15 September in Oregon and Washington, 15 April – 15 September in British Columbia, and 15 May – 5 August in southeastern and south-central Alaska.

Canopy Height (Canopy): in relation to murrelet behaviors and weather conditions during surveys, is the height of the tallest tree within the station effective area. See *Appendix J: Data Forms and Instructions* in the *2024 Inland Survey Protocol*. The term canopy may also refer to the forest layer comprised of the crowns of the overstory trees.

Conservation Zone: Six conservation zones were established in the Marbled Murrelet Recovery Plan (USFWS 1997), for that part of the murrelet's range south of Canada. Zones 1 and 2 are in Washington (Puget Sound and western coast range, respectively), Zone 3 includes the northern and central Oregon coast range, Zone 4 includes southwestern Oregon and northern California (Siskiyou coast range), Zone 5 includes south of Cape Mendocino to San Francisco Bay (Mendocino), and Zone 6 includes the Santa Cruz Mountains. See Lorenz et al. (2021) and USFWS (1997) for maps of these zones.

Contiguous Habitat: For purposes of defining **Survey Areas**, within 402 m (0.25 mi) of the Project Footprint, contiguous habitat is all **Habitat** that is either connected to (within 200 m [656 ft] of) the **Project Footprint** or within 200 m (656 ft) of habitat connected to the project footprint. For any other purpose, contiguous habitat is all areas of habitat that are connected to (within 200 m [656 ft] of) each other.

Detection (Detection Type): Murrelet detections can be classified into three categories: occupied; presence; or no detections, depending on the types of behavior observed. **Presence Detection** and **Occupied Detection** are defined below.

False Omission Rate: The False Omission Rate (FOR) quantifies: If the decision was that the area is not occupied, what is the chance that it was in fact occupied? See *Appendices A and B* in the *2024 Inland Survey Protocol* for more details.

Forest Stand: a contiguous group of trees relatively uniform in composition, age class, location, origin, size class, structure, and distribution.

Habitat (Nesting Habitat): Coniferous forest with one or more **Platform Trees**, where the surrounding forest **Canopy** (surrounding trees or within the platform tree itself) provides some cover and functional protection.

Hard Edge: An edge created by the dissimilarity of two cover types, such as a recent clearcut next to older forest (van Rooyen et al. 2011). A hard edge in this study, in the southwestern British Columbia coastal western hemlock (*Tsuga heterophylla*) biogeoclimatic zone, occurred in instances where the heights of trees in adjacent areas differed by at least 7 m (23 feet). A forest edge with trees younger than approximately 15 years adjacent to older forest is also defined as a hard edge (Malt and Lank 2007, van Rooyen et al. 2011).

Hazard Tree: A live or dead tree with damage or defects that potentially could cause injury or death to people or damage to property.

Megafire: A wildfire of such exceptional intensity that it would not likely have occurred if the variables that determine fire severity had not been altered by climate change.

Natural Edge: A forest edge that has developed naturally within a stand, for example by a large tree falling creating a gap, a river, an avalanche chute, or a naturally occurring meadow (Malt and Lank 2007, van Rooyen et al. 2011). A natural edge, in the van Rooyen et al. (2011) southwestern British Columbia coastal western hemlock biogeoclimatic zone study, occurred in instances where the heights of trees in adjacent areas differed by approximately 4 m (13 ft).

Not Occupied Area: If none of the behaviors or conditions for occupancy designation were detected anywhere in the **Survey Area** after completing the required number of surveys, the **Survey Area** is designated as not occupied for a period of five years.

Occupancy Classification: An occupancy classification of occupied or **Not Occupied** (formerly unoccupied), based on observed murrelet behaviors, applies at the scale of the entire **Survey Area**. Occupied results from one or more **Survey Strata** [site] within a **Survey Area** apply to the entire survey area. However, when delineating an **Occupied Area** from these results, all **Contiguous Habitat** within 402 m (0.25 mi) of the **Project Footprint** should be protected at a minimum, to maintain contiguity of **Habitat** for murrelet survival and recovery.

Occupied Area (Occupied Site): **Survey Area** where at least one occupied behavior or condition is detected or, if using the **Presence Approach**, three or more survey visits with at least one **Presence Detection** of any type, have been documented. Results from any **Survey Strata** [site] within a **Survey Area** apply to the entire **Survey Area**. Occupied areas include the survey area and all **Contiguous Habitat** within 402 m (0.25 mi) of the **Project Footprint** at a minimum. An occupied area is a nesting area which is delineated as such in perpetuity, so long as the area continues to support **Habitat**.

Occupied Detection: Behaviors indicative of occupancy, or occupied behaviors, are associated with visual **Detections** of murrelets below the forest **Canopy**, circling above the Canopy (≤ 3

canopy heights; see the *2024 Inland Survey Protocol* for more details), or audio detections indicating a murrelet is close to the surveyor or stationary in a tree.

Occupied Habitat: **Habitat** where one or more **Occupied Detections** or three or more survey visits with at least one **Presence Detection** were recorded.

Occupied Only Approach: A survey approach in which one **Detection** of an occupied behavior (e.g., subcanopy flights, circling, and landings) at any station within the **Survey Area** leads to an **Occupied Classification**. This approach requires more survey visits than the **Presence Approach**.

Platform (Nest Platform): A relatively flat surface >10 cm (4 in) in diameter created by a wide bare branch, a mistletoe infection or witch's broom, broken top trees, or other deformity, often with nesting substrate like moss, or lichen, needles, or other debris. Platforms are located on a branch or other surface >10 m (33 feet) high in the live crown of a tree.

Platform Tree: A tree of any age that provides a branch or branches with structures appropriate for murrelet nesting.

Presence Approach: A survey approach in which three or more survey visits with at least one **Presence Detection** or one **Detection** of occupied behavior leads to a **Survey Area** being classified as occupied. This approach requires fewer survey visits than the **Occupied Only Approach**.

Presence Detection: Murrelet **Detections** classified as presence detections include: (1) audio detections (except for below-**Canopy**, non-vocal detections of jet sounds or wingbeats, or stationary audio detections, which are classified as **Occupied Detections**); (2) visual detections of direct (straight line) flights above the **Canopy**; (3) visual detections of murrelets circling at greater than three **Canopy Heights**; or, (4) visual detections of murrelets flying in less than a 45-degree arc at a height greater than one **Canopy**. According to the *2024 Inland Survey Protocol*, if a murrelet is seen circling >3 **Canopy Height** with > 45 degree arc, consult your regulatory agency. See *2024 Inland Survey Protocol* for more explanation.

Project Footprint: Geographic boundary of the proposed action, including timber sales, planned new roads or quarries, etc.

Reiteration: A vertical stem that takes the form of a miniature tree and arises from a horizontal branch of a larger tree.

Site-potential Tree Height: The average maximum height of the tallest dominant trees (200 years old or more) for a given site class. Site class is a classification of the relative productive capacity of a forested area based on tree height or volume that is attained at a given age.

Soft Edge: A forest edge such as that which has developed with a regenerating forest (e.g., of about 15-40 years old; Malt and Lank 2007, van Rooyen et al. 2011) next to older-aged forest. A soft edge, in the van Rooyen et al. (2011) southwestern British Columbia coastal western hemlock biogeoclimatic zone study, occurred in instances where the heights of trees differed by less than 1 m (3 ft).

Survey Area: The fundamental unit at which surveys are conducted and **Occupancy Classification** is determined. See **Occupied Area** above and text below for how to apply the results in practice.

Survey Strata (singular Stratum): a survey area can be divided into one to three subunits, called strata, to ensure that the survey effort is distributed more evenly across the survey area. Comparable to survey sites in terminology of the 2003 version of the survey protocol.

INTRODUCTION

This document provides forest management and survey strategy recommendations intended to contribute to the conservation of Marbled Murrelets (*Brachyramphus marmoratus*; murrelet) and their terrestrial **Habitat (Nesting Habitat)**¹, based on the best available science and the collective knowledge of the authors. The Federal, State, and Provincial listings of the murrelet in Washington, Oregon, California, and British Columbia, coupled with continued habitat loss (Lorenz et al. 2021, Valente et al. 2021), emphasize the need for long-term retention of habitat for the conservation and recovery of the species. The loss and fragmentation of terrestrial habitat, both historically and contemporarily, is one of the biggest drivers of the species' status, negatively impacting reproduction, abundance, and recruitment (USFWS 1992, Raphael et al. 2002a). Timber harvest on nonfederal lands has been the majority source of that loss and fragmentation, particularly since the federal listing of the species in 1992 (Valente et al. 2023). Habitat loss and fragmentation directly impacts murrelets by reducing nest site availability and by displacing them from their nest sites, which, for site-faithful species such as murrelets can result in nest abandonment, delayed breeding, failure to breed in subsequent years, and nest failure due to egg, chick, or adult predation (Raphael et al. 2002a). Additionally, timber harvest-related activities within or adjacent to habitat which occur during the **Breeding Season** may lead to aborted, missed, or delayed feedings which can result in juvenile mortality, and increased energetic costs due to increased vigilance by adults, which can have negative impacts on reproductive success (Hébert and Golightly 2006, USFWS 2015).

So as not to exacerbate the impact that timber harvest has already had and is having on murrelets, this document describes specific measures that would minimize the future loss and fragmentation of terrestrial habitat, including strategies for conducting surveys, strategies for delineating **Occupied Areas**, maintaining or improving the integrity of the forested landscape, maintaining and buffering **Occupied Habitat**, enhancing and creating habitat, reducing impacts from human activities (e.g., timber harvest-related activities, construction or maintenance of human infrastructure, etc.), and minimizing disturbance and disruption to murrelets, particularly during the breeding season (e.g., recreation).

The habitat management recommendations contained in this document were initially drafted by the Pacific Seabird Group's Inland Survey Protocol Subcommittee (a subcommittee of the Marbled Murrelet Technical Committee), with the intent that they would be included as a chapter in the recently revised *A Revised Protocol for Surveying Marbled Murrelets in Forests* (PSG Technical Publication 6, <https://pacificseabirdgroup.org/psg-publications/technical-publications/>; hereafter referred to as the *2024 Inland Survey Protocol*). In 2023, the subcommittee agreed to separately publish recommendations for habitat management in this document, under the provision that both documents would reference each other. We consider this document to be a companion document to the survey protocol, each used in conjunction with the other. This document is intended for use by practitioners who are: (1) using the *2024 Inland Survey Protocol*; (2) using the 2003 survey protocol (Evans Mack et al. 2003) under temporary "legacy" scenarios; or (3) assuming occupancy of murrelet habitat on their managed lands and foregoing

¹ Terms used in this document are bolded and capitalized at first mention and are defined in the Glossary. These terms appear in normal fonts in all subsequent uses.

surveys. It is intended to provide recommendations for all who are responsible for managing inland murrelet habitat.

This document builds from the following sources: the Marbled Murrelet Recovery Plan (Recovery Plan; USFWS 1997), the U.S. Fish and Wildlife Service (USFWS) listing decision (USFWS 1992), Critical Habitat Rules (USFWS 1996, 2011, 2016), the 5-year review (USFWS 2019), the *2024 Inland Survey Protocol*, input from species experts, and relevant scientific literature. The Recovery Plan included the following objectives: “(1) stabilizing and then recovering the population by maintaining or increasing productivity and removing or minimizing threats to survivorship, and by maintaining or increasing nesting success by maintaining or increasing marine and terrestrial habitat; (2) providing habitat conditions in the future that will allow the continued existence of viable populations; and (3) gathering data for developing scientific delisting criteria.” The Recovery Plan identified stabilizing and increasing habitat quality and quantity as the key to stopping population decline. In the listing decision, the USFWS recognized habitat loss and fragmentation as the major factors causing the decline of murrelet populations (USFWS 1992; also see Chapter 1: *Species Status* in the *2024 Inland Survey Protocol*). Threats identified in the Recovery Plan and listing decision in the 1990’s remain today.

Marbled Murrelets, like most seabirds, have a habitat-split strategy where they nest and forage in two different habitat types during the breeding phase of their life cycle. Because they depend on more than one habitat type, especially during the breeding season, seabirds are believed to be more sensitive (than non-habitat-split species) to changes in their nesting and foraging habitats (Betts et al. 2020). Their marine and terrestrial ecosystems collectively support murrelet populations, such that maintaining both functional forests and functional marine ecosystems is critical to the species’ survival and recovery.

Murrelets have high fidelity to their nesting sites; forested areas throughout their range first found to be occupied in the 1980s are still occupied today (e.g., Bradley 2002, Nelson and Wilson 2002, Barbaree et al. 2014). Within nesting sites, murrelets can use multiple nest trees within and among years and co-occur with other murrelets. Social information (vocalizations of other murrelets) appears to influence breeding site selection and likely contributes to long-term stand occupancy (Valente et al. 2021). Because of these factors, an occupied stand is considered occupied in perpetuity, so long as the area continues to support habitat. Protecting entire areas of habitat is imperative for successful reproduction, and improving the quality and/or increasing the quantity of habitat at a nest site may help improve that success.

The following actions are essential for the conservation of the murrelet and the terrestrial habitats upon which the species depends:

- delineate occupied areas;
- protect all habitat;
- maintain and enhance (improve the quality and/or increase the size of) forested areas adjacent to habitat (see *Minimizing Edge Effects Through Buffers*);

- maintain and enhance large blocks of contiguous forest cover (maximize stand size and minimize fragmentation; USFWS 1997);
- minimize predation and predator numbers in and near habitat (see *Minimizing Edge Effects Through Buffers*);
- minimize the effects of disturbance near habitat (see *Minimizing Disturbance and Disruption*; USFWS 1997, USFWS 2015, USFWS 2020); and
- avoid or minimize adverse impacts to murrelet habitat due to forest fires, for example by preventing **Megafires** (see *Managing and Reducing Threats of Megafires*).

While this document focuses on inland habitat, it must be recognized that the conservation of marine habitat is also central to the conservation and recovery of murrelet populations (Lorenz et al. 2016, 2017). Therefore, strategies to protect and enhance marine resources to maintain healthy marine food webs will also be critical to ensure murrelet persistence (see details on marine reserves and other marine protected areas here:

https://nmsmarineprotectedareas.blob.core.windows.net/marineprotectedareas-prod/media/archive/pdf/helpful-resources/factsheets/mpa_classification_may2011.pdf).

HABITAT MANAGEMENT RECOMMENDATIONS

Selecting Habitat and Conducting Surveys

The *2024 Inland Survey Protocol* includes a suite of recommendations for conducting inland Marbled Murrelet surveys. In Chapter 2 of the *2024 Inland Survey Protocol*, options for implementing certain aspects of the survey method strategy are offered. In other places, the *2024 Inland Survey Protocol* is clear regarding its recommendations for a single survey strategy, such as using a **False Omission Rate** (FOR) of 0.05 (see *Statistical Analysis Overview* and *Appendix A* in the *2024 Inland Survey Protocol*). Where strategy options are mentioned, the decision to adopt one versus another strategy should be made in consultation with the appropriate regulatory agency.

This document clarifies when one strategy has a higher likelihood of achieving PSG's Marbled Murrelet conservation goals. These strategies include: (1) always using the definition of habitat from Chapter 1 of the *2024 Inland Survey Protocol*; (2) conducting additional surveys in certain situations, described in more detail below; and (3) managing unsurveyed habitat as if it were occupied.

We recommend using the definition of habitat from Chapter 1 of the *2024 Inland Survey Protocol* (coniferous forest with one or more platform trees, where the surrounding forest canopy [surrounding trees or within the platform tree itself] provides some cover and functional protection) and not using alternative criteria to define habitat; See the *Nesting Habitat* section in the *2024 Inland Survey Protocol*, as that may lead to omitting habitat from the survey. Failure to identify and survey all murrelet habitat could lead to missed **Detections** and misclassification of survey areas, which in turn may lead to harvest of occupied habitat. The more occupied habitat that is retained now, the greater the likelihood of species conservation in the future, particularly considering the fact that climate change is predicted to lead to significant losses of terrestrial murrelet habitat (USFWS 2019).

Similar to using the above habitat definition, we recommend the use of a 0.05 FOR (or lower) as is recommended in the *2024 Inland Survey Protocol*. Using it ensures an accurate survey area classification at least 95% of the time, while also achieving survey efficiency. In this manner, only 5% or fewer determinations of **Not Occupied** would be in error, and occupied habitat would be conserved. The 5% value is a common statistical criterion, which in this instance balances error rate and required survey effort.

To improve the chances of accurately determining the occupancy status of a survey area, additional surveys within a season or even additional years of survey may be needed. For example, under the *2024 Inland Survey Protocol*, if an observer only saw a partial arc (<45-degree arc at >1 canopy) of a murrelet on the last visit of a season, and no detections were recorded on other visits, only presence will have been documented in that survey area. Similarly, if fewer than three surveys with presence are recorded over the two years of surveys, only presence will have been recorded. In such circumstances, we recommend following up with additional surveys in the current and/or subsequent year(s) and contacting your regulatory agencies. An area with murrelet presence could in fact be occupied and follow up surveys could help verify the area's actual status. Poor ocean years and other factors (e.g., murrelet health, habitat changes) can affect activity of murrelets at inland sites (Betts et al. 2020), resulting in

inaccurate area status. We recommend postponing surveys during and in the year following poor ocean years or adding years of surveys (i.e., a total of 3 or more consecutive years) to determine the true occupancy status of survey areas. In situations such as the examples given above, but not limited to only these examples, we recommend land managers add additional surveys or survey years and/or consult with their regulatory agencies.

Because both retaining and growing habitat are key to murrelet conservation, the management of unsurveyed habitat is also key. Any areas of habitat that have yet to be surveyed should be managed as though they are occupied, for purposes of species conservation and avoidance of take under the Endangered Species Act. Land managers can avoid survey costs entirely, simply by assuming unsurveyed habitat is occupied. This is a strategy employed by at least one large Federal landowner within the range of the murrelet today. By planning projects in this way, both time and money are saved, and murrelet habitat is conserved.

Application of Survey Results to Designate Occupied Areas

Delineating Occupied Areas

The *2024 Inland Survey Protocol* provides a statistically valid method, through the use of **Audio-Visual Surveys**, for detecting murrelets and determining the **Occupancy Classification** of a survey area with high confidence (see discussion of 0.05 FOR in the previous section, above). The results from the protocol surveys should then guide the protection, conservation, and management of murrelets and their habitat. When a survey area has been determined to be occupied, we recommend delineating **Occupied Areas** that encompass the survey area and all **Contiguous Habitat** within 402 m (0.25 mi) of the **Project Footprint**, at a minimum, to maintain contiguity of habitat for murrelet survival and recovery. As stated earlier, we do not recommend using an alternate definition of habitat; instead we recommend that the occupied area include all coniferous forests with one or more platform trees, where the surrounding forest canopy (surrounding trees or within the platform tree itself) provides some cover and functional protection (canopy cover, canopy layers, complex canopy structure; Nelson and Hamer 1995, Hamer et al 2021). Contiguous habitat is all areas of habitat that are connected to (within 200 m [656 ft] of) each other.

As stated in Chapter 1 of the *2024 Inland Survey Protocol*, larger, contiguous blocks of habitat provide critical, higher quality nesting habitat for murrelets by allowing co-occurrence (multiple pairs of birds using the same **Forest Stands** within the same year) and by providing multiple options for nest tree selection within and between years (pairs will use multiple trees in a stand and not nest in the same tree every year; Nelson and Peck 1995, Burger et al. 2009; Nelson unpublished data). Larger blocks not only increase the amount of interior core habitat at the stand level by providing more cover (canopy cover, canopy layers, complex canopy structure), but also help reduce predation and prevent microclimate impacts (see *Minimizing Edge Effects through Buffers*) such as increased temperatures and changes in moss abundance (e.g., USFWS 1997, Van Rooyen et al. 2011, Frey et al. 2016, Betts et al. 2017, Valente et al. 2021; see below). The importance of social information (vocalizations of other murrelets) and conspecific attraction in nest site selection also indicate that larger blocks of nesting habitat are key to supporting murrelet populations (Valente et al. 2021).

Based on the biology of the species, we recommend the following when delineating an occupied area:

- delineate all the habitat in the survey area plus all contiguous habitat within 402 m (0.25 mi) of the project footprint (or other proposed activities), at a minimum (Figure 1A-F);
- include all habitat up to the stand edge even if platform trees do not extend to the edge (Figure 1D). In some cases, it may not be obvious where the stand edge is, in which case land managers should consult with their regulatory agencies to delineate the occupied area;
- include a 100-m (328-ft) buffer around all occupied areas (see *Minimizing Edge Effects through Buffers* below; Figure 1E-F);
- if all platform trees in an occupied area form a linear feature (e.g. riparian strip), include portions of the surrounding forest, in addition to a 100-m (328-ft) buffer, to create a broader delineation of habitat (e.g., more forest adjacent to the riparian area). See *Minimizing Edge Effects through Buffers*; and
- consider topographic boundaries and extend the delineation of an occupied area out to a ridge, a road, or a river rather than ending at the stand edge to maintain the integrity and function of the contiguous habitat and to make the occupied area easily identifiable for managers and regulators.

In some situations, land managers may choose to extend the delineation of an occupied area to include habitat that has not been surveyed or that has been surveyed and not determined to be occupied. Following are examples of situations where including habitat beyond the survey area and the habitat within 402 m (0.25 mi) may contribute to habitat quality within an occupied area survey area that has been determined to be:

- where contiguous habitat (unsurveyed or not occupied) continues beyond 402 m (0.25 mile) from the project footprint (Figure 1F);
- where including discontinuous habitat would contribute to the functionality and integrity of the occupied area, by maintaining a larger forested area on the landscape;
- where survey areas overlap but not all survey areas are classified as occupied; and
- where the size of a project footprint prompts the need to establish two or more survey areas, but not all survey areas are determined to be occupied based on survey results. In these situations, consider the landscape context and the contiguity of habitat when delineating the extent of the occupied area, so as to protect the integrity of habitat at the landscape scale. For the purpose of murrelet conservation, the maximum amount of habitat should be retained on the landscape.

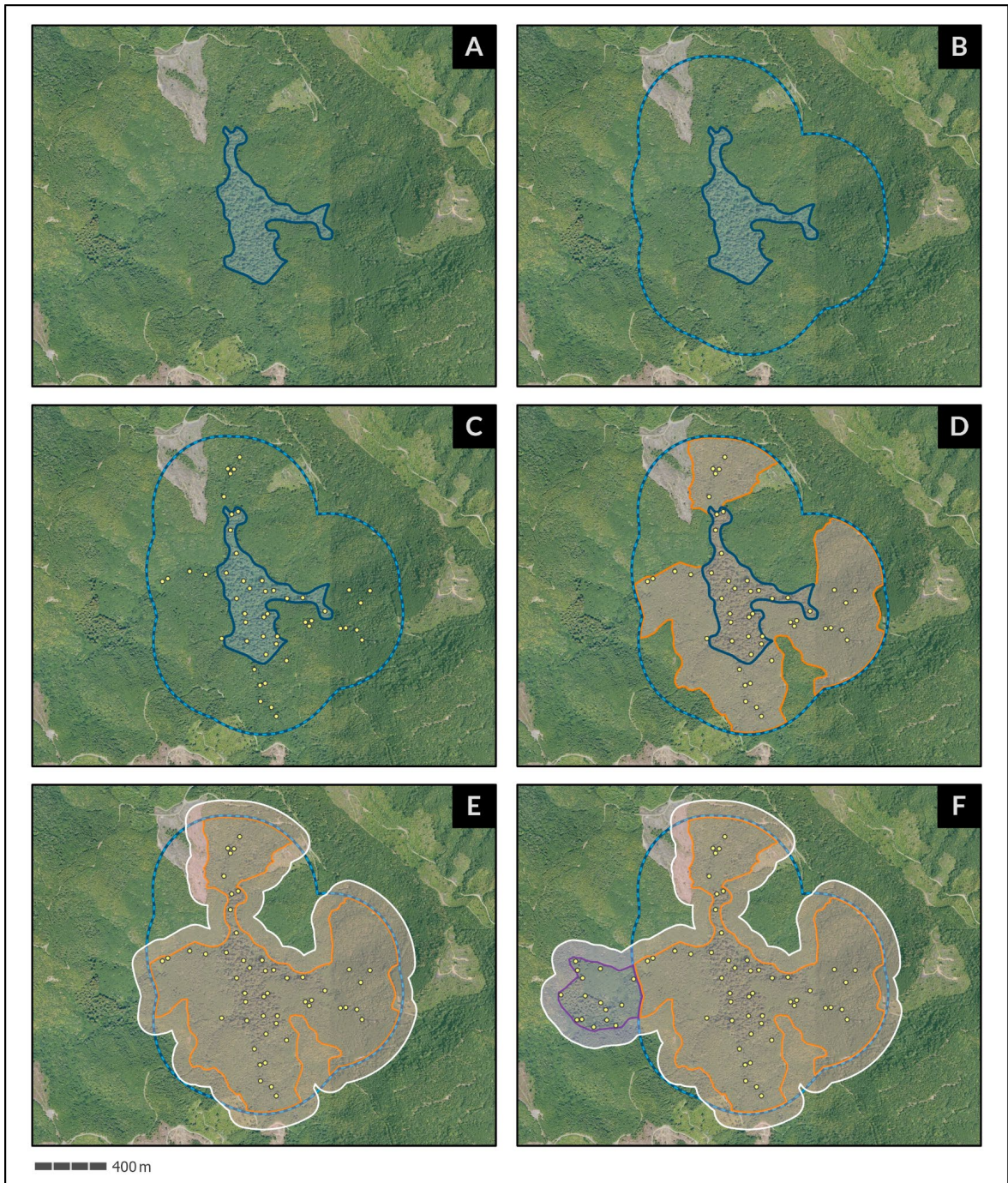


Figure 1. Hypothetical proposed timber harvest, showing: (A) project area (timber harvest unit) [blue line]; (B) 406-m (0.25-mi) boundary around project area [dashed blue line]; (C) platform trees [yellow dots] within the project area and the 406-m boundary; (D) contiguous forested habitat within the project area and the 406-m boundary, delineating the survey area [orange line]; (E) assuming occupancy by murrelets, 100-m (328-ft) buffer around survey area, delineating the occupied area [white line]; and (F) habitat that is contiguous with the occupied area, occurring beyond the 406-m boundary [purple line] and 100-m buffer [white line].; this area could include habitat that has not been surveyed or that has been surveyed and not determined to be occupied.

Determining whether to include additional habitat in the delineation of the occupied area will be informed by many factors, including:

- murrelet observations (the number, type, and location of detections) within the survey area and in nearby areas (e.g., adjacent survey areas, contiguous habitat outside of survey area or between occupied survey areas);
- limitations to visibility or audibility caused by survey station location;
- the quantity and quality of habitat in the surrounding forested landscape;
- topography; and
- land ownership patterns.

The relevant regulatory agency should be consulted for further guidance.

Additionally, while occupied areas include nest sites, they may also include additional terrestrial habitat used by murrelets as part of their life history (Nelson 1997, 2020). For example, in British Columbia, Oregon, and California, murrelets have been observed repeatedly landing in trees without **Platforms (Nest Platforms)** or in areas otherwise unsuitable for nesting that are contiguous with or near habitat (J. Deal, S.E. McAllister, S.K. Nelson, S.W. Singer, pers. comm.). These landings involved more than one murrelet, occurred on multiple occasions at the same locations, and birds remained in these trees for a period of time (a few seconds to about 45 minutes). Such landings may occur outside the nesting season. Thus, places such as these, where birds engage in courtship or other breeding-related activities, or in activities that otherwise serve to maintain a bird or birds' connection to habitat, are important to the species' life history and likely to contribute to increased nesting success. Similar to the *2024 Inland Survey Protocol* (see *Occupancy Classification* section in that document), where landing in trees is an occupied behavior, we recommend occupied habitat delineations in these areas be applied using the same methods.

To improve murrelet conservation, it is important to expand the distribution of large blocks of contiguous older forest (≥ 80 years) throughout the listed range (USFWS 1997). This will allow for an improved population distribution within each **Conservation Zone** and may help mitigate current and future climate change impacts to terrestrial murrelet habitat, including fire, landslides, drought, windthrow, forest diseases, and insect infestations. Climate change is altering, and predicted to further alter, western forests within the range of the murrelet due to increased temperatures, changes in precipitation timing and amount, extended fire seasons, increased fire severity, increased episodes of flooding and landslides, increased forest disease and insect outbreaks, and changes in tree species composition (e.g., Littell et al. 2014). Working now to improve the distribution, abundance, and quality of nesting habitat will help mitigate current and future impacts of climate change and improve the likelihood of conservation of the murrelet. Resisting the effects of climate change may not always be successful; resist-adapt-direct (RAD) management (Schuurman et al. 2020) may be needed to fully contribute to long-term murrelet survival and recovery.

Delineating Not Occupied Areas

Follow guidance in the *2024 Inland Survey Protocol* under *Classification of Survey Areas* to determine if the survey area is occupied or not occupied. To best conserve murrelets and their habitat, a determination of not occupied based on surveys should only apply to the area surveyed. This is especially important if an alternative definition of habitat was used during protocol-level surveys (i.e., not using one tree with one platform in a stand as the definition of habitat; See *2024 Inland Survey Protocol*).

How Long Do Survey Results Apply?

If a survey area is determined to be occupied then it should be classified as occupied indefinitely to provide habitat in the long term, so long as the area continues to support nesting habitat (see *Occupancy Classification* in Chapter 2 of the *2024 Inland Survey Protocol*). The designation of occupied habitat in a forest implies that the area serves as a breeding location for murrelets. Murrelets have high breeding site fidelity; occupied areas monitored for more than 30 years have remained occupied (e.g., Bradley 2002, Nelson and Wilson 2002, Barbaree et al. 2014). Land managers should consult with regulatory agencies if conditions within an occupied area have changed significantly such that it no longer functions as habitat (e.g., due to fire or catastrophic wind events).

To account for variability in availability of forage fish in marine foraging habitats and associated impacts on breeding efforts on land (e.g., Betts et al. 2020), survey areas designated as not occupied under the survey protocol reflect the status of the survey area only within five years of when the surveys were conducted. If five or more years have passed since surveys resulted in a not occupied designation, then habitat needs to be resurveyed before a timber harvest or planned management activity (e.g., blasting, building infrastructure) can proceed. If murrelets are detected in the survey area any time during or after the five-year period following a not occupied classification, then the survey area and all contiguous habitat within 402 m (0.25 mi) of the timber sale/project boundary warrants a change in classification from not occupied to occupied. Consult with your regulatory agencies regarding any changes in occupied area designation.

Data Sharing and Coordination with Adjacent Land Managers

Sharing survey results (occupied, presence, no detections) and coordinating with adjacent land managers to delineate and appropriately manage occupied areas are highly recommended. Data sharing can maximize protection of murrelets and occupied habitat and can minimize and/or lead to efficiencies and cost savings in survey and management efforts. As the *2024 Inland Survey Protocol* is implemented, consistent data collection and consolidation of Federal, State, and private data into shared databases (for all surveys including occupied, presence, and no detections) will allow for detailed and up to date statistical analysis in the future, which will inform the next iteration of the protocol (see *Data Collection and Reporting* in Chapter 2 of the *2024 Inland Survey Protocol*), as well as improve management of murrelet habitat and species status. A data template and information about where to submit data can be found at <https://pacificseabirdgroup.org/psg-publications/technical-publications/>. Similarly, data collected at sea on the distribution and abundance of murrelets nearshore from California to Washington should be archived in the North Pacific Pelagic Seabird Database (NPPSD; <https://www.usgs.gov/centers/alaska-science-center/science/north-pacific-pelagic-seabird-database>), the largest repository of at-sea marine bird data in North America, where it can be used to assess changes in abundance and distribution with respect to changes in marine habitat

quality (Drew et al. 2005). It is also expected that the next iteration of the protocol will benefit from continued research on ocean conditions, specifically the effect of multiple years of poor ocean conditions on inland breeding and the ability to determine occupancy with increased climate change effects (Betts et al. 2020).

Maintaining and Managing Occupied Areas and the Integrity of the Landscape

This section will review techniques for managing existing Marbled Murrelet habitat and developing new habitat. Human activities and infrastructure often result in predictable effects on murrelet habitat, while stochastic events, such as wildfires and windstorms, can cause changes to habitat unexpectedly. By incorporating considerations for the Marbled Murrelet into habitat management decisions, whether occurring proactively or reactively, we expect the landscape would better support murrelet nesting in the long term. The topics in this section highlight certain aspects of murrelet habitat whose importance has been emphasized by the USFWS in both their listing rule and critical habitat rules including platform trees and the forested areas surrounding them (USFWS 1992, 1996, 2011, 2016).

Across forest land ownerships within the range of the murrelet, maintaining and creating large blocks of functional, contiguous habitat is important for murrelet survival and recovery (USFWS 1997). Forested areas containing habitat should be managed to maintain the integrity of the older-tree component and to minimize predation, blowdown, and microclimate effects (Burger 2002, Raphael et al. 2002a, Meyer and Miller 2002, McShane et al. 2004, Nelson et al. 2006, Raphael et al. 2015, 2016; Wilk et al. 2016). Key to these goals are avoiding harvest within occupied areas, minimizing fragmentation of habitat throughout watersheds containing occupied sites, maximizing the canopy cover of mature and young forest areas adjacent to occupied areas, and incorporating no-cut buffers adjacent to occupied sites. Land acquisitions and consolidating land ownership to separate logging activities from existing and future older-aged forests could facilitate the development of larger blocks of habitat (see *Protecting and Managing Residual Old-growth within Second-growth Forests*). Techniques for accelerating growth of new habitat have yet to be proven, but more research is warranted (see *Developing New Habitat*).

Where management of large contiguous blocks of mature forest is not possible, land managers should strive to protect habitat within large heterogeneous (mixed age) landscapes. These landscapes and habitat patches should have **Natural Edges** or buffers of simple-structured mature forests (Raphael et al. 2002a, 2002b; Ripple et al. 2003). Murrelets are most vulnerable when unbuffered habitat is adjacent to clearcuts and regenerating forests with berry-producing plants, which is optimal habitat for predators (Masselink 2001, Marzluff et al. 2004, Marzluff and Neatherlin 2006). To reduce predation pressure, predator management measures may be necessary (Halbert and Singer 2017). In addition, habitat in close proximity to human habitation or areas of high human use has higher predator densities and therefore lower nest success (Miller et al. 1998, Raphael et al. 2002a, Marzluff and Neatherlin 2006). Therefore, it is important to buffer (i.e. add areas of no-cut and no development) any current or future habitat from clearcuts or areas of high human use (see *Minimizing Edge Effects Through Buffers*).

Managing the forested landscape in ways that reduce the threat of wildfires, as well as hazard tree management, are important to the maintenance of murrelet habitat. Wildfire is a significant source of murrelet habitat loss in some conservation zones, with megafires becoming more common in this era of climate change. Proactive techniques for wildfire prevention should be used to curb human-caused fire ignitions, which account for the majority of fire ignitions (see *Managing and Reducing Threats of Megafires*). Wildfire, windstorms, construction, and natural succession can all result in designation of **Hazard Trees** that are cut or removed without consideration for effects to murrelet habitat. As hazard tree removal can eliminate current and future nesting trees and platforms, measures should be taken that would allow these trees to remain on the landscape whenever possible (see *Hazard Trees*).

Various anthropogenic activities can affect the ability of murrelets to nest successfully. Increases in nest predator densities have been tied to the availability of human food waste in recreation sites, but effective strategies exist to protect against this (see *Reducing Impacts from Recreation and Other Human Activities*). Construction and ongoing maintenance of infrastructure such as power lines, roads, and inland wind power developments can lead to direct mortality of murrelets, loss of habitat, or loss of access to habitat. Additionally, murrelets can experience visual or noise disturbance from certain activities occurring in habitat. For many activities, there are alternative methods, locations, or timing that could be incorporated into project design and maintenance that would minimize negative impacts to murrelets (see *Construction and Maintenance of Power Lines, Roads, and Inland Wind Power Developments* and *Minimizing Disturbance and Disruption*).

Forest land managers, particularly Federal land managers or those whose projects are funded, authorized, or carried out by a federal agency, should be aware that the USFWS has designated critical habitat for the Marbled Murrelet (USFWS 1996, 2011, 2016). The designation of critical habitat is intended to highlight the value of a particular area to the recovery of a federally listed species, as well as the important characteristics of that habitat for the species. According to Federal regulations (50 Code of Federal Regulations 424.12(b)), designated critical habitat identifies the physical or biological features essential to the conservation of a species, focusing on the “primary constituent elements” of those features. The USFWS considers the following to be primary constituent elements specific to the murrelet: (1) individual trees with potential nest platforms, and (2) forested areas within 0.8 km (0.5 mi) of individual trees with potential nest platforms, and with a canopy height of at least one-half the **Site-potential Tree Height** (USFWS 1996, 2016). This 2nd primary constituent element includes all such forested areas, regardless of contiguity [with the tree or each other]. These characteristics are considered not only important to the biology of the species, but essential to the conservation of the species. For that reason you’ll see them discussed directly or indirectly in this *Maintaining and Managing Occupied Areas and the Integrity of the Landscape* section. Activities that may affect critical habitat, when carried out, funded, or authorized by a Federal agency, should involve a consultation with the USFWS (USFWS 1996). Therefore, for any activities that may affect federally designated critical habitat, and that are carried out, funded, or authorized by a Federal agency, land managers should consult with the USFWS on the possible effects of their proposed projects on these primary constituent elements.

Protecting and Managing Residual Old-growth within Second-growth Forests

Federal efforts to protect old-growth forests from logging began in the late 19th Century in Washington State, when President Cleveland designated most of the forested land on the Olympic Peninsula as the Olympic Forest Reserve. President Theodore Roosevelt designated part of this reserve as Mount Olympus National Monument in 1909, and in 1938, President Franklin Roosevelt signed legislation that established Olympic National Park. Legislation was introduced as early as 1911 to create a redwood national park; in 1968, President Johnson signed a bill creating Redwood National Park. In the early 20th century, private citizens also initiated efforts to protect old-growth forests, when conservation organizations such as the Sempervirens Fund (formed ca. 1900, then the Sempervirens Club) and Save the Redwoods League (formed ca. 1918) were formed to purchase and/or manage land parcels or conservation easements on parcels containing primarily old-growth trees. In California, several State Parks were established through the initial acquisition of redwood groves by businesspersons and the aforementioned conservation organizations, and subsequent acquisitions during the 20th Century enlarged the acreage of these parks. In addition to the efforts of private conservation groups, older-aged or occupied forest parcels within the range of the murrelet have been purchased through restoration settlement funds from oil spill mitigation.

In Washington, Oregon and California, the majority of contiguous murrelet nesting habitat occurs within State and National parks and forests. Possibly due to a dearth in availability of old-growth parcels for purchase, and for mitigation purposes, in recent years, conservation organizations have begun to consider the purchase and protection of parcels with residual old-growth trees among second-growth trees, with the goal to manage these forests to eventually attain late-seral forest characteristics (e.g., Carey et al. 2003, for coastal redwood). For example, in 2018 in Mendocino County, California, a 235-ha (580-acre) parcel of second-growth redwood forest containing residual old-growth redwood trees was purchased by a power company and transferred to Save the Redwoods League (W. McIver pers. comm.). In 2007, 1,725 ha (4,263 acres) of occupied residual old-growth and second growth was purchased in Oregon as mitigation for the New Carissa oil spill (Kramer et al. 2010). Most of this property will be managed for murrelets in perpetuity by the Confederated Tribes of the Siletz Indians. Federal and State wildlife agencies should coordinate with conservation organizations and others to identify land parcels containing residual old-growth trees within variable-aged second-growth forests, which could be purchased (or on which conservation easements could be purchased) especially in locations in close proximity to known or suspected occupied habitat.

Developing New Habitat

Considering the scale of negative impacts that contemporary and historical habitat loss and fragmentation have on distribution and abundance of murrelets, managers should carefully analyze the potential risks to this listed species when seeking to develop new habitat or to attract birds to unused habitat. Over time a number of techniques have been proposed ranging from stand-wide thinning to individual tree manipulation. Some of these techniques seem promising, while others may be ineffective or counter-productive. None have been thoroughly tested as of yet.

Some land managers may aim to accelerate development of murrelet habitat by thinning young, even-aged, overly dense forested areas not known to be occupied (e.g., those <50 years in age), but there may be substantial short-term risks to murrelets if forest treatments occur in close

proximity to areas of occupancy. Reductions in forest cover can create openings in the canopy, which can lead to change in microclimate conditions and increased access to murrelet habitat by predators, especially jays and ravens (e.g., Masselink 2001, Hagar et al. 2024).

Although silvicultural research shows that forest thinning can accelerate the development of larger diameter trees (e.g., Carey et al. 2003, Comfort et al. 2010), it has not been shown to greatly enhance the development of platforms large enough for murrelet nesting (Carey et al. 2003, Franklin et al. 2007, Plummer et al. 2012, Sillett et al. 2018). Unless carefully planned beforehand and monitored onsite, silvicultural thinning and associated soil disturbance can also lead to increased storm runoff, increased soil erosion, increased flooding, and an increased risk of slope failures (Elliott et al. 1992, U.S. Environmental Protection Agency 1993, Ice et al. 2004, Rice et al. 2004).

Stand-level responses to silvicultural treatments have not been measured long enough in/near murrelet habitat that demonstrate direct benefits to murrelets. Therefore, in general, we do not recommend thinning activities in habitat or in buffers adjacent to habitat. If any treatments are conducted adjacent to murrelet habitat, adequate no-cut buffers are needed to protect the integrity of habitat and to protect murrelets from disturbance, particularly in instances where habitat is known to be occupied (See *Minimizing Edge Effects through Buffers* above and *Minimizing Disturbance and Disruption* below).

On a much smaller scale, individual tree manipulation or manipulation of very small clusters of trees can be done to accelerate the formation of large nest branches in otherwise suitable trees (Carey et al. 2003, Franklin et al. 2007, Sillett et al. 2018). This approach is largely untested but strongly supported by our knowledge of how tree canopies develop. Individual tree manipulation is accomplished by topping an otherwise suitable tree to accelerate the development of branches with **Reiterations**. Murrelets are known to favor branches with reiterations in both redwoods and Douglas-firs, and topping has been shown to accelerate their formation although it will take decades or longer to see results (Sillett et al. 2018). Small cluster tree manipulation is done by increasing sunlight availability to a selected branch or few branches of a heavily shaded tree. This can be done by pruning back or removing a neighboring tree that is blocking sunlight from reaching the target tree. The “released” branch(es) on the target tree will then grow rapidly into the new window of light, growing in both length and girth. This technique can quickly accelerate branch growth in contrast to stand-wide thinning that primarily increases trunk diameter (Carey et al. 2003, Franklin et al. 2007, Sillett et al. 2018).

Another technique that has been suggested is the placement of artificial nest platforms into trees without nest platforms that otherwise would be suitable murrelet nest sites (e.g., trees with sufficient cover) or that lost platforms due to fire or other disturbance. However, this has never been tested and there is no guarantee that murrelets would find or utilize these artificial nest platforms.

In an effort to attract murrelets to unused habitat it has been suggested that recorded murrelet calls be broadcast in such areas during the dawn and dusk activity periods in the nesting season. This type of social attraction has been tried in Oregon with encouraging results (Valente et al. 2021) but is not yet proven to result in nesting attempts by murrelets. It also includes the risk of attracting murrelets to nest in areas that look appropriate for nesting, but which may have high

predator densities or other adverse conditions not known to the project manager, which could act as sink habitat and result in reproductive failure.

Given the paucity of information about all of these techniques, we do not currently recommend their use, unless they are implemented as scientific experiments by qualified researchers who have approval from all appropriate regulatory agencies, including the appropriate federal permits.

Minimizing Edge Effects Through Buffers

The effects to murrelets from anthropogenically created forest edges are well documented in the literature, and edge effects have been identified as a factor threatening murrelet survival (USFWS 1997, 2021). To minimize the effects of forest edges on breeding murrelets, we recommend surrounding all occupied murrelet nesting habitat with a minimum 100 m (328 ft) wide no-cut buffer. A visual example of buffer designation is provided in Figure 1E-F. Several studies have documented consistent below-canopy flight corridors of murrelets to nest sites (Nelson and Peck 1995, Singer et al. 1995). Use of below-canopy flight corridors may provide murrelets with predation protection for both the adults and nests, and these corridors are important to maintain around nest sites. Our recommendation of a 100 m (328 ft) buffer width is based on a study conducted at nest sites that identified under-canopy flight routes used by murrelets of at least 100 m (328 ft) in length (Singer et al. 1995). The remainder of this section is focused on the effects of anthropogenically created forest edges on murrelet nest success.

Research has characterized murrelet nesting failure as a result of nest proximity to edges of all types: hard, natural, and soft. For murrelets, those effects were greatest in proximity to anthropogenically created **Hard Edges** versus natural edges or soft edges. These effects to nest success are likely caused by one or more of the following: loss of epiphyte cover at hard and soft edges (van Rooyen et al. 2011), lower densities of platform trees at hard-edged forest sites (van Rooyen et al. 2011), and increased predation rates at hard edges (Malt and Lank 2007, 2009), particularly when forests are in proximity to human settlements and recreation sites (Raphael et al. 2002a).

Buffers maintain favorable microclimate for epiphytes and platform creation (van Rooyen et al. 2011) and potentially aid in proper thermoregulation of adults and chicks. The term “microclimate” in this context refers to environmental conditions of the canopy within habitat, such as temperature, humidity, and wind speed that differ from those in surrounding areas. Murrelets nest on large mossy limbs within most of their range (Ralph et al. 1995, McShane et al. 2004), except on coast redwood (*Sequoia sempervirens*) where they often nest on bare branches (Singer et al. 1995). Mosses (a type of epiphyte) often contribute positively to the formation and availability of murrelet nest platforms. Bryophytes (mosses and liverworts – also epiphytes) are known to be sensitive to microclimate and are generally positively associated with moisture (Sillett and Antoine 2004). Hard-edged forested areas have lower epiphyte cover and platform tree density than natural-edged forested areas, and this effect occurs at least 50 m (164 ft) into forest stands (Van Rooyen et al. 2011). Such effects would therefore be reduced under our recommendation of a 100 m buffer. Microclimate is often affected by hard edges, with air and soil temperatures, wind velocity, and solar radiation greater in recent clearcuts (10-15 years old) and adjacent forest edges than in nearby forest interiors. Older-aged contiguous forests, with their multi-layered canopies, are known to buffer climate change by maintaining cooler summer

temperatures compared to plantations and younger forests (Frey et al. 2016, Betts et al. 2017, Kim et al. 2022). In addition, air and soil moisture levels are higher inside the older forest (Chen et al. 1993, 1999), including higher up in the canopy where murrelets nest (van Rooyen et al. 2011, Aubrey et al. 2013). Providing buffers to all murrelet habitat will help protect against microclimate changes.

Buffers can also help maintain murrelet habitat integrity by reducing the risk of windthrow or blowdown of habitat, which is often increased by clearcutting (i.e., creating hard edges) adjacent to habitat (Ruel 1995, Sinton et al. 2000). Blowdown risk is affected by a suite of factors, including topography (e.g., risk is greater on ridges exposed to high winds), soils, and other factors (Sinton et al. 2000, Gradowski 1956, Mitchell et al. 2001). Forested areas that do not meet the definition of habitat but are adjacent to habitat and that are identified for treatment (e.g., silviculture and/or fuels management) should be managed to reduce blowdown risk in ways that will support development of future platform trees. If blowdown does occur despite buffers and best management efforts, fallen trees should be left in place to maximize stand recovery and minimize effects to the restoration objectives (Lindenmayer et al. 2004). In addition to minimizing risk of windthrow or blowdown, buffer zones upslope of occupied habitat can reduce the risk of landslides, debris-flows, and channel erosion, all of which can cause loss of trees (Rice et al. 2004) within habitat.

Predation of eggs and nestlings is identified as a primary cause of nest failure and a limiting factor in murrelet populations (Nelson and Hamer 1995, McShane et al. 2004, Peery et al. 2006, Piatt et al. 2007, USFWS 2012, Halbert and Singer 2017). Studies of both real and artificial murrelet nests have found nest success tends to be greater when nests are farther from forest edges (reviewed in Raphael et al. 2018). High predation rates are recorded at least 50 m (164 ft) into forest stands, and areas with nearby human activity experience increased predation within at least 200 m (656 ft; Raphael et al. 2002a). One explanation for increased predation rates in such areas is that increased human presence and recreation activities can attract corvids which are important murrelet nest predators (Webb 2017; see *Reducing Impacts from Recreation and Other Human Activities* below). Another explanation is that edge areas with more sunlight and therefore more berry-producing plants are favorable habitats for some murrelet predators (Masselink 2001, Carey et al. 2003, Marzluff et al. 2004, Marzluff and Neatherlin 2006). For example, Steller's Jays (*Cyanocitta stelleri*) tend to be most abundant in fragmented forests and along edges (Vigallon and Marzluff 2005, Walker et al. 2020). Reducing overstory density or creating canopy gaps increases the probability and abundance of fruiting in some understory shrub species, based on studies in western Oregon and Washington (Wender et al. 2004). No-cut buffers would reduce or avoid the creation of new predator-friendly edges adjacent to or near occupied habitat.

The studies mentioned above provide support for a minimum 100 m (328 ft) buffer, if not wider (see USFWS 1997), based on demonstrated edge effects, because in actuality edge effects may vary continuously over a range of distances from an edge, including distances longer than those studied. Land managers should consult with their regulatory agency to determine an appropriate buffer width that considers site-specific factors such as slope, aspect, and topography, proximity to recreation areas or human settlements, and the objectives of buffers listed above. Buffers greater than 100 m (328 ft) would further minimize risk of windthrow, reduce the risk of nest depredation, and promote the development of larger blocks of interior habitat. Raphael et al.

(2008) recommended that 100% of buffer areas consist of, at a minimum, young pole-sized trees with a single canopy layer. Landscape analyses have shown that even the presence of younger, simple-structured stands adjacent to nesting areas may decrease predation at nests (Raphael et al. 2002a, Ripple et al. 2003), demonstrating the potential benefit of no-cut and no-entry buffers to murrelet nest success.

As of the publication of this document, no studies have been conducted that show thinning buffers improves the effectiveness of the buffer or provides benefits to murrelets or their habitat. In addition, there are no studies that demonstrate how to minimize threats (e.g., attracting corvids) to murrelets when thinning or other types of forest management occur adjacent to occupied sites. However, light to heavy thinning resulting in tree densities between 125-275 trees per hectare (51-111 trees per acre), and clearcut logging in conifer forests, increase corvid abundance (e.g., Masselink 2001, Cahall et al. 2013, Hagar et al. 2024). Increased amounts of edge cause undesirable effects on forest microclimate characteristics as well (e.g., Chen et al. 1995). The same effects could occur if buffers are thinned. For this reason, we do not recommend thinning or other types of forest management within buffers, or other forested areas adjacent to habitat, without first consulting your regulatory agency. See *Managing and Reducing Threats of Megafires* section for information on wildfire considerations.

Edge effects can result from forest management activities occurring within habitat and its buffers as well as outside of habitat and its buffers. Any forest management occurring outside of and adjacent to habitat or its buffers should attempt to maximize retention of canopy cover, minimize anthropogenic gap creation, and minimize ground disturbance associated with roads, landings, skid roads/trails, cable yarding corridors, etc., so that forest management is consistent with the protection and development of platform trees and murrelet habitat characteristics. It is important to note that thinning in multiple younger stands within a single watershed containing occupied habitat can lead to increased negative effects on murrelets (increased predation, microclimate effects, fire hazard; e.g., Chen et al. 1995, Masselink 2001, Vigallon and Marzluff 2005, Van Rooyen et al. 2011). The amount of hard edge and canopy openings present within a watershed at any one time should be minimized. This will serve to maintain the amount and contiguity of habitat across the landscape. Site-specific conditions should inform what approaches are taken. For example, consider these concerns: (1) how soils, geology, and slope steepness contribute to landslides or erosion risk; (2) how or if slope and aspect may contribute to the risk of windthrow, and how to minimize that risk; (3) how the understory composition may contribute to the risk of increased predator densities; (4) how multiple thinnings in younger stands within a watershed with occupied sites can decrease canopy cover in those stands, thereby increasing predation throughout the watershed; (5) how current or future predator response may influence murrelet survival and nest success; and (6) how nearby recreation sites may be negatively affecting murrelets in the area due either to disturbance or increased predator densities (see *Reducing Impacts from Recreation and Other Human Activities*). We recommend that research be conducted to determine the efficacy of any type of management within or adjacent to buffers that may impact buffer performance. These actions should be done in consultation with regulatory agencies.

These buffer recommendations are particularly imperative for conservation of murrelets in the short term as species declines are continuing in some areas and habitat gains are expected to only slowly accumulate over the next 100 years. Evidence indicates murrelet nest-site fidelity occurs

at multiple spatial scales (Plissner et al. 2015), which is similar to many alcid species that are philopatric, with offspring returning to their natal areas to breed (e.g., Gaston and Jones 1998, Frederiksen and Petersen 1999). While there is evidence of philopatry in Marbled Murrelets (i.e., marked birds re-nesting at the same location or stand within or between years in Alaska, British Columbia, and Oregon; Burger et al. 2009, Barbaree et al. 2014; Rivers et al. unpublished data), sample sizes are small. Assuming murrelets are philopatric like other members of their family, then actions contributing to successful nesting, such as reducing risk of predation, are likely to help maintain occupancy of habitat through time. Although some forestry techniques may yet prove to provide long-term habitat benefits (see *Developing New Habitat*), the need to conserve habitat in the short term should take precedence in order to contribute to a precautionary approach to species conservation.

Key buffer recommendations:

- surround all murrelet habitat with a 100 m (328 ft) wide no-cut buffer, at minimum;
- do not conduct forest management in buffers unless special circumstances exist that warrant their use and permission has been obtained from regulatory agencies;
- seek to create and maintain large, contiguous areas of murrelet habitat. Effects to murrelets due to hard edges decrease in larger, more circular areas of habitat;
- when harvesting timber adjacent to occupied habitat and buffers, avoid or reduce negative effects to murrelets or their habitat by minimizing the extent of hard edge present at any given time; and
- reduce the risk of blowdown and landslides due to activities in forested areas adjacent to murrelet habitat and buffers.

Managing and Reducing Threats of Megafires

Managers of suitable murrelet habitat should be cognizant of the threat posed by **Megafires**. Although murrelet habitat was historically subject to lower severity fires, megafires are an entirely new type of fire that pose a very serious threat to murrelet habitat. Megafires burn hotter, kill or damage a greater number of trees within the burn perimeter, and are projected to recur more frequently than historic fires (Rogers et al. 2011, Abatzoglou and Williams 2016, Westerling 2016, Kitzberger et al. 2017, Halofsky et al. 2018, Williams et al. 2019, Halofsky et al. 2020, Robbins 2021, Potter 2023, Turco et al. 2023). They can occur throughout the forested range of murrelets (Rogers et al. 2011, COSEWIC 2012, Environment Canada 2014, Parks et al. 2015, Steel et al. 2015, Westerling 2016, Kitzberger et al. 2017, Williams et al. 2019, Halofsky et al. 2020, Robbins 2021, Singer and Rinkert, in prep.; Alaska Wildlife Fire information <https://blm-egis.maps.arcgis.com/apps/instant/portfolio/index.html?appid=4841da6a16804c07849c27ea7db2a26b>). The primary driver of these fires is human-induced climate stressors (such as increasing temperatures, decreasing precipitation, longer dry seasons, more erratic winds, etc.), while forest fuel levels are a much lesser consideration (van Mantgem et al. 2013, Halofsky et al. 2020, Steel et al. 2015, Abatzoglou et al. 2021, Robbins 2021, and Turco et al. 2023), with the possible exception of the southernmost coast redwood forests where forest fuel levels may play a bigger

role, although conflicting study results suggest that further research is needed (Norman et al. 2009, Steel et al. 2015, Turco et al. 2023).

An example of the damage that a megafire can inflict on an important murrelet nesting area is the 2020 CZU Lightning Complex Fire that burned Big Basin Redwoods State Park, Conservation Zone 6, in northern California. Big Basin contains the largest amount of old-growth redwood–Douglas-fir forest within the Zone and 98% of the park was burned, mostly at a high intensity level (Potter 2023, SCMBC 2020). During the fire, 85% of all Douglas-fir trees larger than 4 cm (1.6 in) dbh were killed (Mahdizadeh and Russell 2021) and although almost all mature redwoods survived the fire by sprouting new branches from base or bole, most of the large branches used by nesting murrelets were consumed by the fire. After the fire, the number of trees remaining with suitable nest platforms was reduced by an estimated 83% (Singer and Rinkert, in prep.). Megafires in Oregon and Washington in recent years (2017-2020), fueled by strong east winds, have also destroyed tens of thousands of acres of murrelet habitat (e.g., Robbins 2021). Where habitat losses are so severe, managers may want to experiment with methods for creating new murrelet habitat, in cooperation with regulatory agencies (see *Developing New Habitat*).

Megafires, being driven by high velocity winds, ultra-dry fuels, and heat waves, are nearly impossible to control by traditional fire-fighting measures unless there is a change to more favorable weather (SCMBC 2020, Potter 2023). Forest fuel reduction treatments, as typically used to prevent historical-fire-regime fires, are largely ineffective against megafires that occur within the forested portion of the murrelet breeding range (Halofsky et al. 2020, Abatzoglou et al. 2021, Robbins 2021, Turco et al. 2023). Forest fuel reduction treatments targeting prevention of megafires should never be used in occupied stands and should not be used in buffers unless special circumstances exist that warrant their use, and even then such use should be approved and permitted by regulatory agencies. Any type of entry (e.g., timber harvest, roads, etc.) into forested murrelet habitat has the potential to negatively modify physical conditions that support murrelet nesting, as well as to damage ecosystem services provided by the forested area if efforts are not made to avoid it.

In the dryer southern part of the redwood region, further research is needed to determine the relative importance of forest fuel levels versus climate change factors in promoting megafires (Noss 2000, Norman et al. 2009, Steel et al. 2015, and Turco et al. 2023). Until that question is resolved, fuel reduction efforts in southern redwood forests should be undertaken only with great caution and performed in consultation with regulatory agencies.

Regardless of their cause, megafires can be controlled in their initial stage when small, and better yet, they can be prevented by blocking human-caused fire ignitions. The vast majority of fire ignitions are caused by human activity (Nagy et al. 2018), so preventative efforts in areas of high human use can be helpful. Managers of forest lands, especially parks and recreation areas, should consider implementing these fire-prevention practices:

- remove grass and flash fuels from road edges in the dry season;
- prohibit any use of fireworks or other incendiary devices;

- use fire tools associated with forest management (e.g., slash pile burning, prescribed burning) only when the risk of escaped fires occurring is very low.
- construct shaded fuel breaks along the margins of campfires, picnic areas, and other areas of concentrated human use;
- ban campfires or restrict them to improved campsites with fire rings;
- conduct regular fire-safety patrols by rangers or park staff in remote areas of the park to prevent illegal camping and illegal campfires;
- during "red flag" fire weather conditions, consider closing the area to all human entry; and
- require public utilities to use wind-safe power lines that cut power off instantaneously when the line is broken, such as by a falling tree, or to bury power lines underground. Recommendations to reduce adverse impacts by burying of power lines can be found in the section below, *Power Lines, Roads, and Inland Wind Power Developments*.

Where habitat loss from a megafire has occurred, we recommend land managers consider creating new murrelet nesting opportunities as discussed in the *Developing New Habitat* section above.

Reducing Impacts from Recreation and Other Human Activities

The presence of late-seral and old-growth forests is one of the primary features that attract visitors to recreation areas, including, but not limited to, Olympic and Mount Rainier national parks in northern Washington, Redwood National and State Parks in northern California, and Big Basin Redwoods State Park in central California. In addition to the potential for directly disturbing breeding murrelets (see *Minimizing Disturbance and Disruption* section, below), recreation and other human activities can directly or indirectly impact murrelets by attracting predators, removing or fragmenting habitat, impeding development of habitat, and causing mortality of murrelets.

Campgrounds and associated food sources within murrelet habitat have been shown to greatly increase the density of known murrelet nest predators such as Steller's Jays, both within campgrounds and in a large surrounding area (Singer et al. 1991, West et al. 2016, 2019). Predation on murrelet eggs and chicks is a major cause of nest failure and low reproductive success, and human actions can increase the density of potential nest predators (See Chapter 1 in *2024 Inland Survey Protocol*). Predators are attracted to human presence, human provisioning of artificial food resources (Marzluff et al. 1994), and human-related noise (Miller et al. 1998). Roads also can attract and concentrate nest predators such as Common Ravens (Scarpignato and George 2013). These factors can cause an increase in predator numbers and increase the potential risk to murrelets or murrelet nests (Hébert and Golightly 2006, 2007, Scarpignato and George 2013). In areas where campgrounds occur in or near murrelet habitat, nesting success is usually low (e.g., the Santa Cruz Mountains; Peery et al. 2004). While campgrounds are a known problem, other developments such as trailheads, off-highway vehicle staging areas, target shooting lanes, and picnic areas are also of concern. The presence of loose garbage, open trash

cans, and other human food sources, such as feeding of wildlife by recreationists, should be eliminated or minimized within and adjacent to habitat and habitat development sites.

Emphasizing the need for garbage management (e.g., wildlife-proof garbage cans) and preventing wildlife feeding by campers and others through education will help reduce predation risk. Because point food sources can affect nest predator abundance for a large surrounding area (West et al. 2016), communication and cooperation with adjacent land managers are especially important where multiple ownerships occur within or near (e.g., within 1-2 km [about 1 mi]) patches of occupied or unsurveyed habitat. Human presence and human-made structures of a wide variety appear to attract or increase the number of ravens, jays, and crows (Liebezeit and George 2002, Rosenberg et al. 2004).

Construction of new campgrounds and other recreation-related features or developments (e.g., trails, stores with food) where people concentrate within or adjacent to habitat should be avoided to help prevent an increase in predators. Where alternative routes exist, trails should not be built through murrelet habitat. For existing campgrounds and other features that occur in or near habitat, detailed signage about rules, including not feeding wildlife (intentionally or otherwise), minimizing garbage and food consumption while on the trails, and reducing noise should be posted. The “Crumb Clean Campaign” of the California Department of Parks and Recreation and National Park Service in redwood forest parks is an effective example of one such effort (https://www.parks.ca.gov/?page_id=29905). If any habitat within 0.8 km (0.5 mile) of existing campgrounds or other recreational developments becomes occupied by murrelets, a re-evaluation of the use and location of those developments is recommended, taking into consideration the potential for negatively impacting nesting murrelets. Where campgrounds and other people-concentrating features are constructed within close proximity to known occupied areas, long-term monitoring of predator densities and mitigation measures for minimizing predator increases should be implemented as part of the project, along with an adaptive management plan to address any increase that occurs (Halbert and Singer 2017).

In summary, we recommend implementing the following measures within and near habitat to reduce the risk of murrelet predation:

- install wildlife-proof trash cans at all campgrounds, day use areas, trailheads, and other areas of concentrated recreational use;
- install wildlife-proof food lockers or other storage containers at campgrounds;
- install dishwashing stations or wastewater drains to collect and allow removal of food particles at all campgrounds;
- educate the public about the negative effects of feeding wildlife on murrelets through the use of signs, displays, videos, or one-to-one contacts by staff at all campgrounds, visitor centers, day use areas, and other areas of concentrated human presence;
- whenever possible, educate campers and other visitors, by reinforcing the message and addressing non-compliance;

- reduce, and where possible avoid, the placement of recreational features within and near (e.g., within 0.8 km [0.5 mi] of) habitat, including but not limited to construction of new campgrounds, picnic areas, off-highway vehicle staging areas, trailheads, and trails;
- inform the public about reducing noise, especially during dawn and dusk (key murrelet activity periods);
- do not create new human settlements, youth camps, recreation areas, and waste management sites in proximity to habitat, as they increase predation rates; and
- relocate or eliminate existing recreation areas and food and waste management sites in proximity to occupied habitat, and if relocation or elimination is not possible, implement methods of limiting impacts to murrelets that are caused by such infrastructure (see above and consider wildlife-proof trash and food management, public education, predator management, adding buffers, etc.).

Hazard trees

Periodically, mature and old-growth trees, that may serve as murrelet nest trees, are designated by land managers as **Hazard Trees** when they might be in danger of falling on structures such as buildings, powerlines, roads, campsites, or other human infrastructure (e.g., Mount Rainier National Park 2010, Angwin et al. 2022). In such circumstances, they are often removed or their large branches are pruned off. We are concerned about their removal as these hazard trees may contain or contribute to suitable murrelet nest sites. We recommend an approach whereby the risks of potential hazard trees are duly evaluated, including whether the resources at risk can be relocated or removed, whether potential hazard trees can be left untouched, or large branches pruned off rather than felling the tree. In this way, habitat features essential to nesting murrelets can be retained. An example of guidelines pertaining to hazard trees along roads is the Forest Service's Hazard Tree Guidelines (Angwin et al. 2022). While such guidelines focus on removal of hazard trees, and not the retention of murrelet habitat, we favor an approach whereby the trees are evaluated for their perceived risk to infrastructure and human life, instead of a blanket approach that removes trees without such an evaluation.

We recommend implementing the following measures within and near habitat to reduce the risk of negative impacts to murrelets and their habitat due to hazard tree management-related activities:

- ensure that a wildlife biologist participates in the design, implementation, and monitoring of proposed hazard tree activities in murrelet habitat. The purpose of this involvement is to ensure the project avoids and minimizes impacts to listed species and that the project is carried out as described in supporting documents;
- require that all trees proposed to be removed or pruned in or adjacent to murrelet habitat be inspected by a qualified forest health protection pathologist or certified arborist to determine whether they are truly hazard trees;

- avoid the removal of active or historic murrelet nest trees. This includes trees with nesting structure and adjacent trees with branches that intertwine the branches of any tree with nesting structure. This also includes potential or known nest limbs or structures that may contribute to nesting;
- avoid and/or minimize the removal of large trees or large branches that may later support nests or nest sites, or contribute to habitat characteristics;
- immediately notify park or agency staff and a qualified wildlife biologist if an active murrelet nest is found, followed immediately with notification to the USFWS. Protecting the site from disturbance while the nest is active is imperative;
- in instances where hazard trees in or adjacent to habitat are being felled or may be felled for purposes of protecting human infrastructure, determine if the infrastructure can be relocated or removed, instead;
- to minimize conflicts between hazard tree management and conservation of murrelet habitat, transition high-use areas, such as campgrounds, out of murrelet habitat or change them to areas with lower human use, such as day-use areas;
- close campgrounds (or trailheads, etc.) or portions thereof during the nesting season, instead of felling or pruning hazard trees (or any trees) during the nesting season, to minimize the potential for disturbance to murrelets;
- consider Natural Resource Damage and Assessment programs (e.g., from oil spills) or USFWS's Endangered Species Conservation and Recovery Grants as appropriate sources of funding for projects such as those that move or eliminate infrastructures when hazard tree management programs may be interfering with maintenance and creation of murrelet habitat;
- avoid or minimize physical impacts to surrounding trees when felling hazard trees. Ensure you are felling hazard trees away from murrelet habitat; and
- experiment with cutting the top off of potential hazard trees to create snag habitat, and/or trimming off some hazard tree limbs, rather than felling them entirely. Although not yet fully proven, this approach could potentially support or help create old-forest habitat characteristics (see *Developing New Habitat*).

Construction and Maintenance of Power Lines, Roads, and Inland Wind Power Developments

Power lines are known to be a source of murrelet mortality through direct collision of murrelets with these structures, especially when they occur adjacent to nesting habitat or otherwise along the flight path between their at-sea habitat and their inland habitat. Since 2015, at least three murrelets were found below power lines with fatal injuries that were indicative of high-speed strikes (e.g., wings sheared off) in northern California (W. McIver pers. comm.). Other powerline deaths are known from Oregon and Washington (one in each state). It is likely additional murrelets have perished in this same way. At Prairie Creek Redwoods State Park, in a meadow adjacent to occupied habitat, approximately 0.8 km (0.5 mi) of power line was buried in 2016, after two murrelets were documented to have died when they struck power lines near their nest (W. McIver pers. comm.). We recommend that utility agencies:

- bury (or “underground”) power lines adjacent to murrelet habitat so as to avoid, minimize, or mitigate impacts to murrelets. Burying power lines will also reduce the risk of megafires (see *Managing and Reducing the Impacts of Megafires*).

Murrelet habitat has the potential to be removed or degraded during maintenance and construction of power line corridors, often in relation to tree removal activities implemented to reduce the risk of fire, power interruptions, or power outages due to trees or branches falling across power lines. We recommend that utility agencies:

- give consideration to the best methods for avoiding destabilization of the soil and disturbance of tree roots;
- use trained wildlife biologists to survey for the presence of platforms or platform trees adjacent to power line corridors, and avoid removal of such habitat; and
- incorporate systems which shut off electricity when there is a break in the power line. This may be as effective as or more effective than removing nearby trees in terms of preventing fire, power interruptions, or power outages.

Watson (2005) described roads as a major contributor to habitat fragmentation on the landscape because roads divide large landscapes into smaller patches and convert interior habitat into edge habitat. Gucinski et al. (2001) provided a synthesis on the scientific information about the physical and biological effects of forest roads. They reported that animal species are affected by habitat fragmentation caused by the presence of forest roads, and that some species avoid roads while others are attracted to them. Those that are most affected by forest roads were often displaced, such as the Northern Spotted Owl (*Strix occidentalis*). Golightly et al. (2009) found that murrelets were more likely to nest farther away from paved roads, which was consistent with findings from other studies that found murrelets avoid edges or fragmented areas (e.g., Meyer et al. 2004). Though likely to a lesser extent than clearcuts, roads contribute to an increase in windthrow events, due to an increase in the wind exposure of remaining trees (Sinton et al. 2000).

Terrestrial wind power projects have the potential to impact murrelets flying to and from terrestrial habitat. To avoid impacts to murrelets, we recommend that terrestrial wind power projects not be located within or near murrelet terrestrial habitat or within or near flight corridors

by which murrelets access their inland nest sites. If impacts cannot be avoided, they should be minimized and mitigated (e.g., protection of additional unimpacted terrestrial habitat through purchase or conservation easements). All terrestrial wind power project planning should be done in consultation with regulatory agencies.

Minimizing Disturbance and Disruption

Anthropogenic activities at or near occupied habitat may cause visual and/or noise disturbance to murrelets, including disruption of incubation, brooding, and feeding of chicks. In extreme cases, chicks may be caused to flush from their nests before they are capable of flight (e.g., a grounded chick was discovered following a low helicopter flight in British Columbia, Canada; J. Cragg pers comm.). The degree of disturbance to murrelets from anthropogenic activities varies based on the distance between the disturbance and murrelet(s), along with considerations of topography, vegetation, and other mitigating factors (e.g., Hebert and Golightly 2006, USFWS 2020). Ambient noise levels in the environment play a role in determining if a specific source of noise will have a negative impact on murrelets (e.g., USFWS 2020).

Below, we provide general guidance for minimizing disturbance or disruption to murrelets. Specific guidance for assessing and avoiding significant noise and visual disturbance is provided by USFWS (e.g., USFWS 2013, 2015, 2020) and may vary regionally. Contact your state's USFWS office for locally relevant guidance.

It is important to recognize that the potential disturbance effects of some activities, which may or may not be associated with timber harvest, such as construction, blasting, pile driving, and use of helicopters, may result in impacts to murrelets that extend beyond 402 m (0.25 mile) from the project footprint. Therefore, audio-visual surveys may need to extend farther out to encompass all areas where, if present, murrelets may be impacted by the project. The project footprint should include the areas within which impacts to murrelets or their habitat may be caused by a project, including but not limited to timber harvest, road construction, reconstruction, or improvement, rock blasting and placement, log or rock hauling, etc. Land managers should consult with their regulatory agencies as project footprint boundaries and subsequent survey areas are established to identify if this might be an issue for their proposed activities.

Projects should be designed such that: (1) activities occur at times of year and/or times of day, and in locations and at times that avoid and minimize the potential for noise or visual disturbance to murrelets (for example, outside of the breeding season or outside of the dawn and dusk high activity periods); (2) activities occur in the area farthest from murrelet habitat during the nesting season; and (3) activity locations and types are adjusted to use topographic and vegetative buffers to minimize noise or visual disturbance to murrelets. Anthropogenic noise above the ambient level should be avoided in occupied habitat during the breeding season. If habitat is unsurveyed, assume occupancy.

The following noise management recommendations are based on those found in Chapter 5 of the Marbled Murrelet Landscape Management Plan for Zone 6 (Golightly 2017) but are applicable for other conservation zones as well:

- project planners should consider not only amplitude (loudness), but also, the type of sound and associated characteristics, such as attenuation, duration, novelty, amplitude

compared to ambient sound levels, sudden sounds, and frequency (low frequency sounds travel further), which have the potential to cause flushing and could be fatal to murrelets;

- loud impulsive noises that quickly reach maximum amplitude (e.g., gun shots, explosions, felling of large trees) should be completely avoided at any time during the nesting season and year-round for approximately 2 hours before to 2 hours after sunrise.

Land managers may use several types of fire tools, such as slash pile burning and prescribed fire when managing forested areas. The following recommendations should be considered when fire is being used near murrelet habitat:

- do not burn near murrelet habitat during the nesting season, to minimize the chance that adults, eggs, nestlings, or fledglings are injured by smoke or flames; and
- consult regulatory agencies for additional guidelines for reducing prescribed fire impacts to habitat. Smoke can sometimes be managed with respect to direction of flow and amount.

LITERATURE CITED

- Abatzoglou, J.T., D.S. Battisti, A.P. Williams, W.D. Hansen, B.J. Harvey, and C.A. Kolden. 2021. Projected Increases in Western US Forest Fire Despite Growing Fuel Constraints. *Communications Earth and Environment* 2:227. <https://doi.org/10.1038/s43247-021-00299-0>
- Abatzoglou, J.T. and A.P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. *PNAS* 113(42):11770–11775. <https://www.pnas.org/doi/10.1073/pnas.1607171113>
- Angwin., P.A., D.R. Cluck, J. Rosen, W.C. Woodruff, A.E. Hawkins, C.W Barnes, P.G. Cannon, and S. Hazelhurst. 2022. Hazard tree identification and mitigation. USDA Forest Service PSW Forest Health Protection Report RO-22-01. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1006739.pdf
- Aubrey, D.A., N.M. Nadkarni, and C.P. Broderick. 2013. Patterns of moisture and temperature in canopy and terrestrial soils in a temperate rainforest, Washington. *Botany* 91:739–744. <https://doi.org/10.1139/cjb-2013-0153>
- Barbaree, B.A., S.K. Nelson, B.D. Dugger, D.D. Roby, H.R. Carter, D.L. Whitworth, and S.H. Newman. 2014. Nesting ecology of Marbled Murrelets at a remote mainland fjord in southeast Alaska. *Condor* 116:173–184.
- Betts, M.G., B. Phalan, S.J.K. Frey, S.J.K., J.S. Rousseau, and Z. Yang. 2017. Old-growth forests buffer climate-sensitive bird populations from warming. *Diversity and Distributions* 24:439–447. <https://doi.org/10.1111/ddi.12688>
- Betts, M.G., J.M. Northrup, J.A. Bailey Guerrero, L.J. Adrean, S.K. Nelson, J.L. Fisher, B.D. Gerber, M.-S. Garcia-Heras, Z. Yang, D.D. Roby, and J.W. Rivers. 2020. Squeezed by a habitat split: warm ocean conditions and old-forest loss interact to reduce long-term occupancy of a threatened seabird. *Conservation Letters* 13(5):e12745. <https://doi.org/10.1111/conl.12745>
- Bradley, R.W. 2002. Breeding ecology of radio-marked Marbled Murrelets (*Brachyramphus marmoratus*) in Desolation Sound, British Columbia. M.S. thesis, Simon Fraser University, Department of Biological Sciences, Burnaby, B.C. 86 pp.
- Burger, A.E. 2002. Conservation assessment of Marbled Murrelets in British Columbia: a review of the biology, populations, habitat associations, and conservation of this threatened species. Technical Report Series No. 387, Canadian Wildlife Service, Delta, British Columbia. 194p. https://publications.gc.ca/collections/collection_2009/ec/CW69-5-387E.pdf
- Burger, A.E., I.A. Manley, M.P. Silvergieter, D.B. Lank, K.M. Jordan, T.D. Bloxton, and M.R. Raphael. 2009. Re-use of nest sites by Marbled Murrelets (*Brachyramphus marmoratus*) in British Columbia. *Northwestern Naturalist* 90:217–226. https://www.fs.usda.gov/pnw/pubs/journals/pnw_2009_burger001.pdf

- Cahall, R.E., J.P. Hayes, and M.G. Betts. 2013. Will they come? Long-term response by forest birds to experimental thinning supports the “Field of Dreams” hypothesis. *Forest Ecology and Management* 304:137–149. https://www.researchgate.net/profile/Matthew-Betts-3/publication/257198336_Will_they_come_Long-term_response_by_forest_birds_to_experimental_thinning_supports_the_Field_of_Dreams_hypothesis/links/59dfe73aaca272386b633ed7/Will-they-come-Long-term-response-by-forest-birds-to-experimental-thinning-supports-the-Field-of-Dreams-hypothesis.pdf
- Carey, A.B., S.P. Courtney, J.F. Franklin, J.M. Marzluff, M.G. Raphael, J.C. Tappeiner, and D.A. Thornburgh. 2003. Managing second-growth forests in the redwood region to enhance Marbled Murrelet habitat. Report of scientific panel on restoration of Marbled Murrelet habitat. Sustainable Ecosystems Institute, Portland, Oregon. 60p.
- Chen, J., J.F. Franklin, and T.A. Spies. 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. *Agricultural and Forest Meteorology* 63:219–237. <https://andrewsforest.oregonstate.edu/sites/default/files/lter/pubs/pdf/pub1420.pdf>
- Chen, J., J.F. Franklin, and T.A. Spies. 1995. Growing-season microclimatic gradients from clearcut edges into old-growth Douglas-fir forests. *Ecological Applications* 5:74–86. <https://andrewsforest.oregonstate.edu/sites/default/files/lter/pubs/pdf/pub2095.pdf>
- Chen, J., S.C. Saunders, T.R. Crow, R.J. Naiman, K.D. Brosfokske, G.D. Mroz, B.L. Brookshire, and J.F. Franklin. 1999. Microclimate in forest ecosystem and landscape ecology - Variations in local climate can be used to monitor and compare the effects of different management regimes. *Bioscience* 49:288–297. https://www.nrs.fs.usda.gov/pubs/jrnl/1999/nc_1999_Chen_001.pdf
- Comfort, E.J., S.D. Roberts, and C.A. Harrington. 2010. Midcanopy growth following thinning in young-growth conifer forests on the Olympic Peninsula western Washington. *Forest Ecology and Management* 259:1606–1614. <https://ecoshare.info/wp-content/uploads/2021/02/Comfort-et-al-2010-FEM.pdf>
- COSEWIC. 2012. COSEWIC assessment and status report on the Marbled Murrelet (*Brachyramphus marmoratus*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 82 pp. URL: https://www.registrelep-sararegistry.gc.ca/virtual_sara/files/cosewic/sr%5Fguillemot%5Fmarbre%5Fmarbled%5Fmurrelet%5F1012%5Fe%2Epdf
- Drew, G.S., S.K. Schoen, M.D. Hood, M.L. Arimitsu, and J.F. Piatt. 2005. North Pacific Pelagic Seabird Database (NPPSD) (ver. 4.1, May 2023). U.S. Geological Survey data release. <https://doi.org/10.5066/F7WQ01T3>
- Elliott, W.J., D.P. Page-Dumroese, and P.R. Robichaud. 1992. The effects of forest management on erosion and soil productivity. In: Lal, R., ed. *Soil quality and soil erosion*. CRC Press, Boca Raton, Florida. https://forest.moscowfs.lwsu.edu/smp/docs/docs/Elliot_1-57444-100-0.html

- Environment Canada. 2014. Recovery Strategy for the Marbled Murrelet (*Brachyramphus marmoratus*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. v + 49p. https://sararegistry.gc.ca/virtual_sara/files/plans/rs_guillemot_marbre_marbled_murrelet_0614_e.pdf
- Evans Mack, D., W.P. Ritchie, S.K. Nelson, E. Kuo-Harrison, P. Harrison, and T.E. Hamer. 2003. Methods for surveying Marbled Murrelets in forests: a revised protocol for land management and research. Pacific Seabird Group Technical Publication Number 2. https://pacificseabirdgroup.org/wp-content/uploads/2016/06/PSG_TechPub2_MAMU_ISP.pdf
- Franklin, J.F., A.B. Carey, S.P. Courtney, J.M. Marzluff, M.G. Raphael, J.C. Tappeiner, and D.A. Thornburgh. 2007. Managing second-growth forests in the redwood region for accelerated development of Marbled Murrelet nesting habitat. 2007. USDA Forest Service General Technical Report PSW-GTR-194, Albany, California. https://www.fs.usda.gov/psw/publications/documents/psw_gtr194/psw_gtr194_44.pdf
- Frederiksen, M. and A. Petersen. 1999. Philopatry and dispersal within a Black Guillemot colony. *Waterbirds* 22:274–281.
- Frey, S.J.K., A.S. Hadley, S.L. Johnson, M. Schulze, J.A. Jones, and M.G. Betts. 2016. Spatial models reveal the microclimatic buffering capacity of old-growth forests. *Science Advances* 2: e1501392. <https://doi.org/10.1126/sciadv.1501392>
- Gaston, A.J. and I.L. Jones. 1998. *The Auks – Alcidae*. Oxford University Press, Oxford, United Kingdom.
- Golightly, R.T., C.D. Hamilton and P.N. Hébert. 2009. Characteristics of Marbled Murrelet habitat in northern California. Unpublished report by Humboldt State University, February 2009, for U.S. National Park Service and California Department of Fish and Game. 49p. <https://tethys.pnnl.gov/sites/default/files/publications/Golightlyetal2009.pdf>
- Golightly, R.T. 2017. Chapter 5: Evaluation of noise impacts on murrelets in Zone 6. Pages 119–139 In: Halbert, P. and S.W. Singer, eds. *Marbled Murrelet landscape management plan for zone 6*. California Department of Parks and Recreation, Santa Cruz, California. http://www.parks.ca.gov/pages/29882/files/Z6-Plan_FINAL_MASTER_V14_07-17.pdf
- Gratowski, H.J. 1956. Windthrow around staggered settings in old-growth Douglas-fir. *Forest Science* 2:60–74.
- Gucinski, H., M.J. Furniss, R.R. Ziemer and M.H. Brooks. 2001. *Forest roads: a synthesis of scientific information*. USDA Forest Service General Technical Report PNW-GTR-509, Portland, Oregon. 120p. https://www.fs.usda.gov/pnw/pubs/pnw_gtr509.pdf
- Hagar, J.C., T. Owen, T.K. Stevens, and L.K. Waianuhe. 2024. Response of corvid nest predators to thinning: implications for balancing short- and long-term goals for

- restoration of forest habitat. *Avian Conservation and Ecology* 19:3. <https://www.ace-eco.org/vol19/iss1/art3>
- Halbert, P. and S.W. Singer, eds. 2017. Marbled Murrelet landscape management plan for Zone 6. California Department of Parks and Recreation, Santa Cruz, California. http://www.parks.ca.gov/pages/29882/files/Z6-Plan_FINAL_MASTER_V14_07-17.pdf
- Halofsky, J.S., D.C. Donato, J.F. Franklin, J.E. Halofsky, D.L. Peterson, and B.J. Harvey. 2018. The nature of the beast: examining climate adaptation options in forests with stand-replacing fire regimes. *Ecosphere* 9(3):e02140 <https://doi.org/10.1002/ecs2.2140>
- Halofsky, J.E., D.L. Peterson, and B.J. Harvey. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. *Fire Ecology* 16:4. <https://fireecology.springeropen.com/articles/10.1186/s42408-019-0062-8>
- Hamer, T.E., S.K. Nelson, J.E. Jones, and J. Verschuyt. 2021. Marbled Murrelet nest site selection at three fine spatial scales. *Avian Conservation and Ecology* 16(2):4. <http://www.ace-eco.org/vol16/iss2/art4/>
- Hébert, P.N. and R.T. Golightly. 2006. Movements, nesting, and response to anthropogenic disturbance of Marbled Murrelets (*Brachyramphus marmoratus*) in Redwood National and State parks, California. Unpublished report to California Department of Transportation, Sacramento, California, by Department of Wildlife, Humboldt State University, Arcata, California. California Department of Fish and Game Report No. 2006-02. <https://scholarworks.calstate.edu/downloads/vd66w225w>
- Hébert, P.N. and R.T. Golightly. 2007. Observations of predation by corvids at a Marbled Murrelet nest. *Journal of Field Ornithology* 78:221–224. <https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1557-9263.2007.00105.x>
- Ice, G.G., P.W. Adams, R.L. Beschta, H.A. Froelich, and G.W. Brown. 2004. Chapter 1: Forest management to meet water quality and fisheries objectives: Watershed studies and assessment tools in the Pacific Northwest. Pages 239–261 In: Ice, G.G. and J.D. Stednick, eds. *A century of forest and wildland watershed lessons*. Society of American Foresters, Bethesda, Maryland.
- Kim, H., B.C. McComb, S.J.K. Frey, D.M. Bell, and M.G. Betts. 2022. Forest microclimate and composition mediate long-term trends of breeding bird populations. *Global Change Biology* 28:6180–6193. <https://doi.org/10.1111/gcb.16353>
- Kitzberger, T., D.A. Falk, A.L. Westerling, and T.W. Swetnam. 2017. Direct and indirect climate controls predict heterogeneous early-mid 21st century wildfire burned area across western and boreal North America. *PLOS ONE* <https://doi.org/10.1371/journal.pone.0188486>
- Kramer, M.J., M. Kennedy, and B. Smith. 2010. Reed-Arnold Creek management plan 2010-2019. Confederated Tribes of the Siletz Indians, Siletz, OR.

- Liebezeit, J.R. and T.L. George. 2002. A summary of predation by corvids on threatened and endangered species in California and management recommendations to reduce corvid predation. Unpublished report, Humboldt State University, Arcata, California. 155p.
- Lindenmayer, D.B., D.R. Foster, J.F. Franklin, M.L. Hunter, R.F. Noss, F.A. Schmiegelow, and D. Perry. 2004. Salvage harvesting policies after natural disturbance. *Science* 303:1303
- Littell, J.S., G.S. Mauger, E.P. Salathe, A.F. Hamlet, S.-Y. Lee, M.R. Stumbaugh, M. Elsner, R. Norheim, E.R. Lutz, and N.J. Mantua. 2014. Uncertainty and extreme events in future climate and hydrologic projections for the Pacific Northwest: Providing a basis for vulnerability and core/corridor assessments.
<https://pubs.er.usgs.gov/publication/70100634>
- Lorenz, T.J., M.G. Raphael, and T.D. Bloxton. 2016. Marine habitat selection by Marbled Murrelets (*Brachyramphus marmoratus*) during the breeding season. *Plos One* 11(9): e0162670. <https://doi.org/10.1371/journal.pone.0162670>
- Lorenz, T.J., M.G. Raphael, T.D. Bloxton, and P.G. Cunningham. 2017. Low breeding propensity and wide-ranging movements by Marbled Murrelets in Washington. *Journal of Wildlife Management* 8:306–321. <https://doi.org/10.1002/jwmg.21192>
- Lorenz, T.J., M.G. Raphael, R.D. Young, D. Lynch, S.K. Nelson, and W.R. McIver. 2021. Status and trend of nesting habitat for the Marbled Murrelet under the Northwest Forest Plan, 1993 to 2017. USDA Forest Service General Technical Report PNW-GTR-998, Portland, Oregon. 64p. https://www.fs.usda.gov/pnw/pubs/pnw_gtr998.pdf
- Mahdizadeh, M. and W. Russell. 2021. Initial floristic response to high severity wildfire in an old-growth coast redwood (*Sequoia sempervirens* (D. Don) Endl.) forest. *Forests* 12:1135. <https://doi.org/10.3390/f12081135>
- Malt, J.M. and D.B. Lank. 2007. Temporal dynamics of edge effects on nest predation risk for the Marbled Murrelet. *Biological Conservation* 140:160–173.
<https://www.sfu.ca/biology/wildberg/NewCWEPage/papers/Malt&LankBiolCons07.pdf>
- Malt, J. and D. Lank. 2009. Marbled Murrelet nest predation risk in managed forest landscapes: dynamic fragmentation effects at multiple scales. *Ecological Applications* 19:1274–87.
- Marzluff, J.M., R.B. Boone, and G.W. Cox. 1994. Historical changes in populations and perceptions of native pest bird species in the west. *Studies in Avian Biology* 15:202–220.
https://sora.unm.edu/sites/default/files/SAB_015_1994%20P202-220_Historical%20Changes%20in%20Populations%20and%20Perceptions%20of%20Native%20Pest%20Bird%20Species..._Marzluff%2C%20Boone%2C%20Cox.pdf
- Marzluff, J.M., J.J. Millspaugh, P. Hurvitz, and M.S. Handcock. 2004. Relating resources to a probabilistic measure of space use: Forest fragments and Steller's Jays. *Ecology* 85:1411–1427.

- Marzluff, J. M. and E. Neatherlin. 2006. Corvid responses to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biological Conservation* 130:301–314.
<http://www.elkhornsloughctp.org/uploads/files/1239986937Marzluff%202006%20Corvids%20Murrelet.pdf>
- Masselink, M.N.M. 2001. Responses of Steller's Jays to forest fragmentation on southwest Vancouver Island and potential impacts on Marbled Murrelets. MS thesis. University of Victoria, Department of Biology, Victoria, B.C. 138p.
- McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the Marbled Murrelet in Washington, Oregon, and California. Report prepared by EDAW, Inc., Seattle, Washington, for the U.S. Fish and Wildlife Service, Region 1, Portland, Oregon. 370p.
<https://www.seattle.gov/light/skagit/relicensing/cs/groups/secure/@scl.skagit.team/documents/document/cm9k/ntcx/~edisp/prod571138.pdf>
- Meyer, C.B. and Miller, S.L. 2002. Use of fragmented landscapes by Marbled Murrelets for nesting in southern Oregon. *Conservation Biology* 16:755–766.
[https://www.fs.usda.gov/psw/publications/miller/psw_2002_miller\(meyer\)002.pdf](https://www.fs.usda.gov/psw/publications/miller/psw_2002_miller(meyer)002.pdf)
- Meyer, C.B., S.L. Miller, and C.J. Ralph. 2004. Stand-scale habitat associations across a large geographic region of an old-growth specialist, the Marbled Murrelet. *Wilson Bulletin* 116:197–210.
- Miller, S.G., R.L. Knight, and C.K. Miller. 1998. Influence of recreational trails on breeding bird communities. *Ecological Applications* 8:162–169.
https://savemtcnobolassca.files.wordpress.com/2018/09/miller-et-al-1998_influence-of-recreation-trails-on-breeding-bird-communities.pdf
- Mitchell, S.J., T. Hailemariam, and Y. Kulis. 2001. Empirical modeling of cutblock edge windthrow risk on Vancouver Island, Canada, using stand level information. *Forest Ecology and Management* 154:117–130.
- Mount Rainier National Park. 2010. Hazard tree management plan environmental assessment. National Park Service, U.S. Department of Interior. 111p.
<https://parkplanning.nps.gov/document.cfm?parkID=323&projectID=19728&documentID=34167>
- Nagy, R.C., E. Fusco, B. Bradley, J.T. Abatzoglou, and J. Balch. 2018. Human-related ignitions increase the number of large wildfires across U.S. Ecoregions. *Fire* 1(4):1010004.
- Nelson, S.K. 1997. Marbled Murrelet (*Brachyramphus marmoratus*). In: A. Poole and F. Gills, eds. *The Birds of North America*, No. 276. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and the American Ornithologists' Union, Washington, D.C.
<https://birdsoftheworld.org/bow/historic/bna/marmur/2.0/introduction>

- Nelson, S.K. 2020. Marbled Murrelet (*Brachyramphus marmoratus*), version 1.0. In: A. F. Poole and F. B. Gill, Eds. Birds of the World. Cornell Lab of Ornithology, Ithaca, New York USA. <https://birdsoftheworld.org/bow/species/marmur/1.0/introduction>
- Nelson, S.K. and T.E. Hamer. 1995. Nest success and the effects of predation on the Marbled Murrelet. Pages 89–97 In: Ralph, C.J., G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt, tech. eds. Ecology and conservation of the Marbled Murrelet. USDA Forest Service General Technical Report PSW- GTR-152, Albany, California. https://www.fs.usda.gov/psw/publications/documents/psw_gtr152/psw_gtr152_chap08.pdf
- Nelson, S.K., M.H. Huff, S.L. Miller, and M.G. Raphael. 2006. Marbled Murrelet biology, habitat relations and populations. Pages 9–30 In: Huff, M.H., M.G. Raphael, S.L. Miller, S.K. Nelson, and J. Baldwin, tech. coords. Northwest Forest Plan - The first 10 years (1994-2003): status and trends of populations and nesting habitat for the Marbled Murrelet. USDA Forest Service General Technical Report PNW-GTR-650, Portland, Oregon. <https://www2.unil.ch/biomapper/Download/Huff-MarbledMurrelet-2006.pdf>
- Nelson, S.K. and R.W. Peck. 1995. Behavior of the Marbled Murrelet at nine nest sites in Oregon. Pages 43-53 In: S.K. Nelson and S.G. Sealy, eds. Biology of the Marbled Murrelet: Inland and At-Sea. Northwestern Naturalist 76(1). <https://pacificseabirdgroup.org/psg-publications/symposia/biology-of-marbled-murrelets-inland-and-at-sea/>
- Nelson, S.K. and A.K. Wilson. 2002. Marbled Murrelet habitat characteristics on State lands in Western Oregon. Unpublished final report to Oregon Department of Forestry, Salem, OR, Oregon Department of Fish and Wildlife, Portland, OR, U.S. Fish and Wildlife Service, Portland, OR, and National Council for Air and Stream Improvement, Corvallis, OR, by Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR. 153 pp.
- Norman, S.P., J.M. Varner, L. Arguello, S. Underwood, and B. Graham. 2009. Fire and fuels management in coast redwood forests. JFSP Research Project Reports 158. <http://digitalcommons.unl.edu/jfspresearch/158>
- Noss, R.F., ed. 2000. The redwood forest. Island Press, Washington, D.C. 339p.
- Pacific Seabird Group (PSG). 2024. A revised protocol for surveying Marbled Murrelets in forests. Pacific Seabird Group Technical Publication Number 6. Available from <https://pacificseabirdgroup.org/psg-publications/technical-publications/>
- Parks, S.A., C. Miller, M. Parisien, L.M. Holsinger, S.Z. Dobrowski, and J. Abatzoglou. 2015. Wildland fire deficit and surplus in the western United States, 1984-2012. Ecosphere 6(12): article 275. https://www.fs.usda.gov/rm/pubs_journals/2015/rmrs_2015_parks_s002.pdf

- Peery, M.Z., S.R. Beissinger, S.H. Newman, E. Burkett, and T.D. Williams. 2004. Applying the declining population paradigm: diagnosing causes of poor reproduction in the Marbled Murrelet. *Conservation Biology* 18:1088–1098.
https://nature.berkeley.edu/beislab/BeissingerLab/publications/Peery_etal_2004_ConsBio.pdf
- Peery, M.Z., S.R. Beissinger, E. Burkett, and S.H. Newman. 2006. Local survival of Marbled Murrelets in central California: roles of oceanographic processes, sex, and radiotagging. *Journal of Wildlife Management* 70:78–88.
- Piatt, J.F., K.J. Kuletz, A.E. Burger, S.A. Hatch, V.L. Friesen, T.P. Birt, M.L. Arimitsu, G.S. Drew, A.M.A. Harding, and K.S. Bixler. 2007. Status Review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia. U.S. Geological Survey, Open-File Report 2006-1387: 630p.
<https://pubs.usgs.gov/of/2006/1387/pdf/ofr20061387.pdf>
- Plissner, J.H., B.A. Cooper, R.H. Day, P.M. Sanzenbacher, A.E. Burger, and M.G. Raphael. 2015. A review of Marbled Murrelet research related to nesting habitat use and nest success. Final report prepared for Oregon Department of Forestry. Salem, Oregon. 424p.
<https://www.oregon.gov/odf/Documents/workingforests/ReviewofMAMUResearchRelatedToNestingHabitatUseandNestSuccess.pdf>
- Plummer, J.F., C.R. Keyes, and J.M. Varner. 2012. Early-stage thinning for the restoration of young redwood-Douglas-fir forests in northern coastal California. *International Scholarly Research Notices*: article 725827. <https://www.hindawi.com/journals/isrn/2012/725827/>
- Potter, C. 2023. Impact of the CZU Lightning Complex Fire of August 2020 on the forests of Big Basin Redwoods State Park. *California Fish and Wildlife Journal* 109:e1.
- Ralph, C.J., G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt, tech. eds. 1995. Ecology and conservation of the Marbled Murrelet. USDA Forest Service General Technical Report PSW- GTR-152, Albany, California.
https://www.fs.usda.gov/psw/publications/documents/psw_gtr152/psw_gtr152.pdf
- Raphael, M.G., D. Evans Mack, J.M. Marzluff, and J.M. Luginbuhl. 2002a. Effects of forest fragmentation on populations of the Marbled Murrelet. *Studies in Avian Biology* 25:221–235. https://sora.unm.edu/sites/default/files/SAB_025_2002%20P221-235_Effects%20of%20Forest%20Fragmentation%20on%20Populations%20of%20the%20Marbled%20Murrelet_Martin%20G.%20Raphael%2C%20Diane%20Evans%20Mack%2C%20John%20M.%20Marzluff%2C%20John%20M.%20Luginbuhl.pdf
- Raphael, M.G., D. Evans Mack, and B.A. Cooper. 2002b. Landscape-scale relationships between abundance of Marbled Murrelets and distribution of nesting habitat. *Condor* 104:331–342.
- Raphael, M.G., S.K. Nelson, P. Swedeen, M. Ostwald, K. Flotlin, S. Desimone, S. Horton, P. Harrison, D. Prenzlowl Escene, and W. Jaross. 2008. Recommendations and supporting analysis of conservation opportunities for the Marbled Murrelet long-term conservation

- strategy. Washington State Department of Natural Resources, Olympia, Washington.
https://www.dnr.wa.gov/publications/lm_mamu_sci_team_report.pdf
- Raphael, M.G., A.J. Shirk, G.A. Falxa, D. Lynch, S.K. Nelson, S.F. Pearson, C. Strong, and R.D. Young. 2016. Chapter 3: Factors influencing status and trend of Marbled Murrelet populations: an integrated perspective. Pages 95-120 In: Falxa, G.A. and M.G. Raphael, tech. coords. Northwest Forest Plan—the first 20 years (1994–2013): status and trend of Marbled Murrelet populations and nesting habitat. USDA Forest Service General Technical Report PNW-GTR-933, Portland, Oregon.
https://www.fs.usda.gov/pnw/pubs/pnw_gtr933.pdf
- Raphael, M.G., A.J. Shirk, G.A. Falxa, and S.F. Pearson. 2015. Habitat associations of Marbled Murrelets during the nesting season in nearshore waters along the Washington to California coast. *Journal of Marine Systems* 146:17-25.
<https://wdfw.wa.gov/sites/default/files/2019-09/Habitat%20associations%20of%20marbled%20murrelets.pdf>
- Raphael, M.G., G.A. Falxa, and A.E. Burger. 2018. Chapter 5: Marbled Murrelet. Pages 301-370 In: Spies, T.A., P.A. Stine, R. Gravenmier, J.W. Long, and M.J. Reilly, tech. coords. 2018. Synthesis of science to inform land management within the Northwest Forest Plan area. USDA Forest Service General Technical Report PNW-GTR-966, Portland, Oregon.
https://www.fs.usda.gov/pnw/pubs/pnw_gtr966_chapter5.pdf
- Rice, R.M., R.R. Ziemer, and J. Lewis. 2004. Chapter 10: Evaluating forest management effects on erosion, sedimentation, and runoff: Caspar Creek and northern California. In: Ice, G.G. and J.S. Stednick, eds. A century of forest and wildland watershed lessons. Society of American Foresters, Bethesda, Maryland.
<http://rziemer.cpphotofinder.com/rziemer/pubs/riceSAF.pdf>
- Ripple, W.J., S.K. Nelson, and E.M. Glenn. 2003. Forest landscape patterns around Marbled Murrelet nest sites in the Oregon Coast Range. *Northwestern Naturalist* 84:80–89.
- Robbins, W.G. 2021. Oregon and climate change: the age of megafires in the American West. *Oregon Historical Society Quarterly* 122(3):250–277. https://www.ohs.org/oregon-historical-quarterly/upload/Robbins_Oregon-and-West-Age-of-Megafires_OHQ-122_3_Fall-2021_web.pdf
- Rogers, B.M., R.P. Neilson, R. Drapek, J.M. Leniham, J.R. Wells, D. Bachelor, and B.E. Law. 2011. Impacts of climate change on fire regimes and carbon stocks in the U.S. Pacific Northwest. *Journal of Geophysical Research* 116:G03037.
<https://doi.org/10.1029/2011JG001695>
- Rosenberg, K.V., B. Kott, R.S. Hames, R.W. Rohrbaugh, Jr., S.B. Swarthout, and J.D. Lowe. 2004. Effects of recreational development on forest-breeding birds in U.S. National Forests. Cornell Lab of Ornithology, Ithaca NY (prepared for USDA Forest Service, Challenge Cost-Share Agreement No. 98-CCS-197).

- Ruel, J.C. 1995. Understanding windthrow: silvicultural implications. *The Forestry Chronicle* 71(4):434–445. <https://pubs.cif-ifc.org/doi/pdf/10.5558/tfc71434-4>
- Santa Cruz Mountains Bioregional Council (SCMBC). 2020. Redwood forest impacts of the CZU Lightning Fire Complex: Climate change hits home with catastrophic results. www.scmhc.org
- Scarpignato, A.L. and T.L. George. 2013. Space use by Common Ravens in Marbled Murrelet nesting habitat in northern California. *Journal of Field Ornithology* 84:147–159.
- Schuurman G.W., C.H. Hoffman, D.N. Cole, D. J. Lawrence, J.M. Morton, D.R. Magness, A.E. Cravens, S. Covington, R. O'Malley, and N.A. Fisichelli. 2020. Resist-accept-direct (RAD)-A framework for the 21st-century natural resource manager. USGS Natural Resource Report, Fort Collins, Colorado. <https://doi.org/10.36967/nrr-2283597>
- Sillett, S.C and M.E. Antoine. 2004. Lichens and bryophytes in forest canopies. *Forest Canopies* 2:151–174.
- Sillett, S.C., M.E. Antoine, J. Campbell-Spickler, A.L. Carroll, E.J. Coonen, R.D. Kramer, and K.H. Scarla. 2018. Manipulating tree crown structure to promote old-growth characteristics in second-growth redwood forest canopies. *Forest Ecology and Management* 417:77–89.
- Singer, S.W. and A. Rinkert. In prep. Impacts of the CZU Lightning Complex Fire on Marbled Murrelet suitable nest trees in Big Basin State Park. Unpublished report prepared for the Santa Cruz District, California State Parks.
- Singer, S.W., N.L. Naslund, S.A. Singer, and C.J. Ralph. 1991. Discovery and observation of two tree nests of the Marbled Murrelet. *Condor* 93:330–339.
- Singer, S.W., D.L. Suddjian, and S.A. Singer. 1995. Fledging behavior, flight patterns, and forest characteristics at Marbled Murrelet tree nests in California. *Northwestern Naturalist* 76:54–62.
- Sinton, D.S., J.A. Jones, J.L. Ohmann, and F.J. Swanson. 2000. Windthrow disturbance, forest composition, and structure in the Bull Run basin, Oregon. *Ecology* 81:2539–2556.
- Steel, Z.L., H.D. Safford, and J.H. Veirs. 2015. The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere* 6(1):8. https://www.sierraforestlegacy.org/Resources/Conservation/FireForestEcology/FireScienceResearch/FireHistory/FireHistory_Steel_etal2015.pdf
- Turco, M., J.T. Abatzoglou, S. Herrera, and I. Cvijanovic. 2023. Anthropogenic climate change impacts exacerbate summer forest fires in California. *PNAS* 120: e2213815120. <https://doi.org/10.1073/pnas.2213815120>
- U.S. Environmental Protection Agency. 1993. Chapter 3: Management measures for forestry. Pages 3-1 to 3-129 In: Guidance specifying management measures for sources of

- nonpoint pollution in coastal waters. Publication number: EPA-840-B-92-002.
www.epa.gov/nps/guidance-specifying-management-measures-sources-nonpoint-pollution-coastal-waters
- U.S. Fish and Wildlife Service (USFWS). 1992. Endangered and threatened wildlife and plants: determination of threatened status for the Washington, Oregon and California population of the Marbled Murrelet. Federal Register 57:45328–45337. October 1, 1992.
https://www.fws.gov/sites/default/files/federal_register_document/FR-1992-10-01.pdf
- U.S. Fish and Wildlife Service (USFWS). 1996. Final designation of critical habitat for the Marbled Murrelet. Federal Register 61:26257–26320. May 24, 1996.
https://www.fws.gov/sites/default/files/federal_register_document/96-12647.pdf
- U.S. Fish and Wildlife Service (USFWS). 1997. Recovery plan for the Marbled Murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Oregon Field Office, Portland, Oregon. 203p. https://ecos.fws.gov/docs/recovery_plan/970924.pdf
- U.S. Fish and Wildlife Service (USFWS). 2011. Revised critical habitat for the Marbled Murrelet: final rule. Federal Register 76:61599–61621 October 5, 2011.
<https://www.federalregister.gov/documents/2011/10/05/2011-25583/endangered-and-threatened-wildlife-and-plants-revised-critical-habitat-for-the-marbled-murrelet>
- U.S. Fish and Wildlife Service (USFWS). 2012. Report on Marbled Murrelet recovery implementation team meeting and stakeholder workshop. April 17, 2012, memorandum from the Field Supervisor of the Washington Fish and Wildlife Office, Lacey, Washington, to Interested Parties. 66 p., including appendices A through F.
- U.S. Fish and Wildlife Service (USFWS). 2013. Appendix C: Guidelines for blasting on Olympic National Forest. Pages C-1 to C-2 In: Formal biological opinion for selected forest management activities on the Olympic National Forest. 13410-2009-F-0388. Washington Fish and Wildlife Office, Lacey, Washington. March 25, 2023. 404p.
<https://www.fs.usda.gov/detailfull/olympic/landmanagement/planning/?cid=fseprd876799&width=full>
- U.S. Fish and Wildlife Service (USFWS). 2015. Appendix H: Revised in-air disturbance analysis for Marbled Murrelets. Pages H-1 to H-20 In: Formal biological opinion for selected forest management activities on the Olympic National Forest. 13410-2009-F-0388. Washington Fish and Wildlife Office, Lacey, Washington. March 25 2023. 404p.
<https://www.fs.usda.gov/detailfull/olympic/landmanagement/planning/?cid=fseprd876799&width=full>
- U.S. Fish and Wildlife Service (USFWS). 2016. Determination of critical habitat for the Marbled Murrelet: final determination. Federal Register 81:51348–51370. August 4, 2016.
<https://www.federalregister.gov/documents/2016/08/04/2016-18376/endangered-and-threatened-wildlife-and-plants-determination-of-critical-habitat-for-the-marbled>

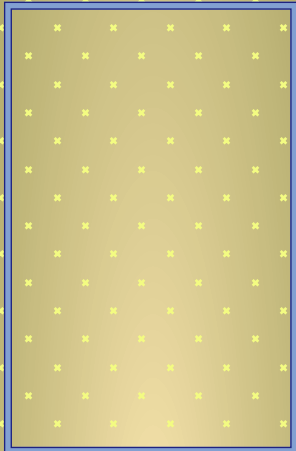
- U.S. Fish and Wildlife Service (USFWS). 2019. Marbled Murrelet (*Brachyramphus marmoratus*): 5-year status review. USDI Washington Fish and Wildlife Office, Lacey, Washington. https://ecos.fws.gov/docs/five_year_review/doc6027.pdf
- U.S. Fish and Wildlife Service (USFWS). 2020. Revised transmittal of guidance: estimating the effects of auditory and visual disturbance to Northern Spotted Owls and Marbled Murrelets in northwestern California. October 28, 2020, Memorandum from the Field Supervisor of the Arcata Fish and Wildlife Office, Arcata, California, to All Interested Parties. 116p. <https://citizensofebeysreserve.com/wp-content/uploads/2022/06/MaMu-Noise-Thresholds-USFWS.pdf>
- Valente, J.J., S.K. Nelson, J.W. Rivers, D.D. Roby, and M.G. Betts. 2021. Experimental evidence that social information affects habitat selection in Marbled Murrelets. *Ornithology* 138:1–13. https://www.jonathonvalente.com/files/ugd/9027a5_14970ffd351944cd88e16b76ca6892a4.pdf
- Valente, J.J., J.W. Rivers, Z. Yang, S.K. Nelson, J.M. Northrup, D.D. Roby, C.B. Meyer, and M.G. Betts. 2023. Fragmentation effects on an endangered species across a gradient from the interior to edge of its range. *Conservation Biology* 14091:1–12. <https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/cobi.14091>
- van Mantgem, P.J., J.C.B. Nesmith, M. Keifer, E.E. Knapp, A. Flint, and L. Flint. 2013. Climate stress increases forest fire severity across the western United States. *Ecology Letters* 16:1151–1156.
- van Rooyen, J.C., J.M. Malt, and D.B. Lank. 2011. Relating microclimate to epiphyte availability: edge effects on nesting habitat availability for the Marbled Murrelet. *Northwest Science* 85:549–561. <https://www.sfu.ca/biology2/wildberg/papers/vanRooyenetalNWSci2011.pdf>
- Vigallon, S.M. and J.M. Marzluff. 2005. Is nest predation by Steller’s jays (*Cyanocitta stelleri*) incidental or the result of specialized search strategy? *Auk* 122:36–49.
- Walker, L.E., P. Pyle, M.A. Patten, E. Greene, W. Davison, and V.R. Muehter. 2020. Steller's jay (*Cyanocitta stelleri*), version 1.0. In: Rodewald, P.G., Editor. *Birds of the World*. Cornell Lab of Ornithology, Ithaca, New York USA. <https://birdsoftheworld.org/bow/species/stejay/cur/introduction>
- Watson, M.L. 2005. Habitat fragmentation and the effects of roads on wildlife habitats - background and literature review. Unpublished report New Mexico Department of Game and Fish, January 2005. 18p. <http://safepassagecoalition.org/resources/Habitat%20Fragmentation.pdf>
- Webb, W.C. 2017. Chapter 3: Management of crows and ravens to reduce the risk of nest predation on Marbled Murrelets in the Santa Cruz Mountains. Pages 71–73 In: Halbert, P. and S.W. Singer, eds. *Marbled Murrelet Landscape Management Plan for Zone 6*.

- California Department of Parks and Recreation, Santa Cruz, California.
http://www.parks.ca.gov/pages/29882/files/Z6-Plan_FINAL_MASTER_V14_07-17.pdf
- Wender, B.A., C.A. Harrington, and J.C. Tappeiner. 2004. Flower and fruit production of understory shrubs in western Oregon and Washington. *Northwest Science* 78:124–140.
https://www.fs.usda.gov/pnw/olympia/silv/publications/opt/490_WenderEtal2004.pdf
- West, E.H. and M.Z. Peery. 2016. Behavioral mechanisms leading to improved fitness in a subsidized predator. *Oecologia* <https://doi.org/10.1007/s00442-017-3898-0>
- West, E.H., K. Brunk, and M.Z. Peery. 2019. When protected areas produce source populations of overabundant species. *Biological Conservation* 238:108220.
- Westerling, A.L. 2016. Increasing western U.S. forest wildfire activity: sensitivity to changes in the timing of spring. *Philosophical Transactions of the Royal Society B* 371:20150178.
<http://doi.org/10.1098/rstb.2015.0178>
- Williams, A.P., J.T. Abatzoglou, A. Gershunov, J. Guzman-Morales, D.A. Bishop, J.K. Balch, and D.P. Lettenmaier. 2019. Observed impacts of anthropogenic climate change on wildfire in California. *Earth's Future* 7:892–910. <https://doi.org/10.1029/2019EF001210>
- Wilk, R., M. Raphael, and T. Bloxton. 2016. Nesting habitat characteristics of Marbled Murrelets occurring in near-shore waters of the Olympic Peninsula, Washington: Nesting habitat of Marbled Murrelets. *Journal of Field Ornithology* 87(2):162–175.
<https://doi.org/10.1111/jof.12150>

INSIDE

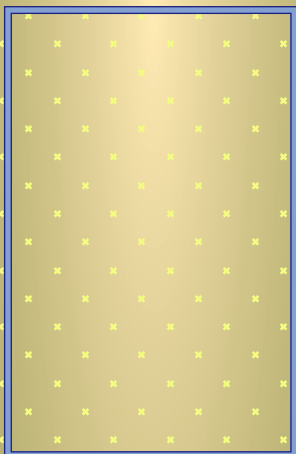
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The BOG Sit 2021



Christmas Bird Count

Santa Cruz Birds

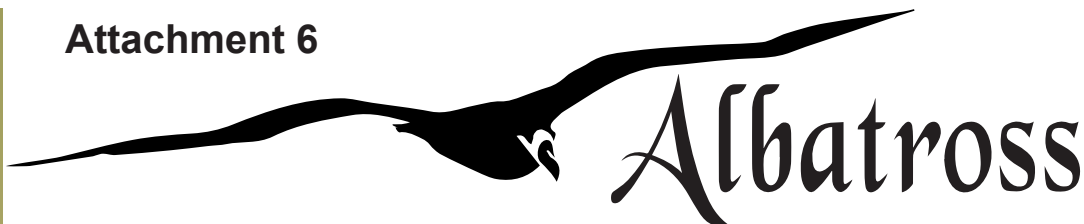


Birders'
Notebook

PARTING SHOT



Attachment 6



Albatross

PHOEBASTRIA NIGRIPES

A Marbled Murrelet Fledges at Big Basin

By Alex Rinkert, Stephanie Singer, Steve Singer



Most birders are introduced to the Marbled Murrelet on boat trips—a small alcid bobbing on the ocean, diving when the boat approaches. Sometimes they're close enough to shore to be seen with a scope.

For those landlubbers who venture into the old-growth forest in the hours before dawn, the murrelet may reveal its second persona. As it flies to and from the ocean, through the giant trees, you may hear its eerie “keer-keer” calls to its fellow murrelets. Find a spot with a view of the sky and you may see them flying like giant bumblebees.

There is a third facet of the Marbled Murrelet, unseen by most. If its forest flights are successful, the bird will find a suitable large branch high in an old-growth tree and lay a single egg. It is a cause for celebration any time that an active murrelet nest is found. The one that Alex Rinkert found this summer in Big Basin Redwoods State Park was extra special, since 98% of the park was burned in the CZU Lightning Complex Fire, and most of it burned with high intensity.

Alex tells the story:

During a dawn survey at the park on July 1, I observed an adult murrelet carrying a fish while flying over a small patch of green, lightly burned forest. The murrelet circled below the canopy and flew up to its nest on a large, moss-covered limb of a Douglas-fir, where a downy chick received its morning meal. A small group of researchers monitored the chick intermittently in the following days as its downy plumage was slowly replaced by juvenal feathers, and, by July 9, the chick had attained full juvenal plumage and was ready to fledge!

That evening, the nest was staked out in anticipation of a fledging. An adult brought the chick one last fish, and then with a “full tank” and in fading light, the chick launched off the limb and took its first flight, 24 minutes after sunset! Renowned local photographer Frans Lanting and crew were on hand, and despite the challenging light and distance, they captured the first ground-based footage of this species fledgling from a tree nest. We left that evening feeling ecstatic, tired, and relieved.

Observations of murrelets over the years have revealed how amazingly fine-tuned their instincts are. The young chick first sees the world as a collage of branches and sky, and has only



This drawing, by Ken Carlson, appeared in The Wilson Bulletin in 1975.

taken a few steps around its nest. For 30 days it sits alone on the branch, and then when the moment is right, it preens off all of the downy feathers revealing its black and white juvenal plumage. After a few bouts of wing-flapping, it jumps off the nest branch and flies rapidly towards the ocean. Alone. No adults around. Once on the water—and it has never before even *seen* water—the fledgling knows how to dive and fly underwater to catch fish!

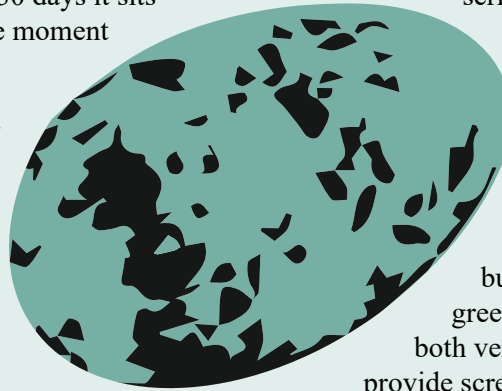
THE SCBC CONNECTION

Santa Cruz County has been a key place for solving the mystery of the Marbled Murrelet's nest. In 1930, long before the Santa Cruz Bird Club was founded, a young Les Hawkins was birding along railroad tracks just south of what is now Henry Cowell State Park. He saw two murrelets chasing each other and calling repeatedly. He noted: *"...I know of no cliffs up the canyon from whence they might have come but many dead stubs full of holes. They are small enough—why can't or why aren't they nesting in holes in trees??...Just see if this prophecy doesn't come true."* He was wrong about nesting in cavities, but right in that they nest in trees—a bizarre location for a seabird.

There were sporadic observations of Marbled Murrelets in the Santa Cruz Mountains from the 1930s through the early 1970s, including a nest search in 1957 by members of the newly formed Santa Cruz Bird Club and other naturalists. They searched along the banks of Pescadero Creek, but failed to find a nest.

It wasn't until 1974 that a nest was found—in a Douglas-fir at Big Basin Redwoods State Park. After two more nests were found at Big Basin in 1989, the Santa Cruz Bird Club joined forces with Steve and Stephanie Singer to search for nests in 1990. Success came in May 1991, when 14 club members met at dawn at Big Basin to stake out potentially suitable nest trees. Bonnie Bedzin and Rebecca Cull made the key observation that led to finding the fourth Marbled Murrelet nest ever found in California. Unlike the other three nests, this one was successful! With nine club members observing, the chick fledged successfully on the evening of July 3. Santa Cruz Bird Club members were the first people to ever observe the fledging of a Marbled Murrelet in person!

In the intervening years, 16 more nests were found in the Santa Cruz Mountains. However there have been no



serious nest-finding efforts in the park in the last 20 years. The parents of this year's nest had to find their way to the breeding area over a landscape that was much different than what they were used to. Their chosen tree was in a rare, tiny 9-acre patch of lightly burned forest that still had some green canopy. The nest itself lacked both vertical and horizontal branches that provide screening cover, and was much more visible than is typical. This year's chick somehow managed to avoid predation by corvids, perhaps because their numbers have been significantly reduced by the fire. Remarkably, the fledging of this year's nest occurred 30 years after Santa Cruz Bird Club members had witnessed the first ever fledging of this species from another tree only 500 meters away.

While there is much excitement about this year's nest, the severely burned old growth forest surrounding this tiny patch of remnant green canopy portrays a different reality. Nearly half of the potentially suitable murrelet nest trees at Big Basin were lost in the fire. Only time will tell whether this unique and endangered species can continue to breed in the rest of the park as the forest slowly recovers.

Links for more information:

Frans Lanting video of the fledge: www.vimeo.com/592467183/5149ad27c7

More about the fire's impact on Big Basin Redwoods State Park: www.scmbsc.org

About the 1991 nest & fledge: https://santacruzbirdclub.org/wp-content/uploads/2021/09/MAMU_Suddjian_-1991_Albatross_V37.No_.1.pdf

About the 1974 nest (in Pacific Discovery):

https://archive.org/details/sim_california-wild_july-august-1975_28_4

(in Wilson Bulletin): <https://sora.unm.edu/node/3375>

About the 1957 search for a nest: https://santacruzbirdclub.org/wp-content/uploads/2021/09/MAMU_Anderson-1972-1_PacDiscovery-article.pdf



Marbled Murrelet nestling - Estrella Bibbey



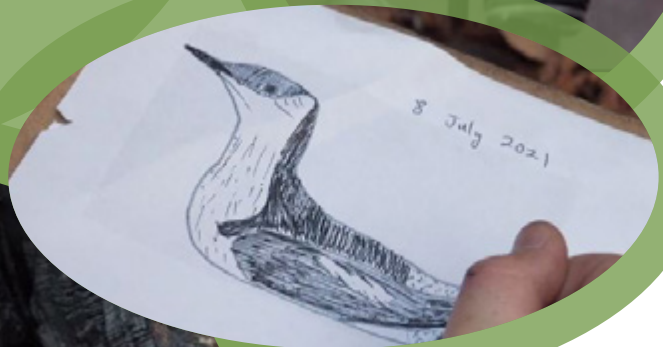
*Adult MAMU, breeding plumage
- Beth Hamel*

What a wonderful bird is the murr'let chick,
He swallows fish whole – that's a neat trick.
From his nest in a tree, he flies straight to the sea,
In pitch dark, no ad'ult to guide it!

- Stephanie Singer



*Right:
Alex Rinkert with scope
Alex' MAMU sketch
Alex sketching*



**Marbled Murrelet (*Brachyramphus marmoratus*)
CA, OR, WA DPS**

**5-Year Review:
Summary and Evaluation**

**U.S. Fish and Wildlife Service
Washington Fish and Wildlife Office
Lacey, WA**

5-YEAR REVIEW

Species reviewed: Marbled Murrelet (*Brachyramphus marmoratus*)

Table of Contents

General Information.....	1
Review Analysis	1
Application of the 1996 Distinct Population Segment (DPS) policy	1
Updated Information and Current Species Status	3
Species Ecological Needs	3
Demographics and Trends	3
Current Viability	5
Threats Analysis.....	6
Timber Harvest	7
Wildfire	8
Predation	8
Coastal and Nearshore Development.....	9
Climate Change.....	10
Conservation Measures	11
Summary	14
Recovery Criteria	14
Synthesis	14
Results.....	16
Recommendations For Future Actions	16
References.....	17
5-Year Review of Marbled Murrelet (CA, OR, WA DPS).....	21

5-YEAR REVIEW

Marbled Murrelet (CA, OR, WA DPS) / *Brachyramphus marmoratus*

GENERAL INFORMATION

Species: Marbled Murrelet (CA, OR, WA DPS)

Date listed: October 1, 1992

FR citation: 57 FR 45328

Classification: Threatened

Critical habitat: Designated May 24, 1996 (61 FR 26257); Revised October 5, 2011 (76 FR 61599); Affirmed August 4, 2016 (81 FR 51349)

Methodology used to complete the review: In accordance with section 4(c)(2) of the Endangered Species Act of 1973, as amended (Act), the purpose of 5-year reviews is to assess each threatened species and endangered species to determine whether its status has changed and whether it should be classified differently or removed from the Lists of Threatened and Endangered Wildlife and Plants. To evaluate the status of the marbled murrelet, we (the U.S. Fish and Wildlife Service [Service]) used the Species Status Assessment (SSA) framework (Service 2016, entire), which uses the concepts of resiliency, redundancy, and representation to assess viability. We reported our findings in a Species Biological Report (SBR).

The SBR (Service 2024, entire) was developed by a writing team from the Service's Washington Ecological Services Office, with review and input from the Service's species experts across the listed range. The SBR represents our evaluation of the best available scientific information, including species ecological needs, factors influencing the species and the current condition of the species. Independent peer reviewers and partner representatives reviewed the SBR before it was used as the scientific basis to support our 5-year review decision-making process.

FR Notice citation announcing the species is under active review:

U.S. Fish and Wildlife Service. 2022. Initiation of 5-year status reviews for 167 species in Oregon, Washington, Idaho, Montana, California, Hawaii, Guam, and the Northern Mariana Islands. Federal Register 87:28031-28034. May 10, 2022.

REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) policy

The marbled murrelet was listed in 1992, prior to implementation of the Service's 1996 Distinct Population Segment (DPS) policy. In 2009, we determined that the murrelet population in Washington, Oregon, and California meets the policy standards of discreteness and significance and is therefore a valid DPS (Service 2009, pp. 3-12). We affirmed this finding in 2019 (Service 2019, pp. 3-10). There is no new information to indicate that the listed DPS does not continue to meet those policy standards. Therefore, we consider the Washington, Oregon, and California population of marbled murrelet to be a valid DPS.

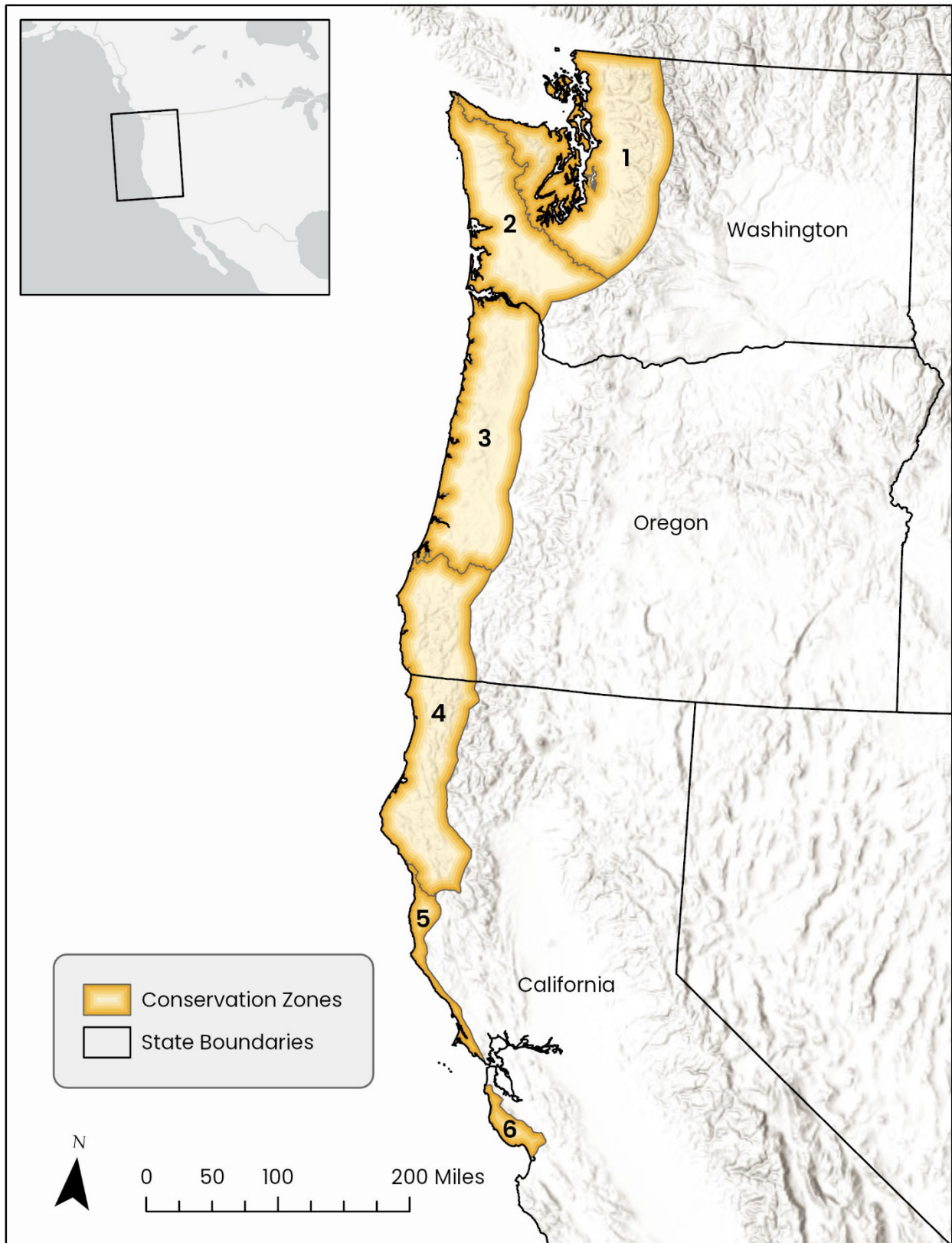


Figure 1. Marbled murrelet Conservation Zones

Updated Information and Current Species Status

The species' life history traits, habitat, and distribution have been previously well-described and are summarized in the SBR (Service 2024, pp. 5-9). Briefly, the marbled murrelet is a small seabird that typically forages in shallow nearshore marine waters and nests in coastal forests that contain older trees, typically up to 89 km (55 miles) inland (Raphael et al. 2018, p. 301). Murrelets do not construct nests, but instead lay a single egg on naturally occurring nesting platforms in large, older-aged trees (Nelson 1997, p. 17). Both parents commute between foraging and nesting habitat to incubate the egg and provision the chick.

Species Ecological Needs

All life stages of the murrelet are dependent upon the presence of adequate nesting habitat, adequate foraging habitat, and connectivity between the two. Adequate nesting habitat, comprising large coniferous trees, large diameter platforms covered in moss and other detritus, overhead cover, and access routes, provides for the establishment of nests and the successful rearing of nestlings. Adequate foraging habitat provides sufficient energetic and nutritional resources to support essential functions, including growth, locomotion, and reproduction. Adequate foraging and nesting habitats must occur within daily commuting distance to allow for foraging by adults while they incubate their egg and rear their chick. These individual resource needs influence the population size and growth rate, which contributes to population resiliency and ultimately to the redundancy and representation of the species.

Since completion of our previous 5-year status review, more information has become available about the relationship between nesting and foraging habitats, and their influence on murrelet movement and distribution. Use of these disparate habitats is not independent; for successful chick rearing, foraging and nesting areas must occur within daily commuting distance of one another to allow for continued foraging by adults while they incubate their egg and rear their chick. Accordingly, murrelet abundance at sea during the breeding season is correlated with the presence of good-quality nesting habitat in the adjacent terrestrial environment (Raphael et al. 2015, p. 20; Lorenz et al. 2016, p. 1; Raphael et al. 2016 p. 101; Pastran et al. 2021, p. 1), while terrestrial sites are most likely to be occupied by murrelets when they occur in areas with more old forest that are closer to high-quality foraging areas (Betts et al. 2020, p. 7). During poor foraging years, which are associated with low nesting propensity, terrestrial features are not the primary drivers of marine habitat use (Garcia-Heras et al. 2024, p. 7).

Demographics and Trends

Murrelet population abundance and trends are estimated through a standardized, coordinated sampling effort within the Northwest Forest Plan (NWFP) area (Conservation Zones 1 through 5) (Figure 1), and a comparable effort in Conservation Zone 6. The most recent population estimate for the entire NWFP area was approximately 19,000 murrelets in 2022 (McIver et al. 2024, p. 4). The annual rate of change between 2001 and 2022, derived from this estimate, is not statistically significant ($P\text{-value} \leq 0.05$) at the scale of the NWFP area (McIver et al. 2024, pp. 4, 20) (Table 1). While population size is not changing in a detectable way across the NWFP area, population trends vary by conservation zone and by state, with murrelet decreases in the north (Conservation Zones 1 and 2) apparently offset by murrelet increases farther south (Conservation Zones 3 and 4). Outside of the NWFP area, in Conservation Zone 6, surveys indicated an

estimated population size of 397 murrelets, with no trends in abundance detected for the 1999 to 2022 time frame (Felis et al. 2022a, p. 3-4) (Table 1).

Table 1. Estimated long-term abundance trend for murrelets, by conservation zone. Asterisk (*) indicates statistically significant annual rate of change ($P\text{-value} \leq 0.05$) (McIver et al. 2024, p. 20; Felis et al. 2022b, pp. 3-5).

Conservation Zone(s)	Period of analysis	Annual rate of change (percent)	95% Confidence interval	Standard error
Zones 1-5 (NWFP Area)	2001-2022	0.0	(-0.8 to 0.8)	
Washington	2001-2022	-4.1*	(-5.2 to -3.0)	
Oregon	2000-2022	1.7	(0.8 to 2.7)	
California (NWFP portion only)	2000-2023	3.6	(2.2 to 5.1)	
Zone 1	2001-2022	-4.6*	(-6.4 to -2.7)	
Zone 2	2001-2023	-3.5*	(-5.8 to -1.0)	
Zone 3	2000-2022	1.6*	(0.03 to 2.9)	
Zone 4	2000-2023	2.8*	(1.3 to 4.4)	
Zone 5	2000-2021	1.5	(-7.1 to 11.7)	
Zone 6	1999-2022	0.01		0.009

Reproductive success, or productivity, is low for murrelets within the listed range. Telemetry-based studies indicate that fecundity rates, calculated from estimates of nesting attempts and nesting success, range from 0.021 to 0.063 (Peery et al. 2004, p. 1094; Service 2024, p. 54). At-sea survey-based methods indicate that juvenile-to-adult ratios range from 0 to 0.067 (Strong 2022, p. 17; Strong 2023, p. 17). Date-corrected juvenile-to-adult ratios, which account for adults that are still incubating eggs and chicks that are not yet fledged at the time of the survey, range from 0 to 0.091 (Lorenz and Raphael 2018, pp. 206, 211; Felis et al. 2022a, p. 4). Each of these estimates is well below the level thought to be necessary to maintain a stable population; demographic modeling, historical records, and comparisons with similar species all suggest that murrelet population stability requires fecundity to be between 0.20 and 0.46 or juvenile-to-adult ratios to be between 0.15 and 0.3 at the end of the breeding season (Beissinger 1995, p. 390; Beissinger and Peery 2007, p. 302; Service 1997, p. B-13). Even the lower end of these ranges is substantially higher than estimates of productivity for any of the conservation zones. Although estimates obtained from telemetry studies and uncorrected juvenile ratios are prone to underestimation, the magnitude of difference between observed rates and required rates indicates that the murrelet reproductive rate is likely insufficient to maintain stable population numbers throughout all the species' listed range.

There are several uncertainties associated with at-sea survey results and other available demographic data. First, these abundance estimates do not reflect the abundance of the local breeding population. Rather, they include both locally breeding and non-breeding birds, as well as transient birds (McIver et al. 2021, p. 26). They also do not account for movement of murrelets

among conservation zones or between the U.S. and Canada, which confounds interpretation of changes in abundance over time, particularly at the conservation zone scale (McIver et al. 2021, p. 26; Loehle et al. 2023, pp. 23-27). Because murrelets are highly mobile and respond to changes in both the marine and terrestrial environments (Raphael et al. 2015, p. 17), reported trends may not reflect meaningful changes in demographic metrics, especially at a local scale. In addition, observed low reproductive rates are at odds with the apparently stable population size. Nevertheless, at-sea abundance estimates represent the best available information relative to murrelet population size, and are a valuable tool for assessing status, particularly at the range-wide scale.

Current Viability

We used the conservation principles of resiliency, redundancy, and representation to assess the viability of marbled murrelet within its listed range, as described in the SBR (Service 2024, pp. 1-2). We evaluated population resiliency at the conservation zone scale, using a condition category model (Figure 2) where we computed a metric of resiliency based on the unweighted mean of three available demographic metrics (abundance, trend in abundance, and productivity). For the first metric, we used the range of at-sea abundance estimates for the last six years (2018 to 2023). For the second metric, we categorized long-term trend according to whether it represents a declining, stable/ambiguous, or increasing populations. We incorporated the third demographic metric, productivity, by considering what the available information indicates about murrelet reproductive potential more broadly. A detailed description of our methodology is available in the SBR (Service 2024, pp. 54-57).

Metric	Condition Scoring			
Abundance	Abundance >5000 murrelets (3 points)	Abundance 500-5000 murrelets (2 points)	Abundance 200-500 murrelets (1 point)	Abundance <200 murrelets (0 points)
Trend in Abundance	Evidence of a long-term population increase (3 points)	No evidence of a long-term population trend (2 points)	Evidence of a long-term population decrease (1 point)	
Productivity	Juvenile ratios > 0.3; Overall fecundity > 0.46 (3 points)	Juvenile ratios 0.15-0.3; Overall fecundity 0.20- 0.46 (2 points)	Juvenile ratios < 0.15; Overall fecundity < 0.20 (1 points)	

Figure 2. Condition category model used to assess current resiliency of marbled murrelets, at the conservation zone scale.

Population resiliency ranges from moderate to very low (Table 2). It is highest in the central portion of the range, in Conservation Zones 3 and 4, and lower in the northern and southern portions of the range, in Conservation Zones 1, 2, 5, and 6. Within our analytical framework, low

resiliency is a result of small population size and/or declining trend, coupled with poor productivity.

Table 2. Murrelet resiliency by conservation zone.

Conservation Zone	Abundance Range 2018-2023	Trend in Abundance	Productivity	Resiliency
Zone 1	3,143-3,843	Decreasing	Low	Low
Zone 2	1,018-1,657	Decreasing	Low	Low
Zone 3	8,249-8,414	Increasing	Low	Moderate
Zone 4	5,132-6,822	Increasing	Low	Moderate
Zone 5	42	No trend	Low	Very low
Zone 6	266-408	No trend	Low	Low

To evaluate species redundancy, we considered the number and distribution of populations relative to the scale of anticipated catastrophic events. To evaluate representation, we considered the breadth of genetic and ecological diversity found within a species. This evaluation indicates that murrelets within the listed range continue to have the ability to withstand catastrophic events (redundancy) and have some ability to adapt to changes in their physical and biological environments (representation). The species continues to occupy its historical range in Washington, Oregon, and California. Given their current widespread distribution, we do not expect that the species will face extinction as a result of one or more catastrophic events. While catastrophic events such as fire and marine heatwaves are currently present on the landscape, may result in deleterious effects to murrelets and their habitat, and are likely to increase in the future, we do not expect that the scope and scale of these events will cause extinction of the species within its listed range. Similarly, the genetic and ecological diversity found with the species indicates that murrelets have at least some capacity to adapt to changing physical and biological conditions. However, this adaptive capacity may be limited for changes that develop rapidly.

Threats Analysis

When analyzing influence factors, we distinguish between factors that have negative impacts (threats) and those that have positive impacts (conservation measures). Additionally, we consider whether the impacts are of sufficient scope and magnitude that they affect not only individual murrelets, but also rise to level of having population-level effects. Although we considered both historical and potential future threats, for the purposes of our threats analysis and evaluation of species' status, we only include influence factors that are currently having a population-level effect.

When the species was listed in 1992, loss and modification of suitable nesting habitat due primarily to timber harvest (Factor A) was identified as the primary threat facing the species. Gill-net fisheries in Washington (Factor E), predation (Factor C), and oil spills (Factor E) were identified as secondary threats. It was also determined that existing regulatory mechanisms (Factor D) were inadequate to ensure the survival of the species. Threats that currently have a population-level effect include timber harvest (Factor A), fire (Factor A), predation (Factor C),

coastal and nearshore development (Factor E), and climate change (Factor E). Existing regulatory mechanisms (Factor D) remain inadequate to fully protect remaining nesting habitat. Additional threats to the species include tree disease (Factor A), wind events (Factor A), toxic contaminants (Factor E), net entanglement (Factor E), oil spills (Factor E), energy generation (Factor E), and Highly Pathogenic Avian Influenza (Factor C). However, the best available information does not indicate that these additional threats currently act on the species at the population level. Therefore, they are not included in our evaluation of status.

Timber Harvest

Timber harvest includes a range of activities such as removal of trees and operation of heavy equipment, which can change the structure and availability of nesting habitat and result in elevated sound levels and visible human activity near nests. The loss and modification of nesting habitat reduces site availability and displaces murrelets with site fidelity, and can have several impacts on murrelets, including nest site abandonment, delayed breeding, failure to initiate breeding in subsequent years, and failed breeding due to increased predation risk at a marginal nesting location (Divoky and Horton 1995, p. 83; Raphael et al. 2002, p. 232). These outcomes reduce nesting success, which ultimately influences recruitment of juvenile birds into the local population (Raphael et al. 2002, pp. 231-233).

Historical timber management during the 20th century significantly reduced the area of potential murrelet habitat in Washington, Oregon, and California (Perry 1995, p. 382). As of 2017, there were approximately 8.1 million ha (20 million acres) of lands capable of supporting forest within the NWFP area. However, only about 7 percent of those lands are currently considered nesting habitat (Lorenz et al. 2021, pp. 2-3, 25). Loss of nesting habitat, primarily due to commercial timber harvest, is implicated in the historical decline of murrelets (57 FR 45328, October 1, 1992). Although loss of nesting habitat due to timber harvest has slowed considerably since the time of listing, these losses continue, with a net loss of 8,436.5 ha (20,847 acres; 1.38 percent) of murrelet nesting habitat across all ownerships within the NWFP area (Conservation Zones 1 through 5) between 1993 and 2017 (Lorenz et al. 2021, pp. 29-30). Timber harvest is the leading attributable cause of nesting habitat loss in each of Conservation Zones 1 through 4, and accounts for approximately 71 percent (63,065.1 ha; 155,837 acres) of gross nesting habitat loss across Conservation Zones 1 through 5, with the majority of losses occurring on nonfederal lands (Lorenz et al. 2021, pp. 33, 43-44). Most of the murrelet nesting habitat in Conservation Zone 6 is found in state parks or other public lands, where logging has not occurred (Halbert and Singer 2017, p. 1). Timber harvest has not been identified as a major contemporary threat or source of nesting habitat loss in Zone 6 (Halbert and Singer 2017, p. 30).

While there are no clear predictions for what magnitude of harvest is likely to occur across the listed range in the future, 96 percent of the nesting habitat loss attributed to timber harvest between 1993 and 2017 occurred on nonfederal lands (Lorenz et al. 2021, p. 33). Nonfederal lands are generally managed on a shorter rotation schedule than what is needed to develop nesting habitat (about 125 years) (Sutherland et al. 2016, p. 66), and there is no indication that these patterns of forest removal will not continue for the foreseeable future.

Wildfire

Wildfire can involve tree mortality, changes in canopy cover, and changes in nest platforms, all of which change the structure and availability of nesting habitat and can result in the direct mortality and reduced fitness of adults and nestlings during a fire event. Loss or modification of nesting habitat from fire can subsequently impact connectivity between nesting and foraging habitat.

Historically, the moist forests of western Washington have been characterized by large, stand-replacing fires occurring at intervals of 200 years or more (Long et al. 1998, p. 784; Halofsky et al. 2018, pp. 3-4; Haugo et al. 2019, pp. 2-3), while forests in southern Oregon and California have been characterized by low- and mixed-severity fires occurring every 35 years or less (Perry et al. 2011, p. 707; Haugo et al. 2019, pp. 2-3). In the past several decades, the duration of fire-weather season in the western U.S. has increased significantly, and the total burn area has more than doubled in size (Abatzoglou and Williams 2016, pp. 11,771-11,772), with the Pacific Northwest having the greatest percent increase in the number of wildfires and extent of area burned (Westerling 2016, p. 4; Davis et al. 2017, p. 176). Annual fire extent has increased over time and can be associated with drought conditions (Reilly et al. 2017, pp. 9-10).

Across all land ownerships within the NWFP area, wildfire accounted for approximately 2 percent (1,350.8 ha; 3,338 acres) of gross nesting habitat loss in Conservation Zones 1 through 5 between 1993 and 2017 (Lorenz et al. 2021, pp. 33, 43-44). While the most acres lost due to wildfire occurred in Washington (Conservation Zones 1 and 2), the highest proportion of murrelet habitat lost occurred in California (Conservation Zone 5). The threat of fire in Conservation Zone 5 is especially concerning given the small amount of murrelet habitat that remains.

Outside of the NWFP area, in Conservation Zone 6, the 2020 CZU Lightning Complex Fire burned approximately 35,008 ha (86,509 acres) (Cal Fire 2021, unpaginated; Singer, S., in litt. 2023). The burn perimeter for the CZU Lightning Complex Fire almost completely overlaps with murrelet favored nesting range in the Santa Cruz mountains and burned roughly 61 percent of acreage where murrelet occupancy had been detected in Conservation Zone 6 (Singer, S., in litt. 2023).

Predation

Predation affects murrelets via direct mortality, whether through nest predation in coastal forests or through adult and juvenile predation inland or at sea (Nelson and Hamer 1995, p. 93). Studies across the species' listed range indicate that nest predation is a limiting factor on murrelet populations (Nelson and Hamer 1995, p. 93; McShane et al. 2004, p. 2-16; Piatt et al. 2007, p. 22), and several studies have identified nest predation as the leading cause of nest failure for murrelets (Luginbuhl et al. 2001, p. 556; Peery et al. 2004, pp. 1093-1094; Golightly and Schneider 2011, p. 4). Some studies suggest that as much as 67, 78, or 81 percent of nest failures are due to predation (Luginbuhl et al. 2001, p. 556; McShane et al. 2004, p. 4-87; Peery et al. 2004, pp. 1093-1094). However, others have not found such evidence of predation in their study of nest failures (Lorenz et al. 2019, p. 160), revealing a degree of uncertainty associated with depredation studies. While the rates of nest failure due to predation are variable from study to

study, reported rates are generally higher in California than in Oregon and Washington (McShane et al. 2004, p. 4-87).

The rate of predation of artificial nests has been significantly correlated to corvid (i.e., crows, ravens, and jays) abundance, particularly near human settlements and campgrounds (Marzluff and Neatherlin 2006, p. 310; Hébert and Golightly 2007, p. 221; Malt and Lank 2009, p. 1274). Food subsidies at campgrounds have contributed to the abundance of Steller's jays (*Cyanocitta stelleri*) in campgrounds (Singer et al. 1991, p. 330; West et al. 2019, p. 6), and reducing these anthropogenic subsidies has been shown to reduce Steller's jay population densities in protected areas (Brunk et al. 2021, p. 6). Bird feeders and roadkill also subsidize corvid populations. Increased nest predation is also associated with proximity of nests to forest edges, which may be because corvids are generalist predators that can utilize these forest edge habitats and are present more frequently and at higher densities than in other portions of the landscape (Malt and Lank 2007, 165, 169; Hagar et al. 2024, pp. 4-5). Corvid management actions, such as visitor education, at some California State Parks have demonstrated that reducing anthropogenic subsidies can successfully reduce generalist predator populations at campgrounds (Brunk et al. 2021, p. 7), which may be ameliorating nest predation of murrelets near campgrounds, and could potentially continue to do so in the future.

Predation of juveniles and adults is also attributable to raptors. Of the tagged adult murrelet fatalities documented in one radio-tagging study, approximately half of the tagged murrelet fatalities were attributed to raptor predation, specifically bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons (*Falco peregrinus*) (Garcia-Heras et al. 2020, unpaginated). Given the recovery of avian predator populations, predation by raptors may represent a growing threat, relative to the time of listing.

Coastal and Nearshore Development

Coastal and nearshore development involves a suite of activities, including underwater detonation; pile-driving; heavy equipment use; vehicle, vessel, and air traffic; culvert and bridge repair; stormwater facilities; shoreline modifications; repair, maintenance, and installation of in-water or overwater structures; and dredging. These activities can produce elevated underwater and in-air sound levels, visual disturbance, and altered forage conditions for murrelets. Specific effects of exposure to these conditions include avoidance behaviors, flushing, diving, increased vigilance, aborted feeding attempts, physiological stress, auditory injury, and barotrauma (Yelverton et al. 1973, pp. 45-51; Yelverton et al. 1975, p. 17; Yelverton and Richmond 1981, p. S84; Korschgen et al. 1985, p. 290; Turnpenny and Nedwell 1994, pp. 29-30; 67 FR 48145, July 23, 2002; Schummer and Eddleman 2003, p. 789; Hastings and Popper 2005, pp. 25-40; Agness et al. 2008, p. 346; Halvorsen et al. 2012, pp. 604-607; Arlettaz et al. 2015, p. 1208; Kleist et al. 2018, pp. E650-E653).

Coastal and nearshore development can also result in degradation of foraging habitat through shading from overwater structures, disruption of natural shoreline processes, increased risk of exposure to contaminants, and, ultimately, reduced prey availability. Foraging activity of murrelets has been shown to have a linear relationship with prey availability (Ronconi and Burger 2008, p. 256), and decreased prey availability leads to increased energy expenditure by murrelets. When forage conditions are moderate to poor, murrelets may forgo breeding (Cairns

1987, p. 264; Furness 2007, p. 249; Cury et al. 2011, p. 1704; Garcia-Heras et al. 2024, pp. 9-12), and it has been demonstrated that murrelets have decreased reproductive success in years with low prey availability (Peery et al. 2004, p. 1094-1095; Becker et al. 2007, p. 276; Ronconi and Burger 2008, p. 252).

Development occurs throughout the listed range of the murrelet in all six Conservation Zones but poses the biggest threat to murrelets in Conservation Zones 1 through 4 and in areas with a dense human population such as Puget Sound or Monterey Bay. An evaluation of the relative influence of marine and terrestrial factors on the distribution and abundance of murrelets within the NWFP area found that marine-human footprint was the second-best predictor in Conservation Zone 1, likely reflecting the relative higher impact of development activities in this conservation zone (Raphael et al. 2016, p. 106; McIver et al. 2021, p. 29) and indicating that coastal and nearshore development occurs at a scope and magnitude sufficient to have a population-level effect. As the human population continues to grow and shipping traffic increases in the coastal areas, the foraging areas used by murrelets may become further restricted by coastal and nearshore development. Elevated sound levels associated with development vary in their intensity and duration, but human population growth can be used as a general surrogate for anthropogenic noise. In the past two decades, populations in Washington, Oregon, and California have all shown an increasing trend that we can expect to continue into the future (World Population Review 2023a, b, c, unpaginated), indicating that the threat of coastal and nearshore development will continue to impact murrelet populations into the future.

Climate Change

Climate change is a multi-dimensional threat that impacts both the terrestrial and marine environments occupied by murrelets. In the terrestrial habitat, atmospheric changes associated with climate change, primarily air temperature and changing precipitation patterns, impact the frequency and intensity of forest disturbances like drought, fires, and insects. Historically, forests within the listed range of the murrelet have not typically been water limited, especially in Washington and northern Oregon (McKenzie et al. 2001, p. 531; Nemani et al. 2003, p. 1560; Littell et al. 2010, p. 139). However, in recent decades, every part of the listed range has been affected by multi-year drought at some point from 1918 to 2014 (Crockett and Westerling 2018, p. 345). In 21st century, water deficits affecting forests are not expected to be uniform, with the California and southern Oregon Coast Ranges, Klamath region, eastern Olympic Peninsula, and parts of the Cascades and northern Oregon Coast Range projected to experience greater hydrological drought, and some portions of the Washington Cascades and Olympic Mountains projected to experience reductions in water deficit (McKenzie and Littell 2017, p. 31).

The effects of climate change are already being observed within the murrelet's listed range. In western Washington, Oregon, and southwestern British Columbia, tree mortality more than doubled from 1975 to 2005, likely due to increasing water stress (van Mantgem et al. 2009, pp. 522-523). Such mortality can be caused directly by warm dry conditions, or when dry conditions compound the effects of fire, insects, and tree disease. Increased drought conditions are associated with increased annual fire extent, and changes in the intensity and frequency of wildfire are related to climatic changes (Reilly et al. 2017, pp. 9-10). Similarly, higher average temperatures and warmer winters likely increase the severity and distribution of insects and

diseases like bark beetles and Swiss needle cast, which can result in tree mortality and changes in canopy cover (Littell et al. 2010, p. 146; Shaw et al. 2021, p. 417).

The primary changes to ocean conditions resulting from climate change include increasing sea surface temperatures; increasing frequency, severity, and duration of marine heatwaves; increasing ocean acidification; rising sea levels; and changes in primary productivity. These changes lead to altered forage conditions (i.e., prey availability, abundance, and quality) for murrelets. In the northeastern Pacific Ocean, capelin, Pacific sand lance, and rockfish (*Sebastes* spp.) abundance are all negatively correlated with seasonal sea surface temperatures (Thayer et al. 2008, p. 1616). The abundance and nutritional quality of forage fishes on the continental shelf, including capelin (*Mallotus catervarius*), sand lance, and Pacific herring, decreased during and after heatwaves that occurred between 2014 and 2016 (Arimitsu et al. 2021, p. 1859; Cushing et al. 2023, p. 23).

Changes in forage conditions can negatively impact reproductive success, fitness, and survival. Murrelets forego breeding when forage conditions are moderate to poor (Cairns 1987, p. 264; Furness 2007, p. 249; Cury et al. 2011, p. 1704; Garcia-Heras et al. 2024, pp. 9-12), and have decreased reproductive success in years with low prey availability (Peery et al. 2004, p. 1094-1095; Becker et al. 2007, p. 276; Ronconi and Burger 2008, p. 252). In other alcids, reproductive success and chick survival is higher when nestling diets consist of energy-dense, high-lipid content prey (Litzow et al. 2002, p. 292; Romano et al. 2006, p. 411), and food limitation during nesting can result in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Øyan and Anker-Nilssen 1996, p. 836). These changes in reproductive success and survival may be further exacerbated by the increased exposure and vulnerability of murrelets to harmful algal blooms and other diseases that are increasing due to climate change.

Climate-related changes in the terrestrial and marine environments are occurring throughout the listed range of the murrelet, and changes are expected to increase in intensity into the future. The effects of these changes impact individuals and populations through loss and modification of nesting habitat, changes to forage conditions, reduced fitness, and reduced nesting success. While the magnitude of these impacts into the future is relatively uncertain and the geographic scope is highly variable, climate change currently affects murrelets at a population level and is expected to continue to do so in the future.

Conservation Measures

Conservation measures exist for murrelets throughout their range. We focus on protections and conservation benefits provided by federal and state statute and regulation (Factor D) while recognizing that conservation benefits to the species may also arise from efforts taken outside of these statutory and regulatory frameworks.

There are several Federal provisions that provide protection for marbled murrelets. Among the most consequential is the NWFP. Protections include a system of congressionally reserved lands and late-successional reserves. These reserves were designed to protect most remaining old-growth forests and encompass a high proportion of murrelet nesting habitat on federal lands. The NWFP requires that, on federal lands within the murrelet range, occupancy surveys be conducted before forest management projects that would remove murrelet nesting habitat begin. If

occupancy surveys are positive, all contiguous existing and recruitment habitat within a 0.81-km (0.5-mile) radius becomes protected (USDA and USDI 1994a, pp. C-8-C-10). As of 2017, there were approximately 8.1 million ha (20 million acres) of lands capable of supporting forest within the NWFP area. However, only about 7 percent of those lands are currently considered nesting habitat (Lorenz et al. 2021, pp. 2-3, 25). The pattern of nesting habitat loss and accrual between 1993 and 2017 varies among conservation zones, with Zones 1, 2, and 5 experiencing an overall loss in nesting habitat, and Zones 3 and 4 experiencing an overall gain in nesting habitat (Table 3) (Lorenz et al. 2021, pp. 29-30). The majority of nesting habitat occurs on federal lands that have been designated reserves in the NWFP, as detailed in Table 4 (Lorenz et al. 2021, pp. 25, 39). Overall, the NWFP is an important mechanism for protecting and assessing the availability of nesting habitat.

Table 3. Net change in modeled nesting habitat from 1993 to 2017 by Conservation Zone (Lorenz et al. 2021, pp. 39-41)

Conservation Zone	Nesting habitat in 1993 (acres)	Nesting habitat in 2017 (acres)	Net change in habitat (acres [percent])
Zone 1	512,645	476,793	-35,851 [-6.99%]
Zone 2	487,372	459,186	-28,186 [-5.78%]
Zone 3	439,852	474,561	34,710 [7.89%]
Zone 4	71,100	79,611	8,511 [11.97%]
Zone 5	2,107	2,077	-31 [-1.49%]
Total	1,513,076	1,492,228	-20,847 [-1.38%]

Table 4. Acres of modeled nesting habitat within the NWFP area by conservation zone and landowner, in 2017 (Lorenz et al. 2021, pp. 25, 39)

Conservation Zone	Federal Reserved (acres)	Federal Non-reserved (acres)	State (acres)	Other Landowners (acres)	Total (acres)
Zone 1	332,707	31,958	50,544	61,584	476,793
Zone 2	369,685	7,683	44,256	37,562	459,186
Zone 3	254,302	35,814	80,235	104,210	474,561
Zone 4	30,167	2,920	20,588	25,936	79,611
Zone 5	484	11	511	1,071	2,077
Total	987,347	78,386	196,144	230,353	1,492,228

Murrelets also receive protections through the Bureau of Land Management (BLM) Resource Management Plans (RMPs). As a result of adoption of new RMPs in 2016, BLM lands in Oregon that were previously managed under the NWFP are now managed under the revised RMPs (BLM 2016a, entire; 2016b, entire). This change resulted in the addition of 12,946 ha (31,991 acres) of habitat designated as reserves, including an additional 7,298 ha (18,034 acres) of highly suitable habitat. In addition, for new murrelet sites recognized under the RMPs, occupied stand protection

and associated Late Successional Reserve mapping changed from only protecting contiguous habitat within 0.8 km (0.5 miles) of an occupied murrelet site to protecting all forest structure within 0.4 km (0.25 mi), with an additional 90 m (300 foot) buffer. The revised RMPs also include protection from disruption in stands known to be occupied by murrelets, which the NWFP did not.

After lands managed by USFS or BLM, most remaining federal lands within the listed range of murrelets are administered by the National Park Service (NPS). Unlike USFS and BLM administered lands, which were included in the NWFP management provisions, NPS administered lands were designated Congressionally Withdrawn Areas under the NWFP (FEMAT 1993, p. II-19). As such, they are not managed according to the NWFP, but are instead managed according to existing management plans and applicable federal law (USDA and USDI 1994b, pp. S-7). In contrast to USFS and BLM, whose mandates include resource extraction, the NPS is mandated to “to conserve the scenery and the natural and historic objects and the wild life [sic] therein” (NPS 2022, unpaginated). Consequently, murrelet habitat that occurs on NPS administered land is considered to be in conservation status. Nesting habitat that occurs on NPS lands are included in the total presented in Table 4.

Several state laws and regulations also offer protections for murrelets. The species is listed as endangered under state endangered species laws in Washington, Oregon, and California (WDFW 2022, p. 1; ODFW 2023, unpaginated; CNDDDB 2023, p. 21). These laws provide similar, but typically more limited, protections than the Federal Endangered Species Act. In addition, murrelet habitat that is not conserved via the NWFP or other federal protections receives at least some protection under state forest practice rules. These rules cover state- and privately-owned lands and apply to known, occupied habitats. Protections vary by state, but generally include buffering occupied sites and restricting harvest within these buffers and retaining vegetation in riparian corridors. Despite these protections, loss of nesting habitat due to timber harvest on state and private land continues. Between 1993 and 2017, approximately 150,000 acres of modeled nesting habitat on non-federal land was lost due to timber harvest, compared to approximately 6,000 acres on federal land (Lorenz et al. 2021, p. 33).

In addition to the murrelet-specific conservation measures discussed above, there are other federal and state laws that provide protections to species and their habitats (e.g., the Migratory Bird Treaty Act, the National Environmental Policy Act, the Clean Water Act). Although murrelets may not be named specifically in these laws, the protections they provide contribute to the overall conservation of murrelets. Many of these laws are described in more detail in Appendix B of the 2009 Marbled Murrelet 5-year review (Service 2009, entire).

There are a number of other conservation measures specific to marbled murrelets within the listed range. These include numerous Habitat Conservation Plans and Safe Harbor Agreements, primarily within Conservation Zones 1 and 2. These agreements, authorized under section 10 of the Act, are intended to provide long term certainty for both murrelet conservation and landowners. In addition, funding for conservation planning, land acquisition, and other conservation activities is available through the Cooperative Endangered Species Conservation Fund, authorized in section 6 of the Act, and the Natural Resource Damage Assessment and Restoration Program, which seeks to restore natural resources that are injured as a result of oil

spills or hazardous substances releases. Finally, within Conservation Zones 1 and 2, there are several Tribal conservation measures that have a federal nexus and for which we have records. Compared to other Federal and state protections described above, these programs have a more modest, but not insignificant impact on murrelet conservation. A more complete summary of these conservation measures is available in the SBR (Service 2024, pp. 38-48).

Summary

The CA, OR, WA DPS of marbled murrelet continues to face a number of threats. Loss and modification of habitat (Factor A) continues to act negatively on murrelets, primarily as a result of timber harvest and wildfire. Regulatory protections (Factor D) have improved since the time of listing, but continued loss of nesting habitat as a result of legally permitted timber harvest indicates that regulatory mechanisms are not sufficient to fully protect remaining habitat. Additional threats include predation (Factor C) and manmade factors (Factor E), including nearshore and coastal development and climate change that act through changes in nesting habitat and foraging conditions. Overutilization for commercial, recreational, scientific, or educational purposes (Factor B) is not a present threat to the species.

Recovery Criteria

Recovery Plan: U.S. Fish and Wildlife Service. 1997. Recovery Plan for the Threatened Marbled Murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. U.S. Fish and Wildlife Service, Region 1. Portland, Oregon. 203 pp.

The recovery plan includes two interim delisting criteria: (1) trends in estimated population size, densities and productivity have been stable or increasing in four of the six Conservation Zones over a 10-year period, which should encompass at least one to two El Niño events, and (2) management commitments, including protection and monitoring in marine and terrestrial habitats, have been implemented to provide adequate protection of marbled murrelets in the six Conservation Zones for at least the near future (50 years). These criteria have not been fully satisfied. Based on the available statistical analysis of trends, population size appears to be decreasing within two conservation zones, increasing within two conservation zones, and showing neither a positive nor negative trend in the remaining two conservation zones. However, because estimates of productivity remain very low throughout the listed range and do not appear adequate to sustain a demographically stable population, Criterion 1 has not been fully met. Research and monitoring of marbled murrelet populations has been ongoing, and implementation of landscape management plans has substantially reduced the loss of nesting habitat. Yet, while trends in nesting habitat vary across conservation zones, rangewide acreage has continued to decline slightly. It is unclear whether these actions are sufficient to ensure long-term protection of the species, given the current and anticipated future threats including climate-related changes in the marine and terrestrial environments; thus Criterion 2 has been only partially met.

Synthesis

Based on available abundance data, the murrelet population appears to be relatively stable at a range-wide scale. However, at the state and conservation zone scale, trends in abundance are variable, with some areas apparently increasing in abundance, and some areas apparently decreasing. The downward trend in abundance in the northern part of the range is of particular

concern, where declines of 58 percent in Conservation Zone 1 and 33 percent in Conservation Zone 2 have been observed since 2001.

The overall lack of recovery of murrelet populations within their listed range is attributable largely to the effects of low productivity. Murrelets have limited reproductive capacity since they lay a single egg per nesting attempt, nest only once per year, and do not reach sexual maturity until 2 to 4 years of age. Even if murrelets realized their full reproductive potential, the pace of recovery would be slow, about 3 percent per year (Service 1997, pp. 9-10). All indications are that murrelets are not achieving their reproductive potential within the listed range. Across the range, measures of nesting attempts, nesting success, and overall fecundity are well below what is required to maintain the stable population size, indicating that low productivity continues to limit recovery. Mortality of fledged juveniles, subadults, and adults also likely contributes to the overall failure of murrelet recovery following listing.

The ultimate drivers of murrelet status are complex and interactive. The current state of nesting habitat, as a function of both historical and contemporary losses due primarily to timber harvest and wildfire, continues to influence murrelet populations through reduction of reproduction and recruitment. In addition, marine factors that affect prey quality and quantity, including coastal and nearshore development and climate change, also likely influence populations, again linked to reproductive success. Long commutes between quality nesting and quality foraging areas may further contribute to low productivity, as they exacerbate energetic bottlenecks associated with nesting and rearing chicks. Finally, direct mortality, especially predation, also appears to be consequential driver of murrelet status within the listed range.

Our evaluation of viability indicates that population resiliency ranges from moderate to very low, but that murrelets within the listed range continue to have the ability to withstand catastrophic events (redundancy) and have some ability to adapt to changes in their physical and biological environments (representation).

Although available conservation measures do appear to be mitigating some threats in some parts of the listed range, the apparent lack of recovery indicates that they do not outweigh the cumulative effects of ongoing threats to murrelets throughout the entire listed range. Loss of nesting habitat, the primary threat identified at the time of listing, has not been fully abated, and additional threats have been identified. In addition, we anticipate that some existing threats will continue to grow in scope and magnitude. In particular, we expect that the effects of climate change and coastal and nearshore development will have increasingly negative effects of reproductive success, fitness, and survival, acting primarily through altered foraging and nesting habitat conditions. Given the existing low productivity rates and lack of population growth, we conclude that the species remains likely to become endangered in the foreseeable future and therefore continues to meet the definition of a threatened species.

Based on our evaluation of the current state of murrelet populations, habitats, and threats, we have determined that the murrelet should remain listed as threatened. As described above, the interim delisting criteria have not been met. While a number of recovery actions have been implemented and research and monitoring are ongoing, at the listed-range scale, demographic indicators are similar to the time of listing, indicating overall lack of recovery.

RESULTS

Recommended Classification:

- ☐ **Downlist to Threatened**
- ☐ **Uplist to Endangered**
 - ☐ **Delist** (*Indicate reasons for delisting per 50 CFR 424.11*):
 - ☐ *Extinction*
 - ☐ *Recovery*
 - ☐ *Original data for classification in error*
- ☒ **No change is needed**

New Recovery Priority Number: NA

Listing and Reclassification Priority Number: NA

RECOMMENDATIONS FOR FUTURE ACTIONS

- Revise the recovery plan (issued in 1997) to incorporate more recent information regarding threats and population status.
- Continue to monitor at-sea abundance and trends, range-wide.
- Continue to monitor terrestrial habitat abundance and trends, range-wide.
- Conduct habitat assessment and evaluate the demographic effects of habitat loss due to fire in Conservation Zone 6.
- Improve our understanding of marine threats, including climate change, and their effects on foraging habitat and associated impacts on diet quality and composition.
- Work with private nonindustrial timberland owners on strategies to retain and enhance murrelet terrestrial habitat, including developing Conservation Benefit Agreements (formerly Safe Harbor Agreements), as appropriate.
- Find opportunities for collaboration on projects that address the above questions and leverage funding sources and existing resources and expertise.

REFERENCES

- Abatzoglou, J.T., and A.P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. *PNAS* 113(42):11770-11775. <https://doi.org/10.1073/pnas.1607171113>
- Agness, A.M., J.F. Piatt, J.C. Ha, and G.R. VanBlaricom. 2008. Effects of vessel activity on the nearshore ecology of the Kittlitz's murrelet in Glacier Bay, Alaska. *The Auk* 125(2) preprint. 25p. <https://doi.org/10.1525/auk.2008.06203>
- Arlettaz, R., S. Nussle, M. Baltic, P. Vogel, R. Palme, S. Jenni-Eiermann, P. Patthey, and M. Genoud. 2015. Disturbance of wildlife by outdoor winter recreation: allostatic stress response and altered activity–energy budgets. *Ecological Applications* 25(5):1197-1212. <https://doi-org.fwslibrary.idm.oclc.org/10.1890/14-1141.1>
- BLM (Bureau of Land Management). 2016a. Record of Decision and Resource Management Plan for Northwestern and Coastal Oregon. Prepared by Oregon/Washington State Office, Bureau of Land Management. Portland, Oregon. 320 pp.
- BLM. 2016b. Record of Decision and Approved Resource Management Plan for Southwestern Oregon. Prepared by Oregon/Washington State Office, Bureau of Land Management. Portland, Oregon. 332 pp.
- Brunk, K., E.H. West, M.Z. Peery, and A.M. Pidgeon. 2021. Reducing anthropogenic subsidies curbs density of an important marbled murrelet nest predator in a protected area. Pages 7-8 In Book of Abstracts from the 2021 Pacific Seabird Group Annual Meeting, February 24-26 3, 2021 (virtual meeting). <https://doi.org/10.1016/j.biocon.2021.109081>
- Cal Fire (California Department of Forestry and Fire Protection). 2021. CZU lightning complex (including Warnella Fire) incident: California Department of Forestry and Fire Protection. Accessed May 10, 2023, at <https://www.fire.ca.gov/incidents/2020/8/16/czu-lightning-complex-including-warnella-fire>
- CNDDDB (California Natural Diversity Database). 2023. State and Federally listed endangered and threatened animals of California. California Department of Fish and Wildlife. Sacramento, CA.
- Davis, R., Z. Yang, A. Yost, C. Belongie, and W. Cohen. 2017. The normal fire environment modeling environmental suitability for large forest wildfires using past, present, and future climate normals. *Forest Ecology and Management* 390:173-186. <https://doi.org/10.1016/j.foreco.2017.01.027>
- Divoky, G.J., and M. Horton. 1995. Breeding and natal dispersal, nest habitat loss and implications for marbled murrelet populations. Pages 83-87 In C.J. Ralph, G.L. Hunt, M.G. Raphael, and J.F. Piatt, eds. *Ecology and conservation of the marbled murrelet*. General Technical Report. PSW-GTR-152, Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. <https://doi.org/10.2737/PSW-GTR-152>
- Felis, J.J., J. Adams, C.A. Horton, E.C. Kelsey, and L.M. White. 2022a. Abundance and productivity of marbled murrelets (*Brachyramphus marmoratus*) off central California during the 2022 breeding seasons: Summary provisional data report to Luckenbach Trustee Council and California State Parks, 10 pp.
- Felis, J.J., J. Adams, C.A. Horton, E.C. Kelsey, and L.M. White. 2022b. Abundance and productivity of marbled murrelets (*Brachyramphus marmoratus*) off central California during the 2020 and 2021 breeding seasons. U.S. Geological Survey Data Report 1157, 22 pp.
- FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. 1039 pp.
- Garcia-Heras, M.S., L.J. Adrean, M.J. Stuber, J. Dachenhaus, and J.W. Rivers. 2020. Bald Eagles and Seabirds: New evidence reveals predation events on Marbled Murrelets and other species in Oregon. Contribution poster presentation at the annual meeting of the Pacific Seabird Group and The Wildlife Society, Oregon, USA.
- Garcia-Heras, C. Wolf, J.A. Bailey Guerrero, L.J. Adrean, S.K. Nelson, D.D. Roby, M.G. Betts, J.W. Rivers. 2024. Marine habitat use and movement in response to ocean warming by a threatened forest-nesting seabird. *Global Ecology and Conservation* 50:e02857.
- Golightly, R.T., and S.R. Schneider. 2011. Years 9 and 10 of a long-term monitoring effort at a marbled murrelet nest in northern California. Unpublished report, Humboldt State University, Arcata, California. 26 pp. <https://scholarworks.calstate.edu/concern/publications/kh04ds310>
- Hagar, J.C., T. Owen, T.K. Stevens, and L.K. Waianuhe. 2024. Response of corvid nest predators to thinning: implications for balancing short- and long-term goals for restoration of forest habitat. *Avian Conservation and Ecology* 19(1):3.
- Halbert, P., and S.W. Singer. 2017. Marbled murrelet landscape management plan for zone 6. California Department of Parks and Recreation, Santa Cruz District, Felton, California. May 2017. 235 pp. https://www.parks.ca.gov/?page_id=29911

- Halofsky, J.S., D.C. Donato, J.F. Franklin, J.E. Halofsky, D.L. Peterson, and B.J. Harvey. 2018. The nature of the beast: examining climate adaptation options in forests with stand-replacing fire regimes. *Ecosphere* 9(3):e02140. <https://doi.org/10.1002/ecs2.2140>
- Halvorsen, M.B., D.G. Zeddies, W.T. Ellison, D.R. Chicoine, and A.N. Popper. 2012. Effects of midfrequency active sonar on hearing in fish. *Journal of Acoustical Society of America* 131(1):599607. <https://doi.org/10.1121/1.3664082>
- Hastings, M. C., and A. N. Popper. 2005. Effects of Sound on Fish. California Department of Transportation Contract No 43A0139, Task Order 1. January 28, 2005. 82 pp. Haugo, R.D., B.S. Kellogg, C.A. Cansler, C.A. Colden, K.B. Kemp, J.C. Robertson, K.L. Metlen, N.M. Vaillant, and C.M. Restrain. 2019. The missing fire: quantifying human exclusion of wildfire in Pacific Northwest forests, USA. *Ecosphere* 10(4):e02702. <https://doi.org/10.1002/ecs2.2702>
- Haugo, R.D., B.S. Kellogg, C.A. Cansler, C.A. Colden, K.B. Kemp, J.C. Robertson, K.L. Metlen, N.M. Vaillant, and C.M. Restaino. 2019. The missing fire: quantifying human exclusion of wildfire in Pacific Northwest forests, USA. *Ecosphere* 10(4):e02702. <https://doi.org/10.1002/ecs2.2702>
- Hébert, P.N. and R.T. Golightly. 2007. Observations of predation by corvids at a marbled murrelet nest. *Journal of Field Ornithology* 78(2):221-224. <https://doi.org/10.1111/j.1557-9263.2007.00105.x>
- Kleist, N.J., R.P. Guralnick, A. Cruz, C.A. Lowry, and C.D. Francis. 2018. Chronic anthropogenic noise disrupts glucocorticoid signaling and has multiple effects on fitness in an avian community. *Proceedings of the National Academy of Sciences* 115(4):E648-E657. <http://doi.org/10.1073/pnas.1709200115>
- Korschgen, C.E., L.S. George, and W.L. Green. 1985. Disturbance of diving ducks by boaters on a migrational staging area. *Wildlife Society Bulletin* 13(3):290-296. <https://www.jstor.org/stable/3782494>
- Loehle, C., J. Verschuyt, K.A. Solarik. 2022. Population trends and vital rates for marbled murrelet (*Brachyramphus marmoratus*) in the pacific northwest, USA. *Northwestern Naturalist* 103:20-29. <https://doi.org/10.1898/1051-1733-103.1.20>
- Long, C.J., C. Whitlock, P.J. Bartlein, and S.H. Millspaugh. 1998. A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study. *Canadian Journal of Forest Research* 28:774-787. <https://doi.org/10.1139/x98-051>
- Lorenz, T.J., M.G. Raphael, and T.D. Bloxton. 2019. Nesting behavior of marbled murrelets *Brachyramphus marmoratus* in Washington and British Columbia. *Marine Ornithology* 47(2):157-166. <https://www.fs.usda.gov/research/treesearch/58516>
- Lorenz, T.J., M.G. Raphael, R.D. Young, D. Lynch, S.K. Nelson, and B. McIver. 2021. Status and Trend of Nesting Habitat for the Marbled Murrelet Under the Northwest Forest Plan, 1993 to 2017. Gen. Tech. Rep. PNW-GTR-998. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p. <https://www.fs.usda.gov/research/treesearch/63314>
- Luginbuhl, J.M., J.M. Marzluff, J.E. Bradley, M.G. Raphael, and D.E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. *Journal of Field Ornithology* 72(4):556-572. <https://doi.org/10.1648/0273-8570-72.4.556>
- Malt, J.M., and D.N. Lank. 2007. Temporal dynamics of edge effects on nest predation risk for the marbled murrelet. *Biological Conservation* 124:160-173. <https://doi.org/10.1016/j.biocon.2007.08.011>
- Malt, J.M., and D.N. Lank. 2009. Marbled Murrelet nest predation risk in managed forest landscapes: dynamic fragmentation effects at multiple scales. *Ecological Applications*, 19:1274-1287. <https://doi.org/10.1890/08-0598.1>
- Marzluff, J.M., and E.A. Neatherlin. 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biological Conservation* 130:301-314. <https://doi.org/10.1016/j.biocon.2005.12.026>
- McIver, W.R., S.F. Pearson, C. Strong, M.M. Lance, J. Baldwin, D. Lynch, M.G. Raphael, R.D. Young, and N. Johnson. 2021. Status and trend of marbled murrelet populations in the Northwest Forest Plan area, 2000 to 2018. Gen. Tech. Rep. PNW-GTR-996. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, Oregon. 37 p.
- McIver, W.R., J. Baldwin, M.M. Lance, S.F. Pearson, C. Strong, M.G. Raphael, A. Duarte, and K. Fitzgerald. 2024. Marbled murrelet effectiveness monitoring, Northwest Forest Plan - 2022 summary report, Northwest Forest Plan Interagency Regional Monitoring Program. February 2024, final report. 25 p.
- McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the marbled murrelet in Washington, Oregon, and California. EDAW, Inc. Seattle, Washington. Prepared for the U.S. Fish and Wildlife Service, Region 1. Portland, Oregon. 370 pp.

- Nelson, S.K., and T.E. Hamer. 1995. Nesting biology and behavior of the marbled murrelet. Pages 57-67 In C.J. Ralph, G.L. Hunt, M.G. Raphael, and J.F. Piatt, eds. Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTR-152, Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. <https://doi.org/10.2737/PSW-GTR-152>
- Nelson, S.K. 1997. The birds of North America, No. 276 - marbled murrelet (*Brachyramphus marmoratus*). Pages 1-32 In A. Poole, and F. Gill, eds. The birds of North America: Life histories for the 21st century, The Academy of Natural Sciences & The American Ornithologists' Union, Philadelphia, PA; Washington, D.C.
- NPS (National Park Service). 2022. Quick history of the National Park Service. National Park Service. Accessed June 23, 2023 at: <https://www.nps.gov/articles/quick-nps-history.htm>
- ODFW (Oregon Department of Fish and Wildlife). 2023. Marbled murrelets in Oregon. https://www.dfw.state.or.us/wildlife/hot_topics/marbled_murrelet.asp. Accessed February 6, 2023.
- Peery, M.Z, S.R. Beissinger, S.H. Newman, E. Burkett, and T.D. Williams. 2004. Applying the declining population paradigm: diagnosing the causes of poor reproduction in the marbled murrelet. Conservation Biology 18(4):1088-1098. <https://doi.org/10.1111/j.1523-1739.2004.00134.x>
- Perry, D.A. 1995. Status of forest habitat of the marbled murrelet. Pages 381-83 In Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTR-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. <https://doi.org/10.2737/PSW-GTR-152>
- Perry, D.A., P.F. Hessburg, C.N. Skinner, T.A. Spies, S.L. Stephens, A.H. Taylor, J.F. Franklin, B. McComb, and G. Riegel. 2011. The ecology of mixed severity fire regimes in Washington, Oregon, and Northern California. Forest Ecology and Management 262:703-717. <https://doi.org/10.1016/j.foreco.2011.05.004>
- Piatt, J.F., K.J. Kuletz, A.E. Burger, S.A. Hatch, V.L. Friesen, T.P. Birt, M.L. Arimitsu, G.S. Drew, A.M.A. Harding, and K.S. Bixler. 2007. Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia: U.S. Geological Survey Open-File Report 2006-1387, 258 p. <http://pubs.water.usgs.gov/ofr20061387>
- Raphael, M.G., D. Evans Mack, J.M. Marzluff, and J. Luginbuhl. 2002. Effects of forest fragmentation on populations of the marbled murrelet. Studies in Avian Biology 25:221-235.
- Raphael, M.G., A.J. Shirk, G.A. Falxa, and S.F. Pearson. 2015. Habitat associations of marbled murrelets during the nesting season in nearshore waters along the Washington to California coast. Journal of Marine Systems. 146:17–25. <https://doi.org/10.1016/j.jmarsys.2014.06.010>
- Raphael, M.G., G.A. Falxa, and A.E. Burger. 2018. Chapter 5: Marbled Murrelet. Pages 301-370 In Spies, T.A., P.A. Stine, R. Gravenmier, J.W. Long, and M.J. Reilly, tech. coords. Synthesis of science to inform land management within the Northwest Forest Plan area. Gen. Tech. Rep. PNW-GTR-966. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon. <https://doi.org/10.2737/PNW-GTR-966>
- Reilly, M.J., C.J. Dunn, G.W. Meigs, T.A. Spies, R.E. Kennedy, J. Bailey, and K. Briggs. 2017. Contemporary patterns of fire extent and severity in forests of the Pacific Northwest, USA (1985–2010). Ecosphere 8(3):e01695. <https://doi.org/10.1002/ecs2.1695>
- Schummer, M.L., and W.R. Eddleman. 2003. Effects of disturbance on activity and energy budgets of migrating waterbirds in south-central Oklahoma. Journal of Wildlife Management 67(4): 789795. <https://doi.org/10.2307/3802686>
- Service (U.S. Fish and Wildlife Service). 1997. Recovery Plan for the threatened marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. U.S. Fish and Wildlife Service, Region 1. Portland, Oregon. 203 pp.
- Service. 2009. Marbled murrelet 5-year review. U.S. Fish and Wildlife Service, Region 1. Portland, Oregon. 85 pp.
- Service. 2016. U.S. Fish and Wildlife Service Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.4 dated August 2016. U.S. Fish and Wildlife Service. 21 pp.
- Service. 2019. Marbled murrelet (*Brachyramphus marmoratus*) 5-year status review. U.S. Fish and Wildlife Service, Region 1. Portland, Oregon. 118 p.
- Service. 2024. Draft Species Biological Report for Marbled Murrelet (*Brachyramphus marmoratus*). Lacey, Washington. iv + 88 pp.
- Singer, S.W., N.L. Naslund, S.A. Singer, and C.J. Ralph. 1991. Discovery and observations of two tree nests of the marbled murrelet. Condor 93:330339. <https://doi.org/10.2307/1368948>
- Singer, S. CZU Fire Update. Marbled Murrelet Technical Committee, February 14, 2023. Recording accessible at: <https://www.youtube.com/watch?v=eYjlkkgWBEI>.

- Sutherland, I.J., E.M. Bennet, and S.E. Gergel. 2016. Recovery trends for multiple ecosystem services reveal non-linear responses and long-term tradeoffs from temperate forest harvesting. *Forest Ecology and Management* 374:61-70. <https://doi.org/10.1016/j.foreco.2016.04.037>
- Turnpenny, A., and J. Nedwell. 1994. The effects on marine fish, diving mammals and birds of underwater sound generated by seismic surveys. Fawley Aquatic Research Laboratories Limited, Marine and Freshwater Biology Unit, Southampton, Hampshire, UK.
- USDA and USDI (U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management). 1994a. Standards and guidelines for management for habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Attachment A to the record of decision for amendments to Forest Service and Bureau of Land Management planning documents with the range of the northern spotted owl. Portland, Oregon. 173 p.
- USDA and USDI. 1994b. Final supplemental environmental impact statement on management of habitat for late-successional and old growth forest related species within the range of the northern spotted owl volume I. Portland, Oregon. 557 p.
- West, E.H., K. Brunk, and M.Z. Peery. 2019. When protected areas produce source populations of overabundant species. *Biological Conservation* 238, 9 pp. <https://doi.org/10.1016/j.biocon.2019.108220>
- Westerling, A.L. 2016. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. *Phil. Trans. R. Soc. B*, 371:20150178. <http://dx.doi.org/10.1098/rstb.2015.0178>
- WDFW (Washington Department of Fish and Wildlife). 2022. State listed species. Washing Department of Fish and Wildlife, Olympia, Washington.
- World Population Review. 2023a. California Population 2023. < <https://worldpopulationreview.com/states/california-population>> (Accessed May 18, 2023).
- World Population Review. 2023b. Oregon Population 2023. < <https://worldpopulationreview.com/states/oregon-population>> (Accessed May 18, 2023).
- World Population Review. 2023c. Washington Population 2023. < <https://worldpopulationreview.com/states/washington-population>> (Accessed May 18, 2023).
- Yelverton, J.T., D.R. Richmond, R.E. Fletcher, and R.K. Jones. 1973. Safe distance from underwater explosions for mammals and birds. Lovelace Foundation for Medical Education and Research, Albuquerque, NM. 67 pp.
- Yelverton, J.T., D.R. Richmond, W. Hicks, K. Saunders, and R.E. Fletcher. 1975. The relationship between fish size and their response to underwater blast. Lovelace Foundation for Medical Education and Research, Albuquerque, NM. 42 pp.
- Yelverton, J.T., and D.R. Richmond. 1981. Underwater explosion damage risk criteria for fish, birds, and mammals. Proceedings of the 102nd Meeting of the Acoustical Society of America, editor 102nd Meeting of the Acoustical Society of America, Miami Beach, Florida. <https://doi.org/10.1121/1.2019076>

**U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW OF MARBLED MURRELET (CA, OR, WA DPS)**

Current Classification: Threatened

Recommendation resulting from the 5-Year Review:

- ☐ Downlist to Threatened
- ☐ Uplist to Endangered
- ☐ Delist (*Indicate reasons for delisting per 50 CFR 424.11*):
 - ☐ Extinction
 - ☐ Recovery
 - ☐ Original data for classification in error
- ☒ No change is needed

Appropriate Listing/Reclassification Priority Number, if applicable: NA

FIELD OFFICE APPROVAL:

BRADLEY
THOMPSON

Digitally signed by BRADLEY
THOMPSON
Date: 2024.08.05 11:47:37 -07'00'

Field Supervisor, Washington Fish and Wildlife Office

REGIONAL OFFICE APPROVAL:



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NORMAN
Date: 2024.08.05 12:16:41 -07'00'

Assistant Regional Director, Ecological Services
Pacific Regional Office

Influence of food subsidies on the foraging ecology of a synanthropic species in protected areas

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Abstract. The expansion of many synanthropic species is linked to changes in the abundance and distribution of human-derived foods, and understanding how food subsidies influence the foraging ecology of synanthropes can facilitate reducing impacts to rare species. We combined stable isotope analyses and radiotelemetry information to characterize space-use and dietary patterns in Steller's jays (*Cyanocitta stelleri*), a known nest predator of marbled murrelets, sampled at both campground and forest sites in California state parks. We classified jays into four groups based on patterns of space use: (1) campground (jays captured in campgrounds that predominantly used these areas), (2) periphery (jays captured in campgrounds that commonly used adjacent forests), (3) intermediate (jays captured at forest sites that made long-distance movements between forests and campgrounds), and (4) forest (jays captured and only detected in forests). In the most heavily visited park, human foods comprised more than half of the diet of campground jays based on stable isotopes; moreover, campground jays consumed a greater proportion of human foods than periphery or intermediate jays, which both consumed more human foods than forest jays. Campground jays exhibited a functional response to human foods as park visitation increased, and breeding individuals preferentially provisioned their young with human-derived foods. Based on space-use patterns of intermediate jays, we estimated that the “ecological footprint” of campgrounds extended 2 km beyond their spatial footprint. Thus, the impacts of seemingly spatially constrained human recreational activities can have spillover effects on animal communities at relatively broad spatial scales within protected areas.

Key words: food subsidies; foraging ecology; home range; marbled murrelet; protected areas; Steller's jay; synanthropic species.

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INTRODUCTION

Human activities are now considered to be the predominant drivers of global change (Ellis et al. 2010) and consequently have widespread and often negative impacts on ecosystems (Vitousek et al. 1997, Kareiva et al. 2007). In addition to direct impacts through habitat loss and fragmentation, ecosystems are altered indirectly by the widespread availability of food subsidies to wildlife that result from human activities.

There is growing evidence that human-derived food subsidies to wildlife have individual- and population-level impacts, with subsequent shifts in community structure and trophic cascades (Newsome et al. 2014). Certain species, referred to collectively as synanthropes (Johnston 2001), benefit from associations with human activities (Hansen et al. 2005), and have increased in abundance as a result of the availability of predictable human foods (Kristan and Boarman 2003, Withey and Marzluff 2008, Webb et al. 2011, Newsome

et al. 2014). In turn, elevated populations of synanthropes threaten a number of less abundant species through predation, competition, and hybridization (Simberloff and Stiling 1996, Jerzak 2001, Vigallon and Marzluff 2005, Marzluff and Neatherlin 2006). Impacts to sensitive species can extend beyond human-dominated areas, as “spillover predation” can occur when synanthropes move into less altered landscapes and prey on sensitive species (Marzluff et al. 1994, Rand and Louda 2006). As a result, the conservation benefit of protected areas can diminish as human activity increases within and around these areas (Radeloff et al. 2012, Wood et al. 2014). Consequently, understanding how individuals respond to spatial and temporal patterns in the availability of food subsidies can inform the conservation of sensitive species occurring in protected areas.

One particularly challenging synanthropic species problem involves nearly global increases in the abundance and distribution of species in the family Corvidae (ravens, crows, magpies, and jays) which have occurred in response to urbanization and human-induced changes in food resources. Corvids threaten a number of sensitive native species through predation on nests and juveniles (Masselink 2001, Webb et al. 2011) and are particularly difficult to manage because they are widely and abundantly distributed (Boarman 2003) and can learn to avoid control measures (Cornell et al. 2011, Peterson and Colwell 2014). While several landscape-scale studies have investigated the effects of human-derived food subsidies on corvid abundance and distribution in urban areas and along urban-rural gradients (Vigallon and Marzluff 2005, Marzluff and Neatherlin 2006, Marzluff et al. 2007, Withey and Marzluff 2008), relatively little research has focused on the response of corvid populations to human-derived food resources inside protected areas (Scarpignato and George 2013, Walker and Marzluff 2015). In addition, most research to date has addressed population-level effects of human-derived resource subsidies on synanthropic species, while relatively few studies have investigated how changes in food subsidies alter aspects of individual behavior such as foraging patterns and space use (Boutin 1990, Schoech and Bowman 2001, Scarpignato and George 2013).

Here, we sought to understand how point sources of human foods within protected areas influenced the foraging ecology of Steller’s jays (*Cyanocitta stelleri*) by combining stable isotope-based diet assessments with fine-scale information on space use. Steller’s jays have increased in abundance in western North America over the past several decades, presumably because of the expansion of human activities and associated food resources within their coniferous forest habitat (Peery and Henry 2010, Sauer et al. 2014, Wood et al. 2014). Within parks, Steller’s jay densities are particularly high around point sources of human foods such as campgrounds. Steller’s jays are considered to be important nest predators of marbled murrelets (*Brachyramphus marmoratus*), a threatened seabird that often nests in remnant stands of old-growth forests occurring in state and federal parks. Indeed, corvid predation, including predation by jays, contributes to low murrelet reproductive rates in these areas, likely because park campgrounds with high jay densities often occur within key murrelet nesting areas (Peery et al. 2004, Peery and Henry 2010). A range of management actions have been implemented in parks to reduce the impact of Steller’s jays on marbled murrelets (Peery and Henry 2010, Gabriel and Golightly 2014), but all are hindered by a dearth of information about jay ecology and the patterns and processes by which human foods subsidize jays. Thus, our specific objectives were to (1) compare the diet of individual jays using subsidized (campgrounds) and unsubsidized (forests) habitats, (2) determine whether the consumption of human foods varies by age and sex and in response to park visitation, (3) relate jay space use to the consumption of human foods, and (4) determine the spatial scale at which human foods in campgrounds subsidize jays. For the fourth objective, we estimated how far jays typically traveled between forest and campground habitats to consume human foods, our logic being that such movements could potentially benefit jay populations at spatial scales that exceed campground footprints.

MATERIALS AND METHODS

Study areas

Our study was conducted in four parks in California containing remnant old-growth forest

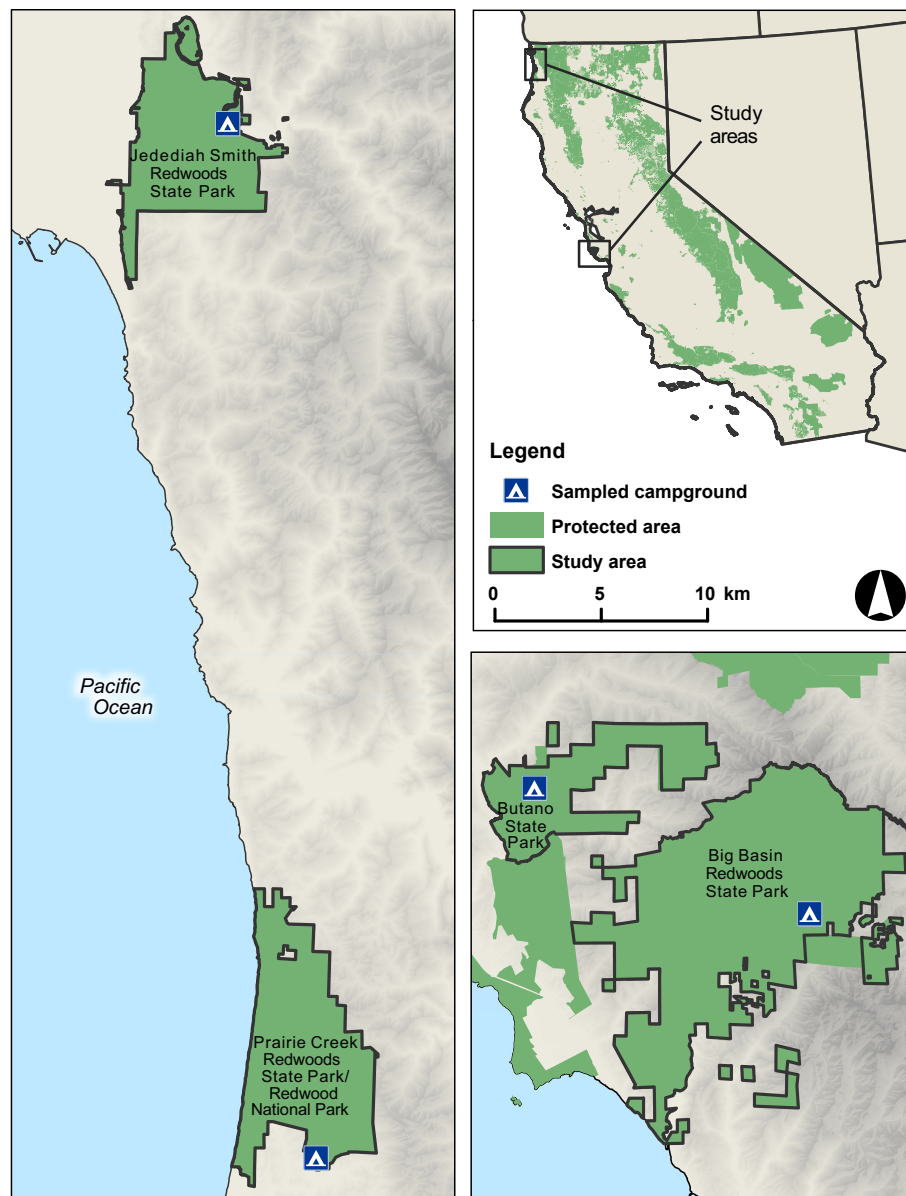


Fig. 1. Location of four protected areas in California where Steller's jays were sampled for isotopic analyses (all parks) and radio-marked (Big Basin Redwoods State Park only).

nesting habitat for marbled murrelets: Big Basin Redwoods State Park, Butano State Park, Jedediah Smith Redwoods State Park, and Prairie Creek Redwoods State Park (Fig. 1). Paired sampling was conducted at campground and non-campground (forest) sites in each park. Forest sites were selected based on accessibility, the presence of territory-holding jays, and were located 1 to 2 km from campgrounds, as previous studies suggest that Steller's jays do not travel

more than 1 km to access human food (Marzluff and Neatherlin 2006). Stable isotope assessments of jay diets were conducted for all four parks, whereas radiotelemetry work was limited to jays sampled in Big Basin.

Captures and sampling

Steller's jays were captured during the breeding season (April to August) using live traps (model 1045; Havahart, Lititz, Pennsylvania,

USA) and mist nets (Avinet, Dryden, New York, USA). Sampling was conducted from 2011 to 2013 in the two central California parks (Big Basin and Butano) and from 2010 to 2011 in the two northern California parks (Jedediah Smith and Prairie Creek). We broadcasted jay vocalizations (Vigallon and Marzluff 2005) and placed shelled peanuts near mist nets to attract jays (peanuts were glued to plates to prevent jays from consuming bait and affecting isotope-based diet estimates). After-hatch-year jays (hereafter, AHY) were distinguished from hatch-year jays (hereafter, HY) based on gape coloration, plumage pattern, the shape of rectrices, and the level of covert contrast (Pyle et al. 1987). We define AHY jays as those known to have hatched before the calendar year of banding and HY jays as those known to have hatched during the calendar year of banding. The sex of all individuals was determined through observations of sex-specific vocalizations, tail length measurements (Pyle et al. 1987) and later confirmed using polymerase chain reaction methods of extracted DNA from blood samples (Griffiths et al. 1998). Blood samples used for molecular sexing and stable isotope analysis were collected by puncture of the brachial vein using a sterile 26-gauge needle and transferred into capillary tubes (150 μ L).

Stable isotope analysis

We used red blood cells (hereafter, blood) to characterize the level of human-derived foods consumed by jays as they reflect diet items incorporated up to approximately 40 d prior to sampling (Hobson and Clark 1992, Bearhop et al. 2002). Stable isotopes are a useful tool for reconstructing consumer diets (Hobson and Clark 1992, Caut et al. 2008, Ben-David and Flaherty 2012) as the isotopic ratios of nitrogen ($^{15}\text{N}/^{14}\text{N}$, noted $\delta^{15}\text{N}$) and carbon ($^{13}\text{C}/^{12}\text{C}$, noted $\delta^{13}\text{C}$) in consumer tissues predictably reflect those in their diets (DeNiro and Epstein 1978). Human foods are often derived from or processed using corn and cane sugar, which are enriched in $\delta^{13}\text{C}$ (Jahren et al. 2006). This $\delta^{13}\text{C}$ signal is traceable in the wildlife that consume human-derived foods (Newsome et al. 2010) and is thus useful for determining Steller's jays' reliance on human food subsidies.

Blood samples collected for stable isotope analyses were centrifuged to separate red blood

cells from sera and were frozen at -20°C until dried for analysis. We sampled jay diet sources (invertebrates, berries, acorns, conifer seeds, and human-derived foods) at capture sites in each park (northern California: 2011, Butano park: 2012 and 2013, and Big Basin: 2011–2013) to estimate the proportional contribution of isotopically distinct items to jay diets (listed in Appendix S1). Potential diet sources were sampled at jay capture sites approximately once every 2 weeks throughout each field season to account for temporal variation in the isotopic signatures of diet items. We also collected representative human food samples at campgrounds when we observed jays foraging in unattended campsites and when we observed campers providing food directly to jays. All invertebrate samples were classified to order. We did not include marbled murrelets eggs or nestlings as a potential dietary source in stable isotope analyses of Steller's jay diet as only a very small fraction of jays were likely to have consumed murrelet eggs given the much greater abundance of jays than murrelet nests in our sampling areas (see Appendix S2). In addition, mixing models tend to attribute some proportion of all dietary sources considered to a consumer's diet, even rare or nonexistent ones, in this case potentially overestimating the importance of murrelets in jay diets and thus underestimating more frequently consumed food sources (Parnell et al. 2008, Phillips et al. 2014).

Blood samples were dried for 48 h at 56°C and homogenized with a spatula. Diet samples were dried for 72 h at 56°C and homogenized in a ball mill. For ^{13}C and ^{15}N analysis, samples were weighed, placed in tin capsules, and were sent to the Stable Isotope Facility at the University of Wyoming to be analyzed with a Costech 4010 elemental analyzer attached to a Thermo Finigan Delta Plus XP Continuous Flow Isotope Ratio Mass Spectrometer. Results are provided as per mil (parts per thousand [‰]) ratios relative to the international standards of Pee Dee Belemnite (PDB; $\delta^{13}\text{C}$) and atmospheric nitrogen (AIR; $\delta^{15}\text{N}$) with calibrated internal laboratory standards.

Statistical analysis of stable isotope data

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for diet groups did not differ significantly among years within any of the four sampled parks based on ANOVA (all

P -values >0.05), and consequently diet groups from each year were combined for each park. Human-derived foods were indistinguishable isotopically among the four parks. Invertebrates and mast differed among Big Basin Redwoods State Park, Butano State Park, and the two combined northern California parks, but were indistinguishable between Jedediah Smith Redwoods State Park and Prairie Creek Redwoods State Park. Thus, K nearest neighbor randomization tests and mixing models were conducted by pooling data for northern California sites, but the two central California parks were treated separately.

We estimated the proportional contribution of isotopically distinct diet groups to jay diets using a Bayesian stable isotope mixing model, Stable Isotope Analysis in R (SIAR) 4.2 (Parnell et al. 2008) within R 3.1.0 (R Development Core Team 2014). SIAR models were conducted separately for each park in central California, but jay samples from the two northern California parks were combined due to small sample sizes. Initially, we ran SIAR models considering three biologically distinct groups: human-derived foods, mast (fruit from trees and shrubs, including acorns, pine seeds, and berries), and invertebrates ($P < 0.05$ for all groups based on K randomization tests; Rosing et al. 1998; Fig. 2; Appendix S1). Given the variability in $\delta^{15}\text{N}$ values across our invertebrate samples and to test the robustness of results from our mixing models, we also estimated jay diets with SIAR models using finer diet groupings. Specifically, K randomization tests revealed five isotopically distinct groups within each park ($P < 0.05$ for all groups): three invertebrate groups (group 1: Araneae, Coleoptera, and Hemiptera; group 2: nonpredatory Diptera and Hymenoptera; group 3: predatory Diptera and Hymenoptera), human-derived foods, and a fifth group that included mast and invertebrates in the orders Lepidoptera and Orthoptera. Mast and Lepidoptera/Orthoptera diet sources were not grouped in the second set of SIAR models—and thus treated as a fifth and sixth group—as they represent biologically relevant diet sources and because the elemental concentration of these diet sources varies significantly. Models were parameterized with uniform priors using default values for MCMC estimation (chain length = 2×10^5 , burning = 5×10^4 , thinning = 15); consequently, the

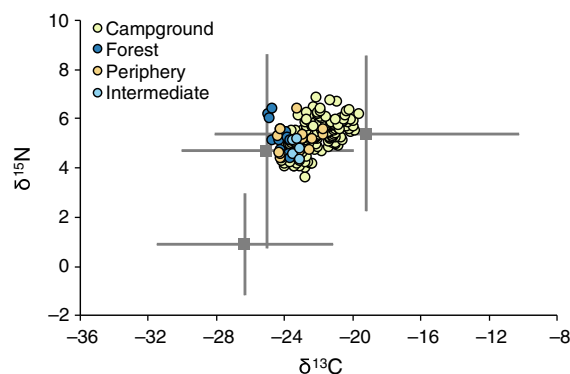


Fig. 2. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope ratios of individual Steller's jays based on blood samples (circles) and their potential diet sources used in Stable Isotope Analysis in R diet calculations, sampled during the breeding season in Big Basin Redwoods State Park, 2011–2013 ($n = 197$). Diet sources show mean with error bars depicting the standard deviation. Diet sources were adjusted using a discrimination factor of 1.5 ± 0.12 and 1.8 ± 0.66 for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, respectively.

distributions of source contributions are based on 10^5 estimations and are presented as Bayesian 95% credible intervals, which represent each prey group's likely proportional contribution to Steller's jay diet (Parnell et al. 2010). The median values of proportional diet estimates were considered the most likely level of contribution to the diet, recognizing that solutions can occur anywhere within the credible interval (Jackson et al. 2009, Parnell et al. 2010). In addition to requiring isotope estimates for consumers and potential diet items, SIAR models require estimates of elemental concentration (wt% C, wt% N) and trophic discrimination (which is the isotopic difference between source and consumer as food is incorporated into the tissues). We used the following isotopic discrimination factors provided in the literature based on an experimental study that estimated discrimination factors for a passerine diet similar to that of wild Steller's jays: $+1.8\text{‰}$ (SD = 0.66) for $\delta^{15}\text{N}$, and $+1.5\text{‰}$ (SD = 0.12) for $\delta^{13}\text{C}$ (Pearson et al. 2003). We used the average measured elemental concentrations for each diet group (Appendix S1).

To characterize factors influencing patterns in the consumption of human-derived foods, we used raw isotope values from blood as a proxy for jay diet, with increased enrichment of

$\delta^{13}\text{C}$ indicating greater consumption of human-derived foods (Phillips et al. 2005, Newsome et al. 2010). We used an analysis of covariance (ANCOVA) framework where $\delta^{13}\text{C}$ was the response variable and Julian date of each sample (20 d prior to sampling date; our estimate of the half-life of blood turnover for Steller's jays) was used as a continuous predictor variable, while year, park, sex, and age class were used as categorical predictor variables. To understand the relationship between the consumption of human-derived foods and changes in human visitation (a proxy for availability of human-derived foods), we conducted a linear regression with $\delta^{13}\text{C}$ derived from blood and mean number of occupied campsites as our response and predictor variables, respectively. Here, we used the number of occupied campsites as an index of human presence, which we estimated by averaging the number of occupied campsites between 17 and 23 d prior to each blood sampling date (using 20 d prior to each sampling date as the median). We estimated the half-life of stable isotopes (blood turnover) in Steller's jay blood (20 d) using known half-life data for red blood cells in American crows (*Corvus brachyrhynchos*), which is approximately 30 d (Hobson and Clark 1992) and the allometric scaling relationship between time and body mass, $M^{1/4}$, where M is mass (West et al. 1997). This analysis of associations between $\delta^{13}\text{C}$ and human visitation was restricted to Big Basin due to smaller sample sizes and a limited range in the number of occupied campgrounds at the other parks.

Radiotelemetry

To characterize individual space use, we fitted a subsample of jays captured in Big Basin in 2011, 2012, and 2013 with backpack-mounted radio-transmitters (model A1050; Advanced Telemetry Systems, Isanti, Minnesota, USA; Buehler et al. 1995). Transmitters had an expected lifespan of 12 weeks and were affixed using 2.5-mm Teflon ribbon (Rappole and Tipton 1991). We tracked jays from 1 May to 15 August, a period that largely coincides with known Steller's jay nest initiation dates in coastal California (Brown 1964). We used a handheld telemetry receiver (model R410; Advanced Telemetry Systems) to relocate focal individuals through daily ground-based telemetry surveys, which were conducted

between 07:00 and 19:00 h by walking trails and driving roads in search of signals emanating from radio-marked individuals, allowing at least 2 h between location determinations taken on the same day (Swihart and Slade 1985). When a signal was heard, we used homing techniques (White and Garrott 2012) and triangulation to locate the individual's location (recorded using GPS units; Garmin 72h, Garmin, Olathe, Kansas, USA). We also opportunistically collected nocturnal roost locations (21:00–04:00 h) for each individual and included these locations in estimates of home range size.

We estimated jay core area and home range size as the area (ha) within 50% and 95% probability contours of fixed kernel density estimates, respectively (Seaman et al. 1999, Kernohan et al. 2001). We used least squares cross-validation for bandwidth (i.e., smoothing parameter) estimation (Silverman 1986, Gitzen et al. 2006) in the Geospatial Modeling Environment for ArcGIS (Beyer 2012). To characterize the use of campgrounds by radio-marked jays in Big Basin, we constructed a geospatial layer representing campground (by walking campground boundaries with a handheld GPS) and noncampground (all remaining forested land cover) areas with ArcInfo GIS software (ESRI 2014) and estimated the proportion of each individual's home range that overlapped campground areas.

We combined stable isotope analyses of blood sampled from radio-marked jays with core and home range data from each individual to relate jay space use and foraging behavior. We determined whether the size of individual jay's home range was correlated with $\delta^{13}\text{C}$ enrichment (i.e., the consumption of human-derived foods) using partial correlation analysis to control for the effect of Julian date. Our expectation was that home range size and $\delta^{13}\text{C}$ enrichment would be negatively related given that space use often contracts with increasing food availability, including in synanthropic species (Boutin 1990, Shochat et al. 2004). We also tested whether the proportion of each jay's home range that overlapped campgrounds was correlated with $\delta^{13}\text{C}$ in the diet, again using partial correlation while controlling for Julian date. Analyses were conducted separately for males and females because of differences in home range size between sexes.

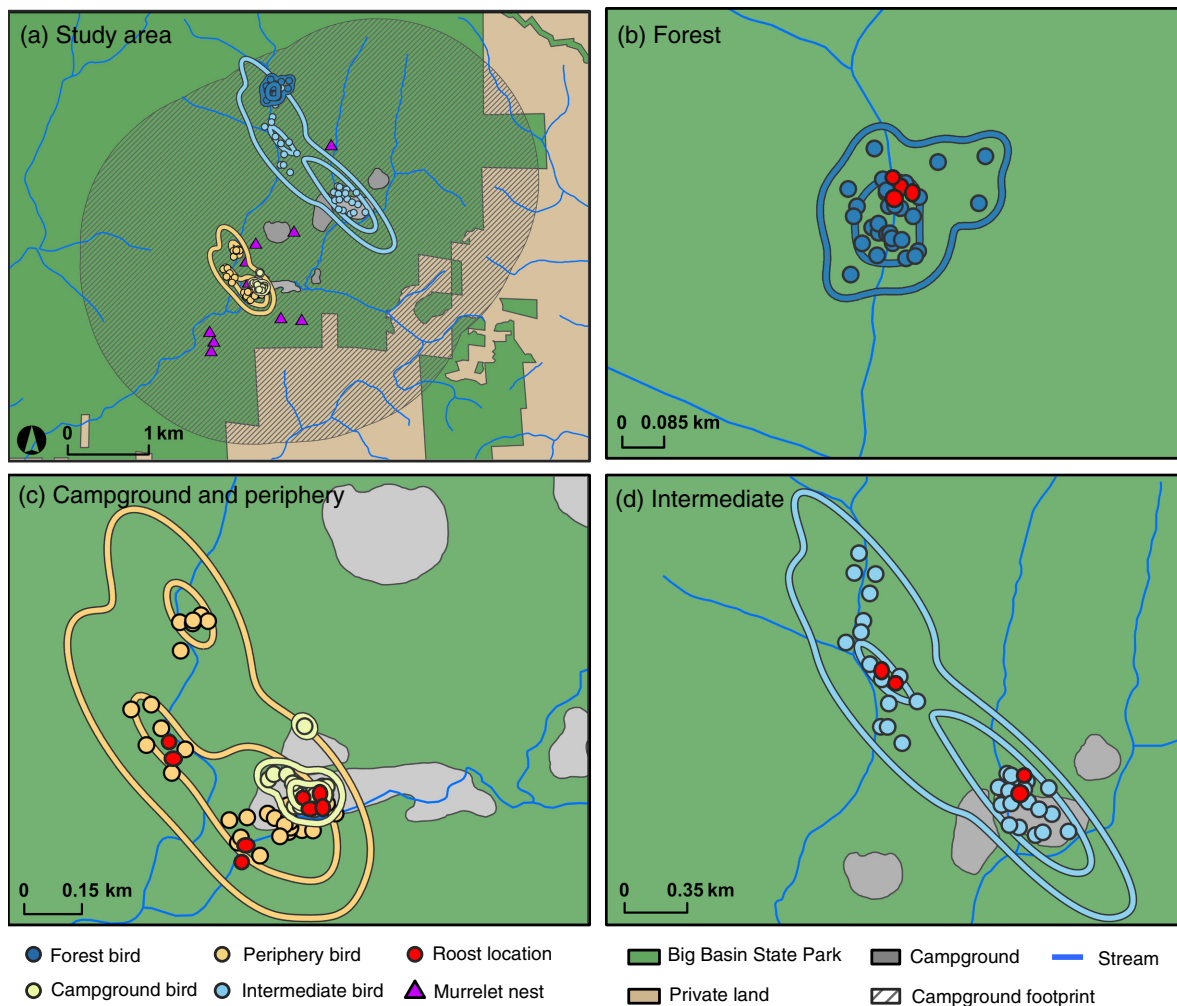


Fig. 3. Representative core areas and home ranges (50% and 95% utilization distributions, respectively) for male forest, campground, periphery, and intermediate Steller's jays radio-marked in Big Basin Redwoods State Park in 2011. Also shown in (a) is the estimated 2-km "ecological footprint" of campgrounds and its overlap with 11 of the 17 known marbled murrelet nests in central California.

RESULTS

Patterns of Steller's jay space use

We radio-marked a total of 62 Steller's jays in Big Basin, 50 in campgrounds and 12 at forest sites (campground: $n = 38$ males and $n = 12$ females; forest: $n = 8$ males and $n = 4$ females). We obtained an average of 34.9 locations per individual (range: 31–40) and tracked individuals for an average of 87 d (range: 62–124 d). We identified four general patterns of space use by radio-marked jays: (1) individuals captured in campgrounds with at least 50% of their core areas

inside campgrounds ("campground jays"; $n = 35$), (2) individuals captured in campgrounds with less than 50% of their core areas inside campgrounds that made extensive use of adjacent surrounding forests ("periphery jays"; $n = 15$), (3) individuals captured in forests that made exclusive use of forests and never visited campgrounds ("forest jays"; $n = 7$), and (4) individuals captured in forests that used both campgrounds and forests ("intermediate jays"; $n = 5$; Fig. 3). Campground jays were regularly detected within campground boundaries as 68% of diurnal locations ($n = 718/1057$) and 86% of nighttime

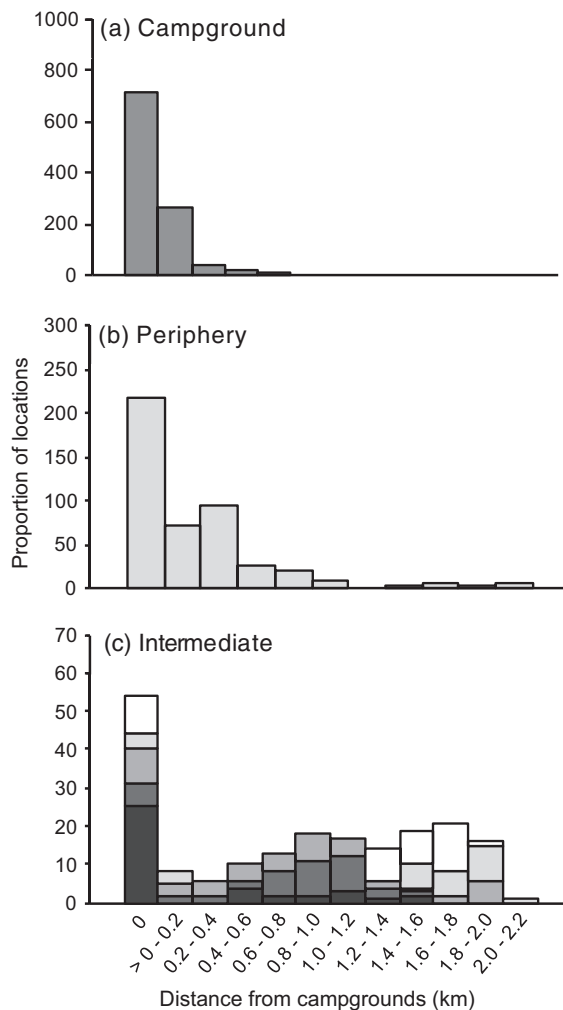


Fig. 4. Frequency distribution of distances that (a) campground, (b) periphery, and (c) intermediate Steller's jays were detected from campgrounds in Big Basin Redwoods State Park during the breeding season (April–August), 2011–2013. The different shades of gray represent individual intermediate jays. Only one shade was used to represent campground and periphery jays because of the relatively large numbers of individuals sampled.

roosting locations ($n = 120/140$) occurred within campground boundaries (Fig. 4a). Periphery jays were detected less frequently in campgrounds with 47% of diurnal ($n = 217/462$) and 30% of roosting ($n = 18/60$) locations occurring within campground boundaries (Fig. 4b). Intermediate jays were detected within campground boundaries less frequently than the other two groups

with 27% of diurnal locations ($n = 54/197$) and 10% of roosting locations ($n = 2/20$) occurring within campground boundaries (Fig. 4c). The frequency distribution of distances from campgrounds was relatively uniform for intermediate jays from 0.4 to 2.0 km and approximately 8% of their locations occurred 1.8 to 2.0 km from campgrounds (Fig. 4c).

Patterns in Steller's jay diet inferred from stable isotopes

We analyzed 295 individual Steller's jay blood samples for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotope ratios (Jedediah Smith: $n = 20$; Prairie Creek: $n = 25$; Big Basin: $n = 197$; Butano: $n = 53$). Both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope signatures of Steller's jay blood samples fell within the mixing space of the three diet groups considered (Fig. 2). $\delta^{13}\text{C}$ signatures were much greater for human-derived foods than mast and invertebrates, and jays enriched in $\delta^{13}\text{C}$ could thus reasonably be assumed to consume a greater proportion of human foods.

Human-derived foods made up a significant proportion of the diet of Steller's jays using campgrounds, and campground jays consumed more human-derived foods than forest jays based on three-source SIAR models (Fig. 5). Indeed, human foods constituted from 35% (95% CI: 28–42%; Butano) to 53% (95% CI: 48–57%; Big Basin) of the diet of campground jays, but only 14% (95% CI: 10–46%; northern parks) to 25% (95% CI: 13–36%; Big Basin) of the diet of forest jays. SIAR models also suggested that both intermediate and periphery jays consumed more human foods than forest jays in Big Basin and that intermediate jays consumed more human foods than forest jays in the northern parks (Fig. 5). Intermediate jays were identified in northern parks based on space-use data in Goldenberg et al. (2016). Mast generally represented a larger proportion of the “natural” dietary component in all four groups of jays, with invertebrates making up a smaller portion of jay diets (Fig. 5). Note that the apparent difference in the relative importance of mast and invertebrates between SIAR models (Fig. 5) and the bivariate isotopic plot (Fig. 2) was likely due to greater nitrogen concentration in invertebrates that led to similar estimates of $\delta^{15}\text{N}$ in jays and invertebrates (Fig. 2), despite the greater importance of mast as a diet source (elemental

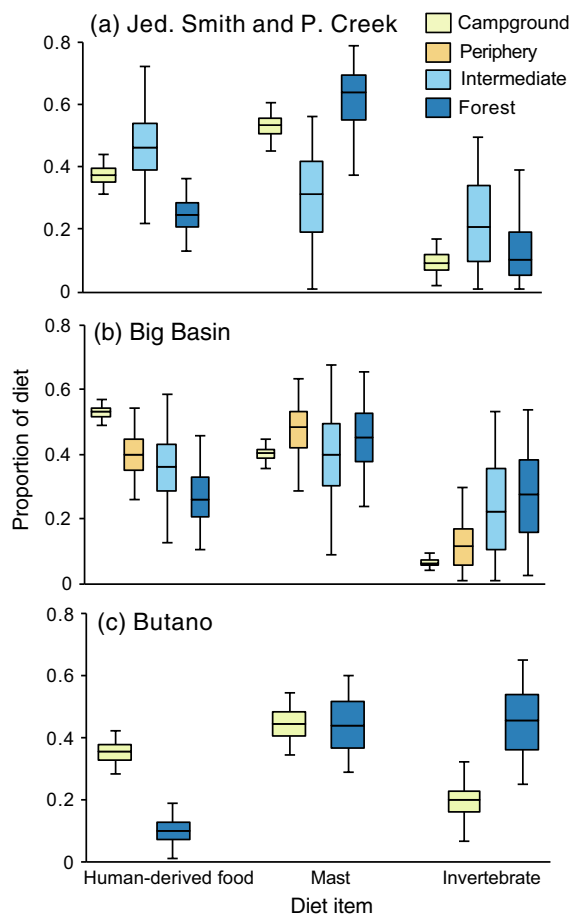


Fig. 5. Three-source Stable Isotope Analysis in R model results for Steller's jays in (a) Jedediah Smith Redwoods and Prairie Creek Redwoods State Parks, 2011, which were merged due to small sample sizes ($n = 45$), (b) Big Basin Redwoods State Park, 2011–2013 ($n = 197$), and (c) Butano State Park, 2012–2013 ($n = 53$). Boxes show 25th and 75th percentiles, whiskers depict the 95% credible interval, and solid lines in the boxes show the median.

concentration was incorporated in SIAR models). Campground jays appeared to shift their diets toward human-derived foods by consuming fewer invertebrates (Fig. 5). Results from SIAR mixing models using six diet sources yielded similar results as the three-source model, supporting the finding that human-derived foods made up a significant proportion of the diet of jays sampled in campgrounds (Appendix S3).

While the consumption of human foods was generally greater in campgrounds, we observed

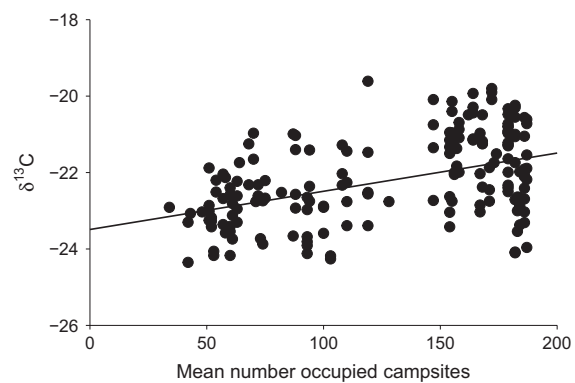


Fig. 6. Relationship between carbon isotope ratios ($\delta^{13}\text{C}$) of blood samples obtained from Steller's jays in campgrounds during the breeding period (April–August) 2011–2013 ($n = 179$) and human presence (mean number occupied campsites) in Big Basin Redwoods State Park. The solid line represents the least-square regression.

considerable variation in isotopic signatures of Steller's jays sampled at these sites ($\delta^{13}\text{C}$: -27.2‰ to -16.1‰ ; $\delta^{15}\text{N}$: $1.2\text{–}7.8\text{‰}$), suggesting that diets varied among individuals. Indeed, across all sampled parks, jays increased their reliance on human-derived foods as the breeding season (May–August) progressed, as evidenced by the significant relationship between $\delta^{13}\text{C}$ and Julian date ($F_{1,278} = 178$, $P < 0.001$, $n = 179$). HY birds were more enriched for $\delta^{13}\text{C}$ than AHY birds (HY: $-20.9\text{‰} \pm 0.2\text{‰}$, $n = 74$; AHY: $-22.5\text{‰} \pm 0.1\text{‰}$, $n = 189$; $F_{1,259} = 96.8$, $P < 0.001$). We did not detect a difference in $\delta^{13}\text{C}$ between sexes (males: $-22.3\text{‰} \pm 0.1\text{‰}$, $n = 179$; females: $-22.2\text{‰} \pm 0.1\text{‰}$, $n = 84$; $F_{1,259} = 0.10$, $P = 0.75$). The interaction between age and sex was not significant ($F_{1,259} = 0.60$, $P = 0.44$). Moreover, we detected a positive relationship between $\delta^{13}\text{C}$ and visitor numbers in Big Basin ($R^2 = 0.22$, $P < 0.001$; Fig. 6).

Relationship between diet and space use of jays in campgrounds

We observed an inverse relationship between $\delta^{13}\text{C}$ enrichment and home range size for male campground and periphery jays after controlling for Julian date (partial $r = -0.39$, $P = 0.01$, $n = 38$; Fig. 7a); thus, males consuming a relatively high proportion of human foods tended to use smaller areas. The proportion of male home ranges that overlapped campgrounds was also positively

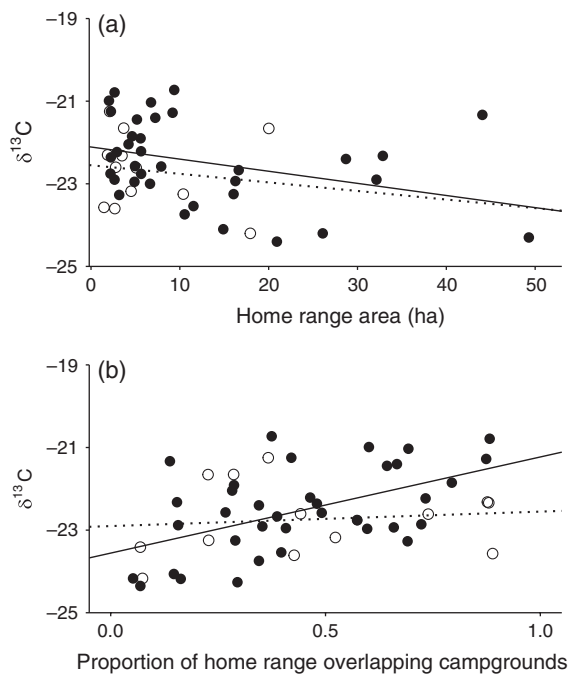


Fig. 7. Carbon isotope ratios ($\delta^{13}\text{C}$) of blood samples from radio-tagged male (filled) and female (unfilled) Steller's jays captured in Big Basin campgrounds (including "periphery" individuals) with respect to size of home range (a) and proportion of core area overlapping campgrounds (b). Solid and dashed lines represent the partial correlation (controlling for Julian date) between variables for males and females, respectively.

associated with $\delta^{13}\text{C}$ enrichment (partial $r = 0.47$, $P = 0.002$; $n = 38$; Fig. 7b); in other words, males that primarily used campgrounds tended to have a greater proportion of human foods in their diet. The relationship between area used and $\delta^{13}\text{C}$ enrichment was not significant for females (partial $r = -0.07$, $P = 0.79$, $n = 12$; Fig. 7a), nor were associations between campground overlap and $\delta^{13}\text{C}$ enrichment (partial $r = 0.16$, $P = 0.54$, $n = 12$; Fig. 7b).

DISCUSSION

Our study was unique in that we combined isotope-based dietary assessments with detailed information on individual space use to provide an understanding of how human-derived foods in protected areas subsidize a synanthropic species. The enrichment of $\delta^{13}\text{C}$ in human-derived

foods allowed us to demonstrate that these foods comprise a greater proportion of the diet of campground than forest jays, presumably because of heavy human visitation and associated food subsidies in campgrounds. Indeed, human-derived foods constituted more than half the diet of campground jays and thus were more important proportionally than both mast and insects combined, in the most heavily visited park (Big Basin with >685,000 visitors in 2013). While the consumption of human-derived foods by campground jays was less pronounced in the least visited park (Butano with 57,034 visitors in 2013), human-derived foods nevertheless constituted 35% of jay diets and could be an important subsidy at this site given their high caloric content. Thus, concordance in results among multiple parks suggests that the subsidization of jays is a regional phenomenon.

Steller's jays in campgrounds exhibited an apparent functional response by consuming an increasing proportion of human-derived foods as park visitation increased. Park visitation peaks in July and August and coincides with the jay fledgling period such that food subsidies are likely most prevalent during the energetically expensive nestling and fledgling provisioning stages. Of note, breeding jays in Big Basin appeared to preferentially feed their juveniles human-derived foods in campgrounds as HY individuals were more enriched in $\delta^{13}\text{C}$ than AHY individuals. Collectively, these results suggest that food subsidies may increase jay reproductive output in campgrounds, as has been observed in numerous other wildlife studies (Rodewald et al. 2011, Webb et al. 2011, Oro et al. 2013, Newsome et al. 2014), and potentially provide a source of young birds that disperse into murrelet nesting areas further from parks. Additional research, however, is needed to understand the potential fitness consequences of human foods in campgrounds, as well as possible larger-scale population effects.

In Big Basin, jays roosting, and presumably breeding, outside of campgrounds regularly traveled to campgrounds to exploit human foods. These individuals could be classified into two categories: jays roosting and breeding in forests at the periphery of campgrounds that regularly made short-distance movements to forage in campgrounds (i.e., periphery jays) and jays

that roosted in interior forests and traveled longer distances (1–2 km) to forage in campgrounds (i.e., intermediate jays). Jays in both groups were enriched for $\delta^{13}\text{C}$ and appeared to consume more human-derived foods than forest jays. Periphery jays may have been subordinate to individuals relegated to roosting and breeding in areas adjacent to campgrounds with limited access to human foods given their intermediate level of $\delta^{13}\text{C}$ enrichment (compared with forest and campground jays). Indeed, pairs of breeding jays exhibit aggressiveness and intolerance over conspecifics in areas immediately surrounding their nests (Brown 1963, 1964, 1969), suggesting that periphery jays may encounter a “landscape” of aggressiveness when attempting to exploit human-derived foods in campgrounds containing high jay densities, recognizing that we do not have observations of social interactions among periphery and campground jays to support this hypothesis. Intermediate jays included two individuals that made periodic longer-distance foraging trips from forests to campgrounds and three individuals that shifted their use of space from forests to campgrounds over the course of the breeding season. Moreover, the fact that five of 12 jays captured and radio-marked in forests were observed foraging in campgrounds (i.e., were intermediate jays) and 37–45% of their diet was comprised of human foods suggests that campgrounds subsidized approximately 42% of the local jay population, recognizing that our modest sample size of jays captured in forests resulted in considerable sampling uncertainty. Moreover, movements by intermediate jays suggests that the “ecological footprint” of campgrounds extended approximately 2 km beyond their spatial footprint, at least in terms of the subsidies they provided to jays during the breeding season. Indeed, our finding that individual jays detected 2 km from campgrounds were subsidized by human foods differs from previous finding that Steller’s jays did not travel more than 1 km to access human foods (Marzluff and Neatherlin 2006). Our results, then, provide additional evidence that campgrounds subsidize Steller’s jays beyond their boundaries and potentially indicate that the quality of old-growth habitat surrounding campgrounds may be reduced for nesting marbled murrelets by these subsidies.

SIAR mixing models indicated that human-derived foods represented a nonnegligible component of the diet of forest jays that were never observed in campgrounds. Forest jays may have had access to human foods provided by visitors using extensive park trail networks to access forested areas containing jays sampled for isotopic analysis. Alternatively, some forest jays may have traveled to campgrounds (a behavior identified in intermediate jays) and consumed human foods prior to sampling, a pattern that would be reflected in the isotopic composition of sampled blood. Forest birds may also have made undetected movements to exploit food resources during radiotracking, although such behavior was readily detected in intermediate jays that either made regular foraging trips or permanently shifted their use to campgrounds. Finally, SIAR models may have overestimated the importance of human foods in the diet of Steller’s jays, as dietary estimates can be sensitive to choice of discrimination factor (Kurle et al. 2013) and we adjusted prey isotopic signatures using factors developed from a surrogate species (Pearson et al. 2003). However, the estimated proportional contribution of human-derived foods in the diet of forest jays was lowest in the park with the fewest visitors (Butano), a pattern that would be expected if forest jays were in fact consuming some human foods.

Observed movement and diet patterns may also help explain previous observations of high Steller’s jay densities in areas of parks frequented by humans in both central California and other regions (Suddjian 2009, Walker and Marzluff 2015). Among campground jays, individuals with home ranges mostly in campgrounds tended to rely more on human-derived foods and had relatively small home ranges, suggesting that human-derived foods allowed individuals to meet their dietary needs within relatively small areas. This finding mirrors a general tendency in birds, where individuals reduce their foraging areas when food is abundant and allows more individuals to occupy a given area (Boutin 1990, Shochat et al. 2004). Tolerance of conspecifics (home range overlap) also appeared to be high in males in campgrounds, despite the fact that this species is generally considered to hold distinct breeding territories (Oberski and Wilson 1991). However, territoriality in birds often weakens

when food is abundant and the incentive to exclude conspecifics from resources decreases, which could explain observed patterns in spacing among jays exploiting human subsidies (Ewald and Carpenter 1978, Hixon 1980, Schoener 1983).

Results from this study have several implications for marbled murrelet conservation as most remaining nesting habitat for this species in California occurs within protected areas receiving heavy recreational visitation (Baker et al. 2006). Of note, 65% of known murrelet nests in central California (Peery et al. 2004), most of which failed due to nest predation, occurred within the ecological footprint (i.e., 2 km) of Big Basin campgrounds, suggesting that point sources of human foods subsidize Steller's jays in important murrelet nesting areas. All four sampled parks have long-standing visitor education and trash management programs designed to reduce food subsidies to Steller's jays, and ultimately to reduce nest predation on marbled murrelets. Our finding that a high proportion of the diet of Steller's jays breeding in and around park campgrounds was comprised of human-derived foods indicates that these programs have not fully achieved their intended effect. While reducing food subsidies in areas receiving high levels of camping and recreation is challenging, changing human behavior for the purposes of species conservation through education and enforcement has been successful in some instances (Craighead et al. 1995, Hopkins et al. 2014). More recently, controlled taste aversion has been implemented to reduce Steller's jay predation on murrelet nests in many regional parks, a strategy that involves deploying noxious eggs that mimic murrelet eggs in appearance at landscape scales (Gabriel and Golightly 2014). Our results suggest that such a strategy would likely need to consider dense deployments of mimic eggs in campgrounds given that jays appear to aggregate in these areas due to the prevalence of human-derived foods. Alternatively, removal of Steller's jays from campgrounds could be an effective means of reducing jay densities in marbled murrelet habitat, but would likely need to be continued on a regular basis to account for jays likely to disperse into these areas from surrounding forests. Ultimately, moving campgrounds and associated human-derived food resources out of marbled murrelet nesting habitat (old-growth

forests) may be the most effective long-term strategy for reducing subsidies to jays in these areas.

In conclusion, our work suggests that point sources of food subsidies in areas of high human activity can influence the behavior and foraging strategies of synanthropic species in less developed areas and over relatively large spatial scales (Brashares et al. 2001, Marzluff and Neatherlin 2006, Wood et al. 2014). Conservation efforts for rare species can thus benefit from identifying key locations on the landscape and periods in the life cycle where food subsidies benefit synanthropes, even for populations within protected areas.

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LITERATURE CITED

- Baker, L. M., M. Z. Peery, E. E. Burkett, S. W. Singer, D. L. Suddjian, and S. R. Beissinger. 2006. Nesting habitat characteristics of the marbled murrelet in central California redwood forests. *Journal of Wildlife Management* 70:939–946.
- Bearhop, S., S. Waldron, S. C. Votier, and R. W. Furness. 2002. Factors that influence assimilation rates and fractionation of nitrogen and carbon stable isotopes in avian blood and feathers. *Physiological and Biochemical Zoology* 75:451–458.
- Ben-David, M., and E. A. Flaherty. 2012. Stable isotopes in mammalian research: a beginner's guide. *Journal of Mammalogy* 93:312–328.
- Beyer, H. L. 2012. Geospatial Modelling Environment. www.spatialecology.com/gme
- Boarman, W. I. 2003. Managing a subsidized predator population: reducing common raven predation on

- desert tortoises. *Environmental Management* 32: 205–217.
- Boutin, S. 1990. Food supplementation experiments with terrestrial vertebrates: patterns, problems, and the future. *Canadian Journal of Zoology* 68: 203–220.
- Brashares, J. S., P. Arcese, and M. K. Sam. 2001. Human demography and reserve size predict wildlife extinction in West Africa. *Proceedings of the Royal Society of London B: Biological Sciences* 268:2473–2478.
- Brown, J. L. 1963. Ecogeographic variation and introgression in an avian visual signal: the crest of the Steller's Jay, *Cyanocitta stelleri*. *Evolution* 17:23–39.
- Brown, J. L. 1964. The evolution of diversity in avian territorial systems. *Wilson Bulletin* 76:160–169.
- Brown, J. L. 1969. Territorial behavior and population regulation in birds: a review and re-evaluation. *Wilson Bulletin* 81:293–329.
- Buehler, D. A., J. D. Fraser, M. R. Fuller, L. S. McAllister, and J. K. D. Seegar. 1995. Captive and field-tested radio transmitter attachments for bald eagles (Adaptadores De Radio Transmisores Para Haliaeetus leucocephalus Probados en Cautiverio y en el Campo). *Journal of Field Ornithology* 66:173–180.
- Caut, S., E. Angulo, and F. Courchamp. 2008. Discrimination factors ($\Delta^{15}\text{N}$ and $\Delta^{13}\text{C}$) in an omnivorous consumer: effect of diet isotopic ratio. *Functional Ecology* 22:255–263.
- Cornell, H. N., J. M. Marzluff, and S. Pecoraro. 2011. Social learning spreads knowledge about dangerous humans among American crows. *Proceedings of the Royal Society of London B: Biological Sciences* 279:499–508.
- Craighead, J. J., J. S. Sumner, and J. A. Mitchell. 1995. The grizzly bears of Yellowstone: their ecology in the Yellowstone ecosystem, 1959–1992. Fourth edition. Island Press, Washington, D.C., USA.
- DeNiro, M. J., and S. Epstein. 1978. Influence of diet on the distribution of carbon isotopes in animals. *Geochimica et Cosmochimica Acta* 42:495–506.
- Ellis, E. C., K. Klein Goldewijk, S. Siebert, D. Lightman, and N. Ramankutty. 2010. Anthropogenic transformation of the biomes, 1700 to 2000. *Global Ecology and Biogeography* 19:589–606.
- ESRI. 2014. ArcGIS 10.2. ESRI, Redlands, California, USA.
- Ewald, P. W., and F. L. Carpenter. 1978. Territorial responses to energy manipulations in the Anna hummingbird. *Oecologia* 31:277–292.
- Gabriel, P. O., and R. T. Golightly. 2014. Aversive conditioning of Steller's Jays to improve marbled murrelet nest survival. *Journal of Wildlife Management* 78:894–903.
- Gitzen, R. A., J. J. Millsaugh, and B. J. Kernohan. 2006. Bandwidth selection for fixed-kernel analysis of animal utilization distributions. *Journal of Wildlife Management* 70:1334–1344.
- Goldenberg, W. P., T. L. George, and J. M. Black. 2016. Steller's Jay (*Cyanocitta stelleri*) space use and behavior in campground and non-campground sites in coastal redwood forests. *Condor* 118: 532–541.
- Griffiths, R., M. C. Double, K. Orr, and R. J. G. Dawson. 1998. A DNA test to sex most birds. *Molecular Ecology* 7:1071–1075.
- Hansen, A. J., R. L. Knight, J. M. Marzluff, S. Powell, K. Brown, P. H. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications* 15:1893–1905.
- Hixon, M. A. 1980. Food production and competitor density as the determinants of feeding territory size. *American Naturalist* 115:510–530.
- Hobson, K. A., and R. G. Clark. 1992. Assessing avian diets using stable isotopes II: factors influencing diet-tissue fractionation. *Condor* 94:189–197.
- Hopkins, J. B., P. L. Koch, J. M. Ferguson, and S. T. Kalinowski. 2014. The changing anthropogenic diets of American black bears over the past century in Yosemite National Park. *Frontiers in Ecology and the Environment* 12:107–114.
- Jackson, A. L., R. Inger, S. Bearhop, and A. Parnell. 2009. Erroneous behaviour of MixSIR, a recently published Bayesian isotope mixing model: a discussion of Moore & Semmens (2008). *Ecology Letters* 12:E1–E5.
- Jahren, A. H., C. Saudek, E. Yeung, W. L. Kao, R. Kraft, and B. Caballero. 2006. An isotopic method for quantifying sweeteners derived from corn and sugar cane. *American Journal of Clinical Nutrition* 84:1380–1384.
- Jerzak, L. 2001. Synurbanization of the magpie in the Palearctic. Pages 403–425 in J. M. Marzluff, R. Bowman, and R. Donnelly, editors. *Avian ecology and conservation in an urbanizing world*. Kluwer Academic Publishers, Boston, Massachusetts, USA.
- Johnston, R. F. 2001. Synanthropic birds of North America. Pages 49–67 in J. M. Marzluff, R. Bowman, and R. Donnelly, editors. *Avian ecology and conservation in an urbanizing world*. Kluwer Academic Publishers, Boston, Massachusetts, USA.
- Kareiva, P., S. Watts, R. McDonald, and T. Boucher. 2007. Domesticated nature: shaping landscapes and ecosystems for human welfare. *Science* 316: 1866–1869.
- Kernohan, B. J., R. A. Gitzen, and J. J. Millsaugh. 2001. Chapter 5 – Analysis of animal space use and movements. Pages 125–166 in J. M. Marzluff and J. J. Millsaugh, editors. *Radio tracking and animal*

- populations. Academic Press, San Diego, California, USA.
- Kristan, W. B., and W. I. Boarman. 2003. Spatial pattern of risk of common raven predation on desert tortoises. *Ecology* 84:2432–2443.
- Kurle, C. M., M. E. Finkelstein, K. R. Smith, D. George, D. Ciani, P. L. Koch, and D. R. Smith. 2013. Discrimination factors for stable isotopes of carbon and nitrogen in blood and feathers from chicks and juveniles of the California condor. *Condor* 115:492–500.
- Marzluff, J. M., R. B. Boone, and G. W. Cox. 1994. Historical changes in populations and perceptions of native pest bird species in the West. *Studies in Avian Biology* 15:202–220.
- Marzluff, J. M., and E. Neatherlin. 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biological Conservation* 130:301–314.
- Marzluff, J. M., J. C. Withey, K. A. Whittaker, M. David Oleyar, T. M. Unfried, S. Rullman, and J. Delap. 2007. Consequences of habitat utilization by nest predators and breeding songbirds across multiple scales in an urbanizing landscape. *Condor* 109:516–534.
- Masselink, M. N. 2001. Responses by Steller's Jays to forest fragmentation on southwest Vancouver Island and potential impacts of marbled murrelets. MS Thesis. University of Victoria, Victoria, British Columbia, Canada.
- Newsome, T. M., J. A. Dellinger, C. R. Pavey, W. J. Ripple, C. R. Shores, A. J. Wirsing, and C. R. Dickman. 2014. The ecological effects of providing resource subsidies to predators. *Global Ecology and Biogeography* 24:1–11.
- Newsome, S. D., K. Ralls, C. V. H. Job, M. L. Fogel, and B. L. Cypher. 2010. Stable isotopes evaluate exploitation of anthropogenic foods by the endangered San Joaquin kit fox (*Vulpes macrotis mutica*). *Journal of Mammalogy* 91:1313–1321.
- Oberski, I. M., and J. D. Wilson. 1991. Territoriality and site-related dominance: on two related concepts in avian social organization. *Ethology* 87:225–236.
- Oro, D., M. Genovart, G. Tavecchia, M. S. Fowler, and A. Martínez-Abraín. 2013. Ecological and evolutionary implications of food subsidies from humans. *Ecology Letters* 16:1501–1514.
- Parnell, A., R. Inger, S. Bearhop, and A. L. Jackson. 2008. Stable isotope analysis in R (SIAR). <http://cran.r-project.org/web/packages/siar/index.html>
- Parnell, A. C., R. Inger, S. Bearhop, and A. L. Jackson. 2010. Source partitioning using stable isotopes: coping with too much variation. *PLoS ONE* 5:e9672.
- Pearson, S. F., D. J. Levey, C. H. Greenberg, and C. M. del Rio. 2003. Effects of elemental composition on the incorporation of dietary nitrogen and carbon isotopic signatures in an omnivorous songbird. *Oecologia* 135:516–523.
- Peery, M. Z., S. R. Beissinger, S. H. Newman, E. B. Burkett, and T. D. Williams. 2004. Applying the declining population paradigm: diagnosing causes of poor reproduction in the marbled murrelet. *Conservation Biology* 18:1088–1098.
- Peery, M. Z., and R. W. Henry. 2010. Recovering marbled murrelets via corvid management: a population viability analysis approach. *Biological Conservation* 143:2414–2424.
- Peterson, S. A., and M. A. Colwell. 2014. Experimental evidence that scare tactics and effigies reduce corvid occurrence. *Northwestern Naturalist* 95: 103–112.
- Phillips, D. L., R. Inger, S. Bearhop, A. L. Jackson, J. W. Moore, A. C. Parnell, B. X. Semmens, and E. J. Ward. 2014. Best practices for use of stable isotope mixing models in food-web studies. *Canadian Journal of Zoology* 92:823–835.
- Phillips, D. L., S. D. Newsome, and J. W. Gregg. 2005. Combining sources in stable isotope mixing models: alternative methods. *Oecologia* 144:520–527.
- Pyle, P., S. N. G. Howell, R. P. Yunick, and D. F. DeSante. 1987. Identification guide to North American passerines. Braun-Brumfield, Ann Arbor, Michigan, USA.
- R Development Core Team. 2014. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>
- Radeloff, V. C., et al. 2012. Economic-based projections of future land use in the conterminous United States under alternative policy scenarios. *Ecological Applications* 22:1036–1049.
- Rand, T. A., and S. M. Louda. 2006. Spillover of agriculturally subsidized predators as a potential threat to native insect herbivores in fragmented landscapes. *Conservation Biology* 20:1720–1729.
- Rappole, J. H., and A. R. Tipton. 1991. New harness design for attachment of radio transmitters to small passerines (Nuevo Diseño de Arnés para Atar Transmisores a Passeriformes Pequeños). *Journal of Field Ornithology* 62:335–337.
- Rodewald, A. D., L. J. Kearns, and D. P. Shustack. 2011. Anthropogenic resource subsidies decouple predator–prey relationships. *Ecological Applications* 21:936–943.
- Rosing, M. N., M. Ben-David, and R. P. Barry. 1998. Analysis of stable isotope data: a K nearest-neighbors randomization test. *The Journal of Wildlife Management* 62:380–388.
- Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, and W. A. Link. 2014. Breeding

- Bird Survey Summary and Analysis 1966–2013. Version 01.30.2015. <http://www.mbr-pwrc.usgs.gov/bbs/bbs.html>
- Scarpignato, A. L., and T. L. George. 2013. Space use by common ravens in marbled murrelet nesting habitat in northern California. *Journal of Field Ornithology* 84:147–159.
- Schoech, S. J., and R. Bowman. 2001. Variation in the timing of breeding between suburban and wildland Florida Scrub-Jays: Do physiologic measures reflect different environments? Pages 289–306 in J. M. Marzluff, R. Bowman, and R. Donnelly, editors. *Avian ecology and conservation in an urbanizing world*. Kluwer Academic Publishers, Boston, Massachusetts, USA.
- Schoener, T. W. 1983. Simple models of optimal feeding-territory size: a reconciliation. *American Naturalist* 121:608–629.
- Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. *Journal of Wildlife Management* 63:739–747.
- Shochat, E., S. B. Lerman, M. Katti, and D. B. Lewis. 2004. Linking optimal foraging behavior to bird community structure in an urban-desert landscape: field experiments with artificial food patches. *American Naturalist* 164:232–243.
- Silverman, B. W. 1986. *Density estimation for statistics and data analysis*. Chapman & Hall/CRC Press, London, UK.
- Simberloff, D., and P. Stiling. 1996. How risky is biological control? *Ecology* 77:1965–1974.
- Suddjian, D. L. 2009. Summary of 2009 corvid monitoring surveys in the Santa Cruz Mountains. Unpublished report prepared for the Command Oil Spill Trustee Council. Sacramento, California, USA.
- Swihart, R. K., and N. A. Slade. 1985. Testing for independence of observations in animal movements. *Ecology* 66:1176–1184.
- Vigallon, S. M., and J. M. Marzluff. 2005. Is nest predation by Steller's jays (*Cyanocitta stelleri*) incidental or the result of a specialized search strategy? *Auk* 122:36–49.
- Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of earth's ecosystems. *Science* 277:494–499.
- Walker, L. E., and J. M. Marzluff. 2015. Recreation changes the use of a wild landscape by corvids. *Condor* 117:262–283.
- Webb, W. C., J. M. Marzluff, and J. Hepinstall-Cyerman. 2011. Linking resource use with demography in a synanthropic population of common ravens. *Biological Conservation* 144:2264–2273.
- West, G. B., J. H. Brown, and B. J. Enquist. 1997. A general model for the origin of allometric scaling laws in biology. *Science* 276:122–126.
- White, G. C., and R. A. Garrott. 2012. *Analysis of wildlife radio-tracking data*. Elsevier Academic Press, San Diego, California, USA.
- Withey, J. C., and J. M. Marzluff. 2008. Multi-scale use of lands providing anthropogenic resources by American Crows in an urbanizing landscape. *Landscape Ecology* 24:281–293.
- Wood, E. M., A. M. Pidgeon, V. C. Radeloff, D. Helmers, P. D. Culbert, N. S. Keuler, and C. H. Flather. 2014. Housing development erodes avian community structure in U.S. protected areas. *Ecological Applications* 24:1445–1462.

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Behavioral mechanisms leading to improved fitness in a subsidized predator

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Abstract General mechanisms underlying the distribution and fitness of synanthropic predators in human-influenced landscapes remain unclear. Under the consumer resource-matching hypothesis, synanthropes are expected to distribute themselves among habitats according to resource availability, such that densities are greater in human-subsidized habitats, but mean individual fitness is equal among habitats because of negative density dependence. However, “under-matching” to human food resources can occur, because dominant individuals exclude subordinates from subsidized habitats and realize relatively high fitness. We integrated physiological, behavioral, and demographic information to test resource-matching hypotheses in Steller’s jays (*Cyanocitta stelleri*), a synanthropic nest predator, to understand how behavior and social systems can influence how synanthropes respond to food subsidies. Jays consumed more human foods at subsidized (park campground) sites than jays at unsubsidized (interior forest) sites based on stable isotope analyses. Jays that occurred at higher densities were in better body condition (based on feather growth bars and lipid analyses), and had greater reproductive output at subsidized than unsubsidized sites.

Jays with breeding territories in subsidized sites maintained relatively small home ranges that overlapped with multiple conspecifics, and exhibited a social system where dominant individuals typically won contests over food. Thus, jays appeared to be under-matched to prevalent resource subsidies despite high densities and behaviors expected to lead to resource matching. Our results also indicate that local resource subsidies within protected areas can result in source habitats for synanthropes, potentially impacting sensitive species over broader spatial scales.

Keywords Resource matching · Synanthropic predators · Protected areas · Resource subsidies

Introduction

Synanthropic species, which benefit from ecological associations with humans (Johnston 2001), have increased nearly globally as a result of land-use intensification and concomitant increases in the availability of anthropogenic foods (Webb et al. 2011). Indeed, predictable anthropogenic food subsidies are considered responsible for increases in populations of many overabundant synanthropes including coyotes, gulls, and corvids that impact a host of sensitive species and community structure (Fedriani et al. 2001; Duhem et al. 2008; Walker and Marzluff 2015). Understanding how patterns of anthropogenic subsidies on the landscape affect the behavior, distribution, and demography of synanthropic species is considered essential for reducing their effects on ecological systems (Sih et al. 2011). Nevertheless, general mechanisms underlying the distribution and fitness of synanthropic predators in human-influenced landscapes remain a source of considerable uncertainty (Marzluff and Neatherlin 2006).

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The oft-cited ideal free (IFD) and ideal despotic models (IDD) of animal distributions (Fretwell and Lucas 1970; Fretwell 1972) represent useful starting points for testing hypotheses about the effects of heterogeneously distributed food subsidies on synanthropic species (Beckmann and Berger 2003). Under an IFD, individuals are assumed to move freely among habitats and are expected to preferentially select high-quality habitats (e.g., where resource subsidies are prevalent). However, as density increases in high-quality habitats, mean individual fitness (productivity as measured by HY:AHY ratios) declines as a result of intraspecific competition (Fretwell and Lucas 1970; Fretwell 1972), and animals begin using lower quality habitats, even though resources are relatively scarce. At equilibrium, individuals become assorted in proportion to resource availability, such that mean individual fitness is equal among habitats and populations are “matched” to the distribution of resources in the environment (Fagen 1987). By contrast, under IDD, dominant individuals exclude subordinate individuals from high-quality habitats via territorial interactions, which drive subordinates to use low-quality habitats (Fretwell 1972). According to this model, mean individual fitness is expected to be greater in high- rather than low-quality habitats, such that populations are “under-matched” to their environment and resource-rich habitats are under-exploited (Kennedy and Gray 1993). If a synanthropic species of management interest conforms to an IDD, the proportion of the population occurring in high-quality habitats contributes disproportionately to population growth, and reducing subsidies or removing these dominant individuals in these areas is more likely to lead to population declines than if the population conforms to an IFD (Haché et al. 2013).

Empirical and model-based studies, however, suggest that IFD and IDD models may be overly simplistic and often do not apply to natural populations, particularly synanthropic species. Both models assume that individuals have perfect knowledge of the distribution of food resources, such that habitat selection is “ideal”. Indeed, some synanthropic species may “over-match” to their environment, where fitness is relatively low in areas with prevalent food subsidies (putatively high-quality habitats), because it attracts immigrants that do not breed (i.e., floaters) or because inferior competitors in contests breed at lower rates (Shochat et al. 2006). Moreover, the IDD assumes that territory size is constant within and among habitats that differ in quality (Ridley et al. 2004; Haché et al. 2013). In natural populations, reductions in territory size resulting from a greater frequency and intensity of agonistic interactions as density increases in high-quality habitats may lead to declines in individual fitness, such that populations of territorial species reflect

an ideal free, rather than an ideal despotic, distribution (Ridley et al. 2004). Thus, detailed assessments of behavioral interactions, in addition to habitat-specific estimates of fitness and density, are needed to understand the ecological processes that govern the distribution of synanthropic species occurring in landscapes with heterogeneously distributed food resources.

In this study, we tested competing distribution models in the Steller’s jay (*Cyanocitta stelleri*), a synanthropic species that has become widely and abundantly distributed throughout its range in western North America (Sauer et al. 2014). Recently, Steller’s jays have gained attention in the Pacific Northwest due to their association as nest predators of marbled murrelets (*Brachyramphus marmoratus*) (Luginbuhl et al. 2001), as well as nesting songbirds (Vigallon and Marzluff 2005). Populations of Steller’s jays have increased dramatically in parks containing remnant populations of marbled murrelets, presumably in response to the availability of anthropogenic food subsidies in these areas (Marzluff and Neatherlin 2006). We evaluated whether Steller’s jays occurring within protected areas receiving low (interior forest) versus high (campgrounds) levels of human use conformed to an IFD or IDD, or were over-matched to their environment. First, we determined the extent to which individuals in these two habitats consumed and, thus were subsidized by, anthropogenic foods using stable isotope analyses. We then tested a series of predictions regarding differences in body condition, reproductive rates, and density between interior forest and campground sites for each of the three competing hypotheses (Table 1). We also (i) tested for differences in home range size and overlap between habitats based on radio-marked individuals and (ii) conducted experimental feeding trials in campgrounds to characterize patterns of agonistic behaviors, both with the objective of understanding how behavioral interactions might mediate responses in fitness and density to food subsidies.

Table 1 Predicted directionality of differences in body condition, reproductive rates, and density according to the ideal free distribution (IFD), ideal despotic distribution (IDD), and over-matching under the hypothesis that areas with anthropogenic food subsidies (S) are of higher habitat quality than unsubsidized (U) areas

	IFD (resource matching)	IDD (under- matching)	Over-matching
Body condition	S = U	S > U	S < U
Reproductive rates	S = U	S > U	S < U
Density	S > U	No prediction	S > U

Materials and methods

Study areas

We studied Steller's jays using a combination of radio-telemetry, stable isotope analyses, physiological assays of body condition, and behavioral observations in two state parks in central California, USA containing remnant old-growth forest nesting habitat for marbled murrelets: Big Basin Redwoods and Butano State Parks (hereafter referred to as Big Basin and Butano, respectively). Sampling was conducted at one-to-four campgrounds and non-campground (forest) sites in each park. Forest sites were selected based on accessibility, the presence of territory-holding jays, and were located 1–2 km from campgrounds. Individuals captured in campgrounds and forest sites were defined as "campground" and "forest" jays, respectively. Previous analyses of the daily movements of radio-marked individuals revealed that some forest jays made periodic movements to campgrounds (i.e., "intermediate" jays) and some campground jays had activity centers focused in forests along the periphery of campgrounds (i.e., "periphery" jays; (West et al. 2016). Stable isotope assessments of jay diets and lipid analyses to determine jay body condition measurements were conducted for each park, whereas radio-telemetry work, point counts, and feeding experiments were limited to Big Basin.

Captures and sampling

We captured Steller's jays during the breeding season (April to August) using live traps (model 1045, Havahart®, Lititz, PA) and mistnets (Avinet, Dryden, NY) from 2010 to 2013. We broadcasted jay vocalizations (Vigallon and Marzluff 2005) and placed shelled peanuts near mistnets to attract jays (peanuts were glued to plates to prevent jays from consuming bait and affecting isotope-based diet estimates). Captured jays were weighed (g), measured for tarsus length (mm), and banded with a stainless steel US Geological Survey metal band and a unique combination of three colored leg bands. After-hatch-year (hereafter AHY) jays were distinguished from hatch-year (hereafter HY) jays based on gape coloration, plumage pattern, the shape of rectrices, and the level of covert contrast (Pyle et al. 1997). The sex of all individuals was determined through observations of sex-specific vocalizations and later confirmed using polymerase chain reaction methods on extracted DNA from blood samples (Griffiths et al. 1998). We fit a subsample of individuals captured in Big Basin in 2011, 2012, and 2013 with backpack-mounted radio transmitters (model A1050, Advanced Telemetry Systems, Isanti, Minnesota; (Buehler et al. 1995). Transmitters had an expected lifespan of 12 weeks and were affixed using 2.5 mm Teflon ribbon.

Stable isotope analysis

We used stable isotope analysis to quantify Steller's jay diet by comparing the isotopic signature ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) of Steller's jay primary feathers to the isotopic signatures of potential diet items. Enrichment of $\delta^{13}\text{C}$, in particular, is indicative of the consumption of anthropogenic foods in this species (West et al. 2016) and wildlife generally (Newsome et al. 2015). Feathers integrate the isotopic signature of diet sources during molt (Bearhop et al. 2002), and primary growth occurs in Steller's jays at the end of the breeding season in July and August. Individual feathers were sampled from jays throughout the summer and represent diet sources from the previous year's molt (collected before July of the sampling year) or diet from the year that they were sampled (collected during or after July of the sampling year). However, it is unlikely that pooling feather samples representing diet sources from different years led to the sampling of diets from different habitats, given that our banding data indicated that jays captured early in the summer are generally long-term residents at their breeding sites (EHW unpubl. data). We collected 50 mm of the first primary of each sampled jay and rinsed samples in a 2:1 chloroform:methanol solution to remove surface contaminants. We sampled food items (invertebrates, berries, acorns, conifer seeds, and anthropogenic food, as listed in Online Resources 1 and 2) at capture sites in all parks during each field season in three of the four study years (2011–2013) following methods in (West et al. 2016) to compare the isotopic signature (in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) of jay feathers to the isotopic signatures of potential prey items. We did not include marbled murrelets as a potential dietary source in stable isotope analyses of Steller's jay diet, because murrelet abundance is very low relative to jay abundance and murrelets likely constitute a negligible portion of jay diets (West et al. 2016). Diet samples were dried for 72 h at 56 °C and homogenized in a ball mill. For ^{13}C and ^{15}N analysis, samples were weighed, placed in tin capsules, and analyzed with a Costech 4010 elemental analyzer attached to a ThermoFinnigan DeltaPlus XP Continuous Flow Isotope Ratio Mass Spectrometer at the Stable Isotope Facility at the University of Wyoming. Results are provided as per mil [parts per thousand ‰] ratios relative to the international standards of Pee Dee Belemnite (PDB; $\delta^{13}\text{C}$) and atmospheric nitrogen (AIR; $\delta^{15}\text{N}$) with calibrated internal laboratory standards. We grouped jay diet samples into three biologically and isotopically distinct groups within each park: anthropogenic food, mast (fruit from trees and shrubs, including acorns, pine seeds, and berries), and invertebrates based on West et al. (2016). We adjusted the isotopic values of diet sources using correction factors derived for feathers based on an experimental study of a passerine with a diet similar to that of Steller's

jays $+3.3\text{‰}$ (SD = 0.04) for $\delta^{15}\text{N}$ and $+3.5\text{‰}$ (SD = 0.1) for $\delta^{13}\text{C}$ (Pearson et al. 2003). We tested for differences in the consumption of human foods, among the four groups of jays (forest, intermediate, periphery, and campground) in Big Basin and among two groups of jays (forest and campground) in Butano using analysis of variance (ANOVA) with $\delta^{13}\text{C}$ as the dependent variable.

Assessing body condition

We assessed Steller's jay body condition using two different methods, total body lipid content and the width of feather growth bars. For both analyses, we used a subsample of jays removed as part of the US Department of Agriculture and California State Parks predator management activities in Big Basin and Butano State Parks. Collected birds were frozen and stored for post-mortem analysis of lipid content. At a later date, thawed birds were dissected to remove the small intestine, liver, heart, and gizzard. After flushing with avian Ringer solution (aqueous sodium, potassium, and calcium salts; 0.01%), the wet masses of internal organs were recorded (± 0.10 mg), placed into aluminum weigh boats, and dried in a 60 °C drying oven to a constant mass until analyzed for composition. Dry masses of tissue samples were recorded and individually wrapped in pre-dried filter paper. Lipids were extracted from the samples using diethyl ether in a modified Soxhlet side-arm extractor. Lean dry mass, tissue mass extracted (g dry tissue–g lean dry tissue), and tissue lipid content (g tissue extracted g⁻¹ lean dry tissue) were calculated to assess total body and organ lipid content, hereafter total body lipid content. We used analysis of covariance (ANCOVA), where standardized total body lipid content (hereafter body condition index) was the response variable and ordinal date of each removal date was used as a continuous predictor variable, while year, park, sex, and habitat (forest or campground) were used as categorical predictor variables (note that we were unable to identify “periphery” and “intermediate” jays among lethally sampled individuals).

We assessed feather growth bar width (mm) in the outer-right rectrix from removed jays. Each growth bar, consisting of alternating dark and light bands, a few millimeters in width, is formed over a 24-h period. Wide growth bars reflect fast feather growth, and because feather growth is costly, the width of the bar reflects the condition of the bird during molt (Grubb 2006). Feathers were photographed using a Canon PowerShot S95 digital camera and growth bars were visualized using the ImageJ software for measurement of growth bar width following methods outlined in Grubb (2006). Measurements (in mm) were averaged for a final mean growth bar size for each feather. We standardized both measures by tarsus length cubed (mm³), which reflects body size ‘volume’ and is related to structural

body size (Sibly et al. 1987). We used ANOVA to compare feather growth bar width between habitats, years, parks, sexes, and among years.

Estimating density and reproductive rates

We used point counts and distance-sampling techniques to compare population density and reproductive rates of Steller's jays at campground and forest sites in Big Basin. Point counts were conducted following standard, 5-min survey methods (Ralph et al. 1995) at 14 sample points (7 campground and 7 forest sites) four times per year from mid-May to mid-August (once per month) in 2011, 2012, and 2013. Points at campground sites were located in the center of campgrounds so as to avoid counting birds on the periphery of these areas. Points at forest sites were located a minimum of 2 km from any campground or picnic area and were located along roads or trails to facilitate access. We began point counts at 0700 and continued for approximately 3 h if weather conditions were acceptable (i.e., low wind and no rain). We measured and flagged distances in 10-m increments from the center of each point to estimate distances to detected birds. Individuals detected >50 m beyond the plot center were excluded from analyses. HY individuals were distinguished from AHY individuals based on their distinctive vocalizations such as begging calls, as well as plumage characteristics such as their gray breast feathers (compared to the blue breast feathers of AHYs; Pyle et al. 1997).

We estimated jay densities from the point count data (both visual and auditory detections) using distance-sampling techniques implemented in Program Distance to account for imperfect detection (Thomas et al. 2004). We estimated jay densities within each habitat type (campground and forest) and for each age class (HY and AHY) in four separate analyses, treating month and year as covariates. Details regarding the modeling of detection functions are provided in Online Resource 3. We then estimated reproductive rates for Steller's jays by calculating the ratio of HY density to AHY density in each habitat, which can provide a “snapshot” of the per-capita reproductive output of a group of individuals that incorporates all of the components of reproduction, including the proportion of breeders, nest success rates, and productivity (Peery et al. 2007). We used AHY density estimates from the month of June to minimize the potential impacts of post-breeding movements given that AHY jay densities in campgrounds increased by 22% from June to August (West et al. 2016). Although some AHY jays radio-marked in forests used campgrounds for foraging (West et al. 2016), 93% of the detections of these individuals in campgrounds occurred in July and August, and thus immigration likely had little effect on June estimates of AHY density in campgrounds.

Moreover, none of the 50 radio-marked AHY jays dispersed out of campgrounds prior to the end of June and AHY jays present within campgrounds in June were, thus, reasonably assumed to represent locally breeding individuals. We used HY density estimates from the month of August to calculate age ratios, because this month represents the peak fledgling period and precedes juvenile dispersal, which begins in September (EHW unpubl. data). We observed one instance of two HY jays moving with their radio-marked parent from the forest to a campground, but such movements were sufficiently rare that they did not substantively impact comparisons of HY:AHY ratios between campground and forest habitats (see calculations in “Results”). We averaged annual estimates for both the numerator and the denominator when estimating an overall HY:AHY ratio for both campground and forest habitats. We used the delta method to approximate sampling variance for campground and forest HY:AHY ratios (Powell 2007).

Estimating home range size and overlap

We compared home range size and overlap between radio-marked forest, intermediate, periphery, and campground individuals to determine if anthropogenic food subsidies reduced home range size and increased home range overlap. We tracked jays from May 1 to August 15, a period that largely coincides with known Steller’s jay nesting dates in coastal California (April–July; Brown 1963). We used a handheld telemetry receiver (model R410, Advanced Telemetry Systems, Isanti, Minnesota) to relocate focal individuals through daily ground-based telemetry surveys, which were conducted between 0700 and 1900 h by walking trails and driving roads in search of signals emanating from radio-marked individuals, allowing at least 2 h between location determinations taken on the same day (Swihart and Slade 1985).

We estimated jay home range size as the area (ha) based on 95% utilization distributions derived using fixed kernel density estimates (Kernohan et al. 2001). We used Least Squares Cross Validation for bandwidth (i.e., smoothing parameter) estimation (Gitzen et al. 2006) in the Geospatial Modeling Environment for ArcGIS (Beyer 2012). We quantified home range overlap between pairs of AHY jays captured within 100 m of one another during the same breeding season. We limited overlap analyses to pairs that were captured in close proximity, because jays captured at forest sites tended to be captured further away from one another than jays captured in campgrounds. Moreover, we did not include male–female pairs as these might have represented mated individuals and thus not reflected territory spacing. Home range overlap was quantified using the Utilization Distribution Overlap Index (UDOI) (Fieberg and Kochanny

2005) with the adehabitat package (Calenge 2006) in the R statistical environment (R Development Core Team 2014). The UDOI is based on the product of the two home range utilization distributions and generally ranges from 0 (no overlap) to 1 (100% overlap) (Fieberg and Kochanny 2005).

Experimental tests of agonistic interactions

To further explore the behavioral mechanisms that may facilitate or impede resource matching, we conducted feeding experiments designed to assess the level of agonistic interactions that occurred in response to food subsidies in campgrounds. Thirty-six feeding trials were conducted on individually banded AHY jays in Big Basin campgrounds during the breeding season (April–August) in 2014. We presented jays with supplemental food in the form of six peanuts, replenished as needed, and placed on randomly selected picnic tables separated by at least 30 m. We assumed that the table presentation was an accurate reflection of foraging behavior in the park, because jays frequently consume human-provided food in campgrounds, and are conditioned to forage on picnic tables (EHW pers obs). Feeding trials were conducted between 0800 and 1200 h and jays were attracted to trial locations by broadcasting recorded vocalizations. During trials, we recorded the color band combination of each individual that visited the location, but did not record the behavior of unbanded jays given their unknown identity. Each interaction between a pair of banded individuals was scored on a numerical scale (0–5) based on the intensity of the aggression: no aggression (0); wing-flicking displays and calls (1); displacement behaviors (2); chasing (3); aggressive sidling (4); and fighting (5). Each aggressive (non-zero) interaction was assigned a winner and a loser based on which individual was dominant over the other (i.e., if subordinate birds were supplanted by dominant birds during the course of agonistic interactions that were scored >0). We then characterized jay dominance hierarchies with respect to access to food subsidies at a subset of five neighboring trial locations. Specifically, we assessed the relative rank of each individual at each location based on the outcome of agonistic interactions (i.e., win versus loss) with other individuals that regularly occurred in the area. Results including $\pm$ are given as the standard error.

Results

Stable isotope analyses

We analyzed feather samples from 105 individual AHY Steller’s jay feathers for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotope ratios (Big Basin campground sites: $n = 13$ females and 41

males; Big Basin forest sites: $n = 6$ females and 12 males; Butano campground sites: $n = 5$ females and 12 males; Butano forest sites: $n = 1$ female and 15 males; sexes were pooled for analyses). Both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope signatures of Steller's jay feather samples fell within the mixing space of the three diet groups considered, suggesting that dietary sources were well represented by our sampling of potential food sources (Fig. 1a, b). $\delta^{13}\text{C}$ was greater for anthropogenic food than for mast and invertebrates, and Steller's jays enriched in $\delta^{13}\text{C}$ were, therefore, assumed to have consumed a greater proportion of anthropogenic food sources. In Big Basin, $\delta^{13}\text{C}$ differed among the four groups of jays (campground: $-18.9\text{‰} \pm 0.27\text{‰}$, $n = 35$; periphery: $-19.6\text{‰} \pm 0.35\text{‰}$, $n = 15$; forest: $-23.3\text{‰} \pm 0.36\text{‰}$, $n = 13$; intermediate: $-20.25\text{‰} \pm 0.37\text{‰}$, $n = 5$) based on one-way ANOVA ($F_{3,68} = 27.55$, $P < 0.001$). Post hoc Tukey's tests indicated that campground, periphery, and intermediate jays were more enriched than forest jays (all

$P_s < 0.01$) and that campground, periphery, and intermediate jays did not differ in $\delta^{13}\text{C}$ enrichment (all $P_s > 0.21$). In Butano, campground birds were more enriched for $\delta^{13}\text{C}$ than forest birds (campground: $-22.2\text{‰} \pm 0.22\text{‰}$, $n = 17$; forest: $-23.2\text{‰} \pm 0.11\text{‰}$, $n = 16$) based on one-way ANOVA ($F_{1,31} = 257.21$, $P < 0.001$).

Body condition

Campground jays were in better body condition than forest jays in both parks based on lipid composition analysis and feather growth bar measurements of lethally sampled AHY jays.

Specifically, standardized lipid mass was greater in campground than forest jays ($F_{1,34} = 28.81$, $P < 0.01$, $n = 41$; Fig. 2a), as was feather growth bar width: ANOVA, $F_{1,32} = 32.27$, $P < 0.01$, $n = 38$; Fig. 2b). Lipid mass was not associated with ordinal date, year, park or sex, or the interaction between ordinal date and sex (ordinal date: $F_{1,34} = 0.45$, $P = 0.50$; year: $F_{1,34} = 0.025$, $P = 0.87$; park: $F_{1,34} = 0.004$, $P = 0.95$; sex: $F_{1,34} = 1.57$, $P = 0.22$; ordinal

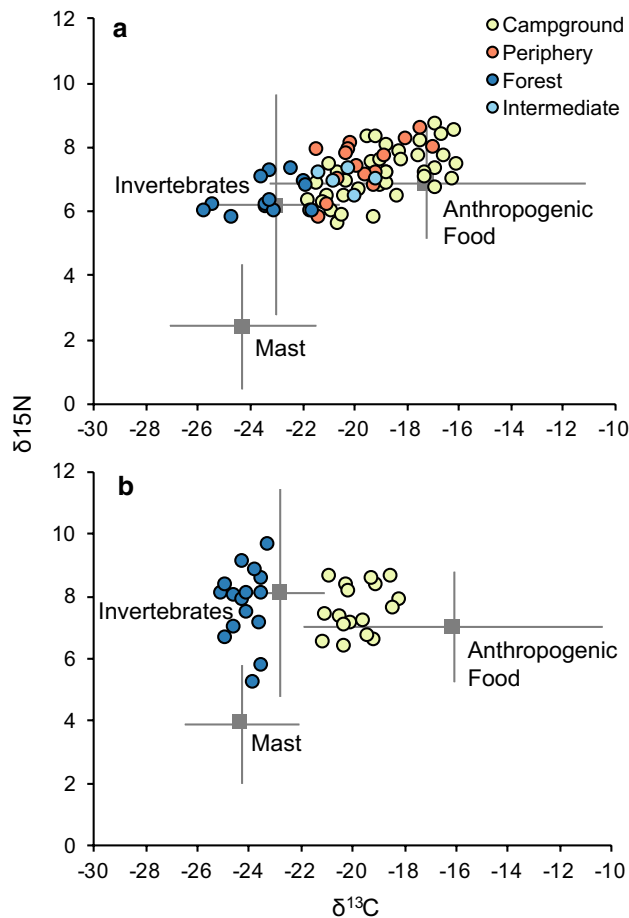


Fig. 1 $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope ratios of individual Steller's jays based on feather samples (circles) and their potential diet sources, sampled during the breeding season in **a** Big Basin Redwoods State Park, 2011–2013 ($n = 72$), and **b** Butano State Park, 2012–2013 ($n = 33$). Diet sources show mean with error bars depicting the standard deviation

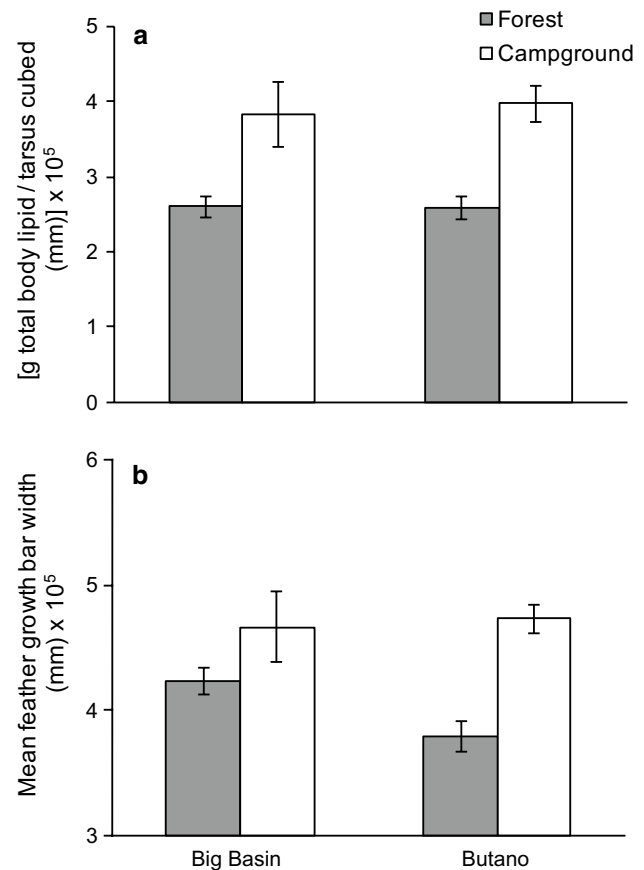


Fig. 2 Mean $\pm$ SE total body lipids **a** and mean $\pm$ SE feather growth bar width **b** with respect to body size (tarsus length cubed) of Steller's jays sampled in Big Basin and Butano State Parks, 2012–2013 ($n = 45$) at forest (filled) and campground (unfilled) sites

date and sex: $F_{1,34} = 0.34$, $P = 0.56$). Feather growth bar width was different among years (ANOVA, $F_{1,32} = 6.27$, $P = 0.02$), but did not differ between parks and sexes (park: $F_{1,32} = 2.49$, $P = 0.12$; sex: $F_{1,32} = 0.28$, $P = 0.59$).

Density and reproductive rates

AHY density was significantly greater in Big Basin campgrounds (4.33 jays/ha $\pm$ 0.91) than at forest sites (0.70 jays/ha $\pm$ 0.22) based on June point counts ($F_{1,17} = 855.58$, $P < 0.01$; Fig. 3a). HY densities were significantly greater in campgrounds (3.30 jays/ha $\pm$ 0.82) in August than at forest sites (0.18 jays/ha $\pm$ 0.08; Fig. 3a). Reproductive rates, as indexed by the ratio of August HY to June AHY density, were threefold greater in campgrounds (0.76 $\pm$ 0.22) than at forest sites (0.25 $\pm$ 0.12; $F_{1,2} = 990.02$, $P < 0.01$, Fig. 3b). While we observed two sibling HY jays that were the offspring of a radio-marked jay moving from forest to campground sites in July, we estimated that such movements only resulted in a small upward bias in campground HY:AHY ratios that were unlikely to impact our inference of greater reproductive rates in campground than forest sites. Specifically, if the 22% increase that we observed in AHY densities from June (4.33 jays/ha) to August (5.30 jays/ha) was the result of dispersal from forest sites, and the proportion of these dispersers that brought HY offspring with them was the same as we estimated for jays radio-marked at forest sites (20%), the “true” campground HY:AHY ratio would be 0.67 and thus 2.8 times greater than at forest sites.

Home range size and overlap

We radio-marked a total of 62 AHY jays in Big Basin, 50 in campgrounds and 12 at forest sites ($n = 45$ males, $n = 17$ females). We obtained an average of 34.4 locations per individual (range: 31–40) and tracked individuals for an

average of 87 days (range: 62–124 days). Five individuals captured at forest sites made regular movements to campgrounds to make use of anthropogenic food and hereafter are referred to as “intermediate jays”. Therefore, we compared home range size among all four groups of jays (forest, intermediate, periphery, and campground jays) using a two-way ANOVA with sex as an additional factor and log-transformed home range size for normality. Home range size was different among habitats ($F_{3,61} = 49.38$, $P < 0.01$) but not between sexes ($F_{1,61} = 1.09$, $P = 0.30$). Mean home range size was 5.40 ha $\pm$ 0.62 for campground jays, 43.8 ha $\pm$ 18.7 for forest jays, 88.3 ha $\pm$ 45.8 for periphery jays, and 276.8 ha $\pm$ 91.1 for intermediate jays. Post hoc t tests of least-square means of home range size indicated that all pairwise comparisons were highly significant (all P s < 0.01) except between forest and periphery jays ($P = 0.62$).

Male AHY jays radio-marked in the same campground and breeding season exhibited a high degree of home range overlap based on a qualitative examination of relocation data (Fig. 4a). Indeed, home range overlap among AHY jays was greater in campgrounds (median campground UDOI = 0.45, $n = 34$ pairs) than at forest sites (median forest UDOI = 0.07, $n = 6$ pairs; $U = 156$, $P < 0.01$; Fig. 4b).

Experimental tests of agonistic interactions

Most pairwise interactions (65%, $n = 438$) observed among banded Steller’s jays during experimental feeding trials involved agonistic behaviors (i.e., score > 0 ; Fig. 5a). The mean agonistic score across all 36 trials was 2.7. However, the intensity of agonistic interactions weakened over the breeding season ($F_{1,635} = 29.50$, $P < 0.01$; Fig. 5b). Our analysis of dominance hierarchies of male Steller’s jays at nearby picnic tables indicated a linear and stable social rank of each individual and revealed fine-scale shifts in dominance among the picnic tables (Fig. 5c). Individual

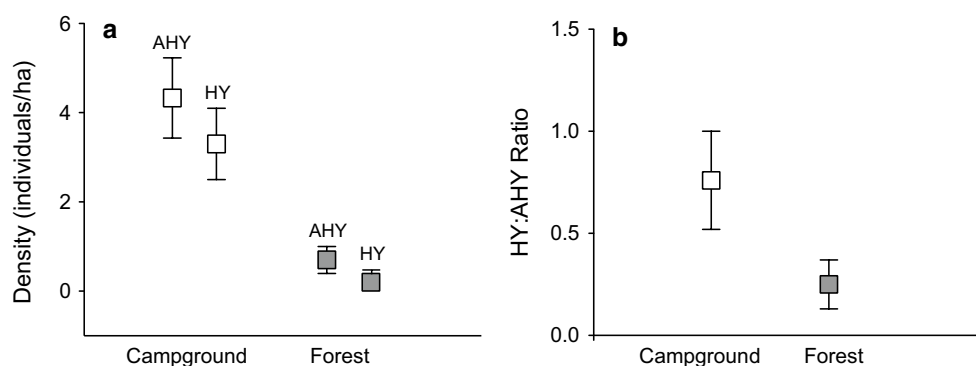


Fig. 3 Population density estimates for Steller’s jays in Big Basin Redwoods State Park campgrounds (a) and forest sites (b), grouped by age class, 2011–2013, and c HY-to-AHY age ratios for forest (filled) and campground (unfilled) sites

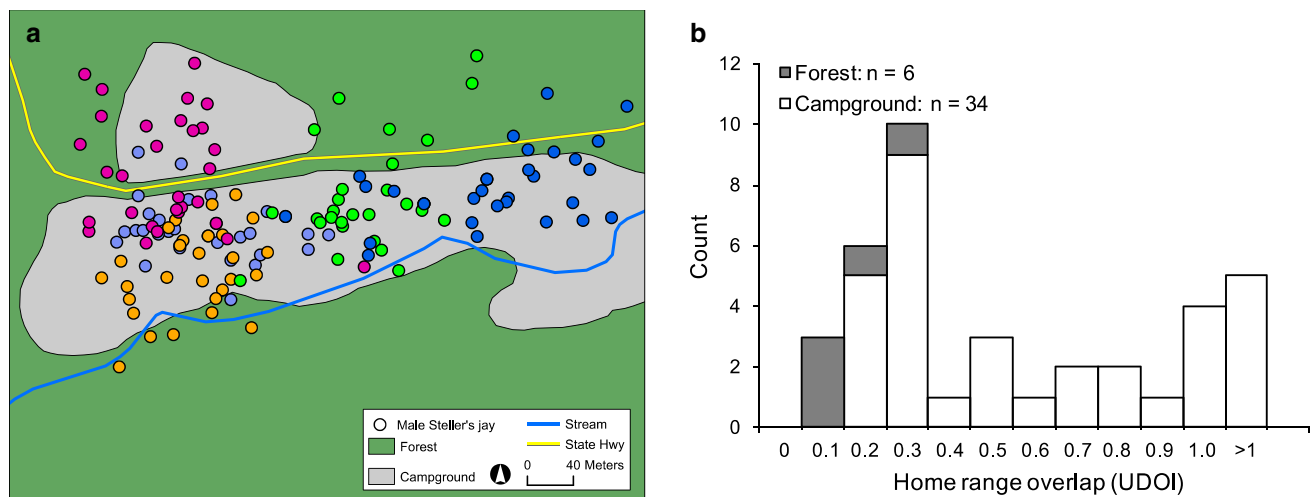


Fig. 4 **a** Home range overlap between five AHY male Steller's jays at Bloom's Creek campground radio-tracked during the 2011 breeding season in Big Basin Redwoods State Park. Colored points correspond to individual jays and **b** pairwise index of home range overlap

(utilization distribution overlap index or UDOI) for male AHY Steller's jays in Big Basin Redwoods State Park forest sites (filled bars; $n = 6$, including two female jays to increase sample size) and campgrounds (unfilled bars; $n = 34$), 2011–2013

male jays ($n = 7$) were determined to be dominant over other jays ($n = 5$) based on the number and outcome of agonistic interactions (win versus loss; Online Resource 4). In general, high-ranking jays supplanted subordinates at individual picnic tables much more frequently than being supplanted themselves, and were thus deemed dominant at those locations (Online Resource 4).

Discussion

A priori predictions (Table 1) supported the hypothesis that Steller's jays were under-matched to resource subsidies present within campgrounds. In particular, jays in campgrounds were enriched in $\delta^{13}\text{C}$, indicating that these sites provided a source of anthropogenic foods from the ~100,000 visitors per year that camp and consume food in Big Basin and Butano campgrounds (California State Parks, unpubl. data). Moreover, jays in campgrounds tended to be in better body condition, as indicated by both lipid stores and feather growth bars, presumably as a result of these resource subsidies. Improved body condition, in turn, appeared to promote higher reproductive output compared to putatively unsubsidized jays at nearby forest sites. We were unable to compare survival rates between habitats, given that forest jays were not habituated to humans, resulting in a modest sample size of individuals radio-marked in this habitat ($n = 12$). In principle, higher survival rates in forest than in campground jays could compensate for greater reproductive rates in campground jays, leading to similar fitness between the two habitats. Indeed, survival rates differ between subsidized and unsubsidized habitats in

other bird species (Evans et al. 2015), often with greater top-down effects and lower survival in urban systems (Loss et al. 2014). However, our study differs from studies of subsidized bird populations in urban systems as: (1) campgrounds were small in extent and embedded within the broader forested landscape (a single raptor home range could encompass all sampled areas in both habitats) and (2) cats were not present, suggesting that appreciable differences in predation pressures may not exist between the two habitats. Moreover, annual survival rates for HY and AHY jays in campgrounds are high based on radio-telemetry ($S_{\text{HY}} = 0.74$, $n = 50$ and $S_{\text{AHY}} = 0.92$, $n = 30$; EHW, unpubl. data), indicating that survival in forest jays would need to be exceptionally high to compensate for the estimated ~3× greater reproductive rates in campground jays. Therefore, we suggest that jay total fitness was greater in campgrounds than forests and that, collectively, our results indicate that campgrounds provided higher quality habitat for jays than forests.

The pattern of under-matching to locally abundant resources that we observed in Steller's jays was consistent with expectations under an ideal despotic distribution. Under-matching, however, was observed despite high densities and space use overlap in campgrounds, even though negative density dependence and the absence of territorial exclusion are key mechanisms believed to promote resource matching or over-matching (Ridley et al. 2004). We also observed regular agonistic interactions and space use contraction in the presence of food subsidies within campgrounds, both of which are expected to reduce the benefits of selecting resource-rich habitats and potentially homogenize fitness of individuals occurring in habitats

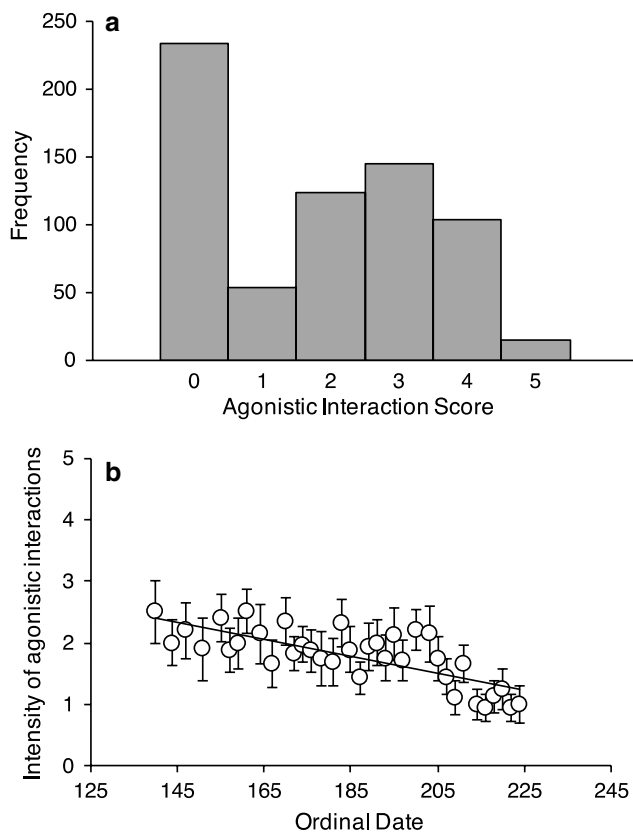
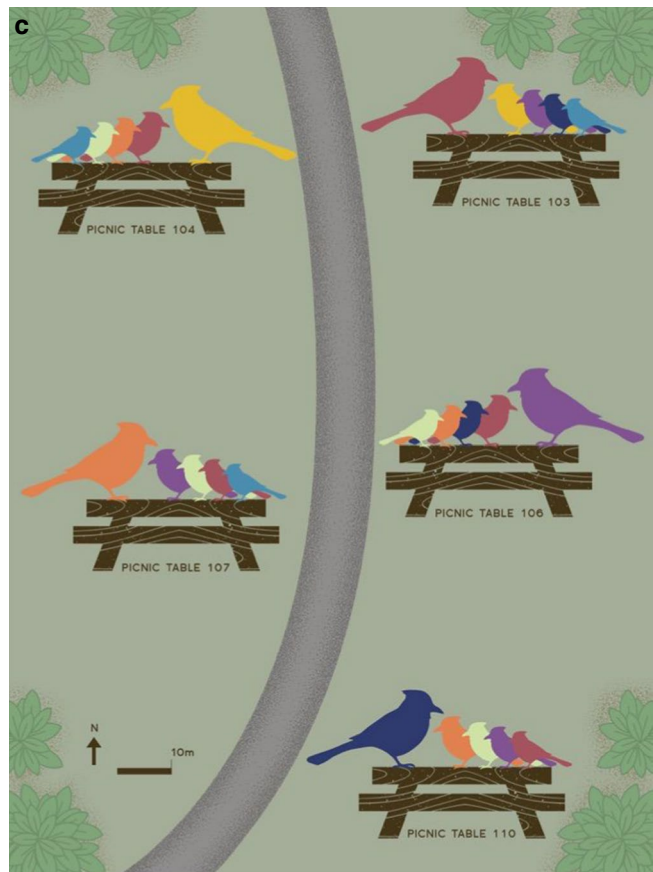


Fig. 5 **a** Frequency of agonistic interactions between Steller's jay dyads conducted during experimental trials. Interactions were scored on a scale from 0 (no aggression) to 5 (fighting); **b** mean intensity of aggressive interactions between Steller's jay dyads with respect to ordinal date for 36 experimental trials conducted during the 2014 breeding season in Big Basin Redwoods State Park campgrounds; and **c** dominance hierarchies of male Steller's jays ($n = 7$) at nearby



picnic tables ($n = 5$) in a campground in Big Basin Redwoods State Park. Individual jays were ranked based on the number and outcome of each agonistic interaction between dyads, which were determined during 36 experimental trials in 2014. Each color represents an individual and the size of each jay represents rank, from largest (dominant) to smallest (least dominant) at each picnic table (color figure online)

with different levels of resources (Shochat et al. 2006). Thus, the site-related dominance structure that both we and previous studies (Brown 1963) have described in Steller's jays appears to have led to fitness patterns consistent with an ideal despotic distribution, despite also facilitating behavioral processes typically believed to lead to the breakdown of this form of habitat selection and, instead, promote resource matching or overmatching.

How, then, is under-matching maintained in jays using subsidized habitats? Collectively, the results of our experimental evaluation of dominance hierarchies, stable isotope-based dietary assessments, and space use analyses indicated that socially dominant jays in campgrounds likely limited, but did not entirely exclude subordinate individuals from access to anthropogenic foods. Our experiment and associated behavioral observations revealed that even subordinate individuals were able to access some anthropogenic foods (Online Resource 4). Moreover, periphery and intermediate

jays, both of which were presumably nesting and roosting in surrounding forests (West et al. 2016), were as enriched for $\delta^{13}\text{C}$ as "true" campground jays. While we did not have direct evidence that individuals in these two groups were subordinates, they were unlikely to be at the top of dominance hierarchies given that site-related dominance in Steller's jays typically attenuates from breeding sites (Brown 1963). Finally, all periphery and intermediate jays were more enriched for $\delta^{13}\text{C}$ than the most enriched forest jays (Fig. 1). These results are perhaps unsurprising given that dominant individuals must attend nests and young and are unlikely to be able to contest access to food by subordinate individuals at all times. The behavioral plasticity and cognitive abilities of corvids may also allow even putatively subordinate jays to take advantage of locally abundant resources in campgrounds in spite of agonistic interactions, as corvids possess episodic-like memory, can predict the behavior of conspecifics (reviewed in Emery et al. 2007),

and can learn to recognize individual conspecifics and humans (Cornell et al. 2012). In sum, food subsidies appear to provide a significant food source regardless of social status and jays using campgrounds may mostly be “winners” rather than mostly “losers” as Shochat (2004) proposed for subsidized bird populations. The net result being that jays in campgrounds appear to acquire sufficient human food resources, such that density dependence effects, even at remarkably high densities, do not equalize population-level reproductive rates between subsidized and unsubsidized habitats.

Nevertheless, in the absence of strict territoriality, habitat selection theory suggests that jays in forests were expected to exploit anthropogenic foods in campgrounds given that there appears to be a surplus of such resources on a per-capita basis (i.e., reproductive rates are greater in campgrounds). In other words, why were jay densities in campgrounds not even higher than estimated, such that density dependence homogenized reproductive rates between habitats? Jays that exclusively used forests may have had imperfect knowledge of available resources in campgrounds. Alternatively, energy costs associated with traveling beyond the general vicinity of nests, as well as the risk of leaving nests unattended, may reduce the fitness benefits of movements to campgrounds. Indeed, while movements from forests to campgrounds were detected in jays captured 1–2 km from campgrounds, similar movements by the broader pool of jays occurring beyond 2 km are less likely for the reasons described above.

While the under-matching of dense Steller’s jay populations to resource subsidies was perhaps unexpected based on habitat selection theory and our observations of jay behavior and social system, the response of synanthropic species to resource subsidies in general appears to be somewhat idiosyncratic. A meta-analysis suggested that subsidized urban birds tend to have comparatively low reproductive rates and thus are overmatched to food subsidies, a finding that the authors attributed to competition over lower quality food resources resulting from a relative paucity of invertebrates (Shochat 2004; Shochat et al. 2006). Nevertheless, many individual studies have detected higher reproductive output in subsidized habitats (Horak and Lebreton 1998; McGowan 2001), whereas others have observed that mean reproductive output in subsidized populations was matched to the distribution of food resources (Rodewald and Shustack 2008). Distangling the mechanisms behind differences in results among studies is challenging because of differing methodologies and sample sizes, differences in species life history, and heterogeneity in environmental conditions across studies. However, our system differed from the growing body of studies of birds in subsidized urban habitats in that our study area was embedded within a much broader unsubsidized landscape; moreover,

other than the prevalence of human foods, campgrounds and surrounding forests were similar in structure and vegetation conditions. Indeed, the diet of campground jays was composed of up to 20% invertebrates (West et al. 2016) and it is, therefore, possible that anthropogenic food subsidies in campgrounds provided a caloric benefit without an associated reduction in overall nutritional quality to jay diets. This finding may extend to synanthropes in protected areas with access to both natural and human foods, and it is unlikely that Shochat’s (2004) ecological trap principle extends to such systems. Rather, local food subsidies within protected areas may provide fitness benefits to a broader array of synanthropic species.

Our study has novel implications for the management of Steller’s jays in protected areas, because population growth rates for species that select habitats according to an IDD are expected to be more sensitive to the removal of high-quality habitats than species conforming to an IFD (Haché et al. 2013). As such, reducing the quality of high-quality sites—i.e., campgrounds with heavy human food subsidies—has the potential to be an effective approach for reducing jay population size and growth rates within marbled murrelet nesting habitat. Presumably, doing so could reduce not just locally high jay densities in campgrounds, but potentially the number of offspring produced in campgrounds that ultimately disperse to establish breeding territories in other forested areas used by murrelets. In a separate study, 60% of radio-marked HY jays ($n = 40$) produced in campgrounds dispersed into murrelet nesting habitat during their hatch year (EHW, unpubl. data). Curbing human food subsidies is challenged by the large numbers of campers in these areas; in fact, jays occurred at densities, had reproductive rates, and were in good body condition in campgrounds despite extensive and ongoing visitor education and trash management efforts. Nevertheless, changing human behavior through a combination of education, enforcement, and improved trash management has been successful in other systems (Hopkins et al. 2014), and greater efforts to increase public awareness of the consequences of feeding jays and other corvid predators could benefit declining murrelet populations. Relocating campgrounds could be an effective method for reducing high jay densities at specific sites regularly used by nesting murrelets (Peery et al. 2004), but poses political challenges for park managers tasked both with providing recreational opportunities for park visitors and preserving natural resources. Moreover, without concomitant reductions in food subsidies at relocated campgrounds, these sites may still act as source habitats that produce large numbers of young jays that disperse into murrelet nesting habitat within parks (Marzluff and Neatherlin 2006).

Our results also have implications for the management of synanthropic species in general. The fact that we observed

an IDD in a species that does not exhibit strict territoriality indicates that non-territorial species do not necessarily conform to an IFD. Conversely, Haché et al. (2013) showed that territorial species can exhibit patterns of habitat selection consistent with an IFD, which also contrasts to theoretical expectations (Ridley et al. 2004). Thus, removing high-quality sites may not necessarily be the most effective control strategy for territorial species, whereas such an approach may be effective for some non-territorial species. Moreover, these results suggest that predicting general patterns in distribution and fitness for generalist predators occurring in heterogeneous landscapes based on their social system may be challenging. Rather, integrative autecological studies of foraging ecology, space use, body condition, and demography may be required to develop effective management strategies for overabundant species.

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Author contribution statement EHW and MZP conceived the idea, design, and experiment. EHW performed the experiment. EHW and MZP analyzed the data and wrote the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Animal ethics All applicable institutional and national guidelines for the care and use of animals were followed. The research was conducted under animal ethics permit A01424-0-01-10 and scientific collection permit SC-011200.

Data availability The data sets analyzed during the current study are available from the corresponding author on reasonable request.

References

- Bearhop S, Waldron S, Votier SC, Furness RW (2002) Factors that influence assimilation rates and fractionation of nitrogen and carbon stable isotopes in avian blood and feathers. *Physiol Biochem Zool* 75:451–458
- Beckmann JP, Berger J (2003) Using black bears to test ideal-free distribution models experimentally. *J Mammal* 84:594–606
- Beyer HL (2012) Geospatial Modelling Environment (version 0.7.3.0) (software). <http://www.spatialecology.com/gme>. Accessed 9 Mar 2016
- Brown JL (1963) Aggressiveness, dominance and social organization in the Steller Jay. *Condor* 65:460–484
- Buehler DA, Fraser JD, Fuller MR et al (1995) Captive and field-tested radio transmitter attachments for bald eagles. *J Field Ornithol* 66:173–180
- Calenge C (2006) The package “adehabitat” for the R software: a tool for the analysis of space and habitat use by animals. *Ecol Model* 197:516–519
- Cornell HN, Marzluff JM, Pecoraro S (2012) Social learning spreads knowledge about dangerous humans among American crows. *Proc R Soc Lond B Biol Sci* 279:499–508
- Duhem C, Roche P, Vidal E, Tatoni T (2008) Effects of anthropogenic food resources on yellow-legged gull colony size on Mediterranean islands. *Popul Ecol* 50:91–100
- Emery NJ, Seed AM, von Bayern AMP, Clayton NS (2007) Cognitive adaptations of social bonding in birds. *Philos Trans R Soc B Biol Sci* 362:489–505
- Evans BS, Ryder TB, Reitsma R et al (2015) Characterizing avian survival along a rural-to-urban land use gradient. *Ecology* 96:1631–1640. doi:10.1890/14-0171.1
- Fagen R (1987) A generalized habitat matching rule. *Evol Ecol* 1:5–10
- Fedriani JM, Fuller TK, Sauvajot RM (2001) Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. *Ecography* 24:325–331
- Fieberg J, Kochanny CO (2005) Quantifying home-range overlap: the importance of the utilization distribution. *J Wildl Manag* 69:1346–1359
- Fretwell SD (1972) *Populations in a seasonal environment*. Princeton University Press, Princeton
- Fretwell SD, Lucas JS (1970) On territorial behavior and other factors influencing habitat distribution in birds. *Theor Dev Acta Biotheor* 19:16–36
- Gitzen RA, Millspaugh JJ, Kernohan BJ (2006) Bandwidth selection for fixed-kernel analysis of animal utilization distributions. *J Wildl Manag* 70:1334–1344
- Griffiths R, Double MC, Orr K, Dawson RJG (1998) A DNA test to sex most birds. *Mol Ecol* 7:1071–1075
- Grubb JTC (2006) *Ptilochronology: feather time and the biology of birds*. Oxford University Press, Oxford
- Haché S, Villard M-A, Bayne EM (2013) Experimental evidence for an ideal free distribution in a breeding population of a territorial songbird. *Ecology* 94:861–869
- Hopkins JB, Koch PL, Ferguson JM, Kalinowski ST (2014) The changing anthropogenic diets of American black bears over the past century in Yosemite National Park. *Front Ecol Environ* 12:107–114
- Horak P, Lebreton J-D (1998) Survival of adult Great Tits *Parus major* in relation to sex and habitat: a comparison of urban and rural populations. *Ibis* 140:205–209
- Johnston RF (2001) Synanthropic birds of North America. In: Marzluff JM, Bowman R, Donnelly R (eds) *Avian ecology and conservation in an urbanizing world*. Kluwer Academic Publishers, Boston, pp 49–67
- Kennedy M, Gray RD (1993) Can ecological theory predict the distribution of foraging animals? A critical analysis of experiments on the ideal free distribution. *Oikos* 68:158–166
- Kernohan BJ, Gitzen RA, Millspaugh JJ (2001) Analysis of animal space use and movements. In: Marzluff JM, Millspaugh JJ (eds) *Radio tracking and animal populations*. Academic Press, San Diego, pp 125–166
- Loss SR, Will T, Loss SS, Marra PP (2014) Bird-building collisions in the United States: estimates of annual mortality and species vulnerability. *Condor* 116:8–23. doi:10.1650/CONDOR-13-090.1
- Luginbuhl JM, Marzluff JM, Bradley JE et al (2001) Corvid survey techniques and the relationship between corvid relative abundance and nest predation. *J Field Ornithol* 72:556–572
- Marzluff JM, Neatherlin E (2006) Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biol Conserv* 130:301–314

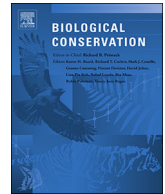
- McGowan KJ (2001) Demographic and behavioral comparisons of suburban and rural American Crows. In: Marzluff JM, Bowman R, Donnelly R (eds) Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, MA
- Newsome SD, Garbe HM, Wilson EC, Gehrt SD (2015) Individual variation in anthropogenic resource use in an urban carnivore. *Oecologia* 178(1):115–128
- Pearson SF, Levey DJ, Greenberg CH, del Rio CM (2003) Effects of elemental composition on the incorporation of dietary nitrogen and carbon isotopic signatures in an omnivorous songbird. *Oecologia* 135:516–523
- Peery MZ, Beissinger SR, Newman SH et al (2004) Applying the declining population paradigm: diagnosing causes of poor reproduction in the marbled murrelet. *Conserv Biol* 18:1088–1098. doi:10.1111/j.1523-1739.2004.00134.x
- Peery MZ, Becker BH, Beissinger SR, Burger AE (2007) Age ratios as estimators of productivity: testing assumptions on a threatened seabird, the marbled murrelet (*Brachyramphus marmoratus*). *Auk* 124:224–240
- Powell LA (2007) Approximating variance of demographic parameters using the delta method: a reference for avian biologists. *The Condor* 109:949–954
- Pyle P, Howell SNG, Yunkin RP, DeSante DF (1997) Identification guide to North American passerines. Slate Creek Press, Bolinas, California
- R Development Core Team (2014) R: a language and environment for statistical computing. R Foundation for Statistical Computing
- Ralph CJ, Droege S, Sauer JR (1995) Managing and monitoring birds using point counts: Standards and applications. U.S. Forest Service, Pacific Southwest Research Station, Albany, California
- Ridley J, Komdeur J, Sutherland W (2004) Incorporating territory compression into population models. *Oikos* 105:101–108
- Rodewald AD, Shustack DP (2008) Consumer resource matching in urbanizing landscapes: are synanthropic species over-matching. *Ecology* 89:515–521
- Sauer JR, Hines JE, Fallon JE, et al (2014) Breeding Bird Survey Summary and Analysis 1966–2013. Version 01.30.2015. In: USGS Patuxent Wildl. Res. Cent. Laurel MD. <http://www.mbr-pwrc.usgs.gov/bbs/bbs.html>. Accessed 28 May 2015
- Shochat E (2004) Credit or debit? Resource input changes population dynamics of city-slicker birds. *Oikos* 106:622–626
- Shochat E, Warren P, Faeth S et al (2006) From patterns to emerging processes in mechanistic urban ecology. *Trends Ecol Evol* 21:186–191. doi:10.1016/j.tree.2005.11.019
- Sibly RM, Jones PJ, Houston DC (1987) The use of body dimensions of lesser black-backed gulls *Larus fuscus* to indicate size and to estimate body reserves. *Funct Ecol* 1:275–279
- Sih A, Ferrari MCO, Harris DJ (2011) Evolution and behavioural responses to human-induced rapid environmental change. *Evol Appl* 4:367–387
- Swihart RK, Slade NA (1985) Testing for independence of observations in animal movements. *Ecology* 66(4):1176–1184
- Thomas L, Laake JL, Strindberg S et al (2004) Distance 4.1 Release 2. Research unit for wildlife population assessment. (online)
- Vigallon SM, Marzluff JM (2005) Is nest predation by Steller's jays (*Cyanocitta stelleri*) incidental or the result of a specialized search strategy? *Auk* 122:36–49
- Walker LE, Marzluff JM (2015) Recreation changes the use of a wild landscape by corvids. *Condor* 117:262–283
- Webb WC, Marzluff JM, Hepinstall-Cymerman J (2011) Linking resource use with demography in a synanthropic population of common ravens. *Bio Conserv* 144(9):2264–2273
- West EH, Henry WR, Goldenberg W, Peery MZ (2016) Influence of food subsidies on the foraging ecology of a synanthropic species in protected areas. *Ecosphere* 7(10):e01532

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When protected areas produce source populations of overabundant species

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ABSTRACT

While protected areas are a cornerstone of biodiversity conservation, human activities in these areas can negatively affect native species in direct and indirect ways. However, the potential effects of food subsidies provided by visitors on the local- and landscape-scale population dynamics of overabundant species, and how these effects may be augmented by human development outside of parks, are largely unexplored. Here, we investigated how human foods at heavily-visited sites within California parks benefited populations of Steller's jays (*Cyanocitta stelleri*), an overabundant predator of a threatened seabird that nests in remnant old-growth forests. Our study population was heavily subsidized with both juveniles and adults consuming substantial amounts of human foods by biomass (46% and 57%, respectively), as indicated by stable isotope analyses. Juvenile survival, adult survival, and fecundity—estimated from radio-telemetry data—were high and the population was projected to grow rapidly (25% annually). Most juveniles dispersed from parks following seasonal declines in human visitation to areas with high housing densities and more stable resources—with almost half of dispersers returning to old-growth forests the following breeding season. Thus, we found that local food subsidies at heavily-visited sites promoted source populations of jays that may bolster populations in old-growth forests at broader spatial scales, and that this effect was likely augmented by more temporally stable resources in developed areas outside of parks during the nonbreeding season. These novel results indicate that curbing populations of overabundant predators may require reductions in food subsidies both within protected areas and surrounding landscapes.

1. Introduction

While protected areas are a cornerstone of global biodiversity conservation (Watson et al., 2014), they face a host of challenges from human recreational activities that can affect species, biological communities, and ecosystems in undesirable ways (Hansen and DeFries, 2007; Wood et al., 2014). These challenges are unlikely to diminish in magnitude or complexity as human populations grow in proximity to protected areas, increasing both the intensity of consumptive and non-consumptive uses within these sites (McDonald et al., 2008; Radeloff et al., 2010). As a result, the conservation benefits of many protected areas have been compromised (Radeloff et al., 2010; Wood et al., 2014) and many have called for a redoubling of conservation efforts intended to maintain and promote biodiversity within protected areas (Carwardine et al., 2012; Laurance et al., 2012; McCarthy et al., 2012). Ensuring the effective stewardship of natural resources in protected areas, however, requires an improved understanding of the impacts of human activities on biodiversity in these areas (Hansen and DeFries, 2007).

While research in the field of “recreation ecology” has typically

focused on the direct impacts of human activities on species and ecological systems in protected areas (Monz et al., 2013), there is an increasing recognition of the role that recreation—and associated food subsidies—play in aggregating and promoting unnaturally high densities of human-associated wildlife species at relatively small, but heavily-visited sites in protected areas (Hopkins et al., 2014; Walker and Marzluff, 2015). Elevated densities of these synanthropic species can promote biotic interactions that result in indirect, negative effects on the rarer, more sensitive species protected areas are intended to conserve (Bradley et al., 2003; Gutzwiller and Riffell, 2008; Marzluff and Neatherlin, 2006; Robb et al., 2008). However, little is known about the extent to which local food subsidies in protected areas may benefit overabundant synanthropic species (and impact sensitive species) at broader spatial scales via source-sink dynamics. Moreover, the timing of peak resource subsidization (i.e., human activities) in such landscapes often coincides with animal breeding seasons in temperate ecosystems such that human-provided foods may benefit reproductive activities (Chamberlain et al., 2009; Robb et al., 2008), but not necessarily year-round survival (Brittingham and Temple, 1988; Orell, 1989). In such cases, synanthropes may need to switch to natural food

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sources or disperse to other areas, such as more urbanized landscapes that provide seasonally stable resources (Robb et al., 2008). Nevertheless, how synanthropes respond behaviorally to spatio-temporal variability in resource subsidies, as well as the fitness consequences of heterogeneously distributed resources, is not well understood.

Steller's jays (*Cyanocitta stelleri*) are synanthropic species that are found in a variety of coniferous landscapes in western North America, but are particularly common in fragmented and high-contrast edge settings near urban, suburban, and recreation areas (Brand and George, 2001; Marzluff et al., 2004; Raphael et al., 2002; Sieving and Willson, 1998). Steller's jays prey on the nests of a variety of native song birds (Vigallon and Marzluff, 2005) and have gained particular attention of the conservation community as a nest predator of the marbled murrelet (*Brachyramphus marmoratus*) (Luginbuhl et al., 2001; Sieving and Willson, 1998), an iconic, US-threatened seabird that nests in remnant stands of old-growth forest in recreation areas such as state and national parks (Nelson, 1997). In central California, which harbors a genetically distinct and particularly imperiled population of murrelets, 75% of murrelet nesting habitat occurs within parks (Halbert and Singer, 2017). In this region, nest predation rates are high (67 to 81%) for murrelets, with most predation attributed to jays and other corvids, which contributes to low murrelet reproductive rates in these areas (Peery et al., 2004; Peery and Henry, 2010). Moreover, population viability analyses indicate that reducing corvid predation has the potential to substantially reduce local extinction probabilities for murrelets (Peery and Henry, 2010). Steller's jay densities are particularly high in park campgrounds due to the availability of seasonally abundant human food subsidies provided by park visitors during the jay and murrelet breeding season (ca. May to August) (Marzluff and Neatherlin, 2006; West et al., 2016; West and Peery, 2017). Indeed, our previous work indicates that subsidized jays breeding in campgrounds tend to be in better body condition than unsubsidized jays breeding in surrounding forests and that the ratio of juvenile to adult individuals (an index of productivity) is nearly three times greater in campgrounds than surrounding forests (West and Peery, 2017). These local-scale subsidies, then, have the potential to produce source populations of jays that produce excess young that disperse into old-growth forests and murrelet nesting habitat at broader scales. However, park visitation, as well as associated human subsidies, decline steeply in September after the jay breeding season, potentially leading to resource scarcities that could curb population growth or require that jays disperse out of parks to exploit more temporally stable human-provided food subsidies (West et al., 2016). Addressing both of these uncertainties would benefit the development and refinement of a host of conservation measures being taken to limit jay impacts on marbled murrelets in parks (Gabriel and Goghtly, 2014).

To understand how spatio-temporal patterns of food subsidies at heavily-visited sites in protected areas influence jay population dynamics and behavior at both local and landscape scales, we (i) used stable isotope analyses to quantify age-specific consumption of human foods by jays; (ii) characterized patterns of juvenile and adult dispersal from these sites during the non-breeding season; and (iii) assessed demographic characteristics (reproductive, survival, population growth rates) of jays at these sites. Collectively, our results indicate that seasonal pulses of food subsidies at these sites, in conjunction with more temporally stable resources from surrounding developed areas, produced source populations of jays that potentially threaten sensitive species such as marbled murrelets at broader spatial scales.

2. Materials and methods

2.1. Study area

Our work was conducted in the redwood and redwood-Douglas fir forests of the Santa Cruz Mountains, central California, USA. Capture-sampling and radio-marking of Steller's jays were conducted in heavily-

visited campgrounds (~770,000 visitors/year) in Big Basin Redwoods State Park (hereafter Big Basin). This protected area contains approximately half of the remaining old-growth forest that constitutes nesting habitat for marbled murrelets in this region, and capture sites were located near the center of these forests. Half of all previously-located murrelet nests, as determined by tracking radio-marked birds tagged at sea to nesting locations, occurred within 1 km of these campgrounds in this region (Peery et al., 2004). Radio-tracking of jay movements during the non-breeding season was conducted outside of Big Basin and throughout the Santa Cruz Mountains, which includes a mosaic of state and county parks, privately-held lands, and second-growth forests. These areas are interspersed by varying amounts of development, from highly urban, exurban and rural.

2.2. Captures, sampling, and radio-tracking

We captured a total of 116 jays from May to August from 2012 to 2018 using mistnets (Avinet, Dryden, NY). We broadcasted jay vocalizations through a portable speaker and placed shelled peanuts near mistnets to attract jays (peanuts were glued to plates to prevent jays from consuming bait and affecting isotope-based diet estimates). Captured jays were banded with a stainless steel U.S. Geological Survey metal band and a unique combination of three colored leg bands. Hatch-year (hereafter HY) individuals were distinguished from after-hatch-year (hereafter AHY) jays based on their distinctive vocalizations such as begging calls, as well as plumage characteristics such as their gray breast feathers (compared to the blue breast feathers of AHYs; (Pyle et al., 1997). Sex was determined using PCR methods on DNA extracted from blood samples (Griffiths et al., 1998). We clipped 50 mm of the first primary feather from individual jays captured in August for stable isotope analyses. To characterize dispersal patterns and survival rates (see below), we fitted 49 HY and 31 AHY individuals captured in August with backpack-mounted radio transmitters (model A1050, Advanced Telemetry Systems, Isanti, Minnesota) that had an expected lifespan of 10 months (i.e. through May the following calendar year); (Buehler et al., 1995). We tracked radio-marked jays from August until the following May in each study year through ground-based telemetry surveys and by flying a fixed-wing aircraft over the Santa Cruz Mountains twice per month and surrounding areas when jays went undetected. When a bird was detected during aerial surveys, we visited the area where the signal originated to obtain a more precise location, observe the individual visually, and determine fate (mortality). An individual was considered to be alive if a visual location was obtained or in a small number of cases where private property prevented a visual observation, ground telemetry indicated that the individual was actively moving. We inferred a mortality when remains were located. We considered jays to be depredated if 1) remains and plucked feathers were found with the transmitter or leg bands; 2) tooth or beak marks were imprinted on the transmitter; or 3) the transmitter was buried. Twelve individuals were removed from dispersal analyses due to mortalities ($n = 10$) or early loss of signals from radios ($n = 2$), the latter of which were also censored from survival analyses. To estimate fecundity rates (see below), we fitted 36 AHY individuals captured from May to early June with the same transmitters but configured with an expected lifespan of three months.

2.3. Assessing the consumption of human food resources

We used stable isotope analysis to quantify the diet of Steller's jays by comparing the isotopic signature ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) of primary feathers to the isotopic signatures of potential diet items. Increased enrichment in $\delta^{13}\text{C}$ in particular is indicative of greater consumption of human foods in this species (West et al., 2016) and wildlife generally (Newsome et al., 2015; Phillips et al., 2005). Feathers integrate the isotopic signature of diet sources during molt (Bearhop et al., 2002; Hobson and Clark, 1992), and primary growth occurs in Steller's jays at

the end of the breeding season in July and August. Because this study was part of a larger research project on Steller's jays, individual feathers from AHY birds were sampled throughout the summer and represent diet sources from the previous year's molt (collected before July of the sampling year) or diet from the year they were sampled (collected during or after July of the sampling year). Individual feathers sampled from HY birds were collected at the time of capture for radio-tagging purposes (August) and represent diet sources from the year they were sampled. We collected jay diet items (invertebrates, berries, acorns, conifer seeds, and human food) at capture sites in Big Basin during the breeding season (2012–2013) following methods in (West et al., 2016). We used the isotopic signature of feather and diet samples (see below) to estimate the proportional contribution of isotopically distinct items to jay diets. We did not include marbled murrelets eggs or nestlings as a potential dietary source in stable isotope analyses of Steller's jay diet as only a very small fraction of jays were likely to have consumed murrelet eggs given the much greater abundance of jays than murrelet nests in our sampling areas (West et al., 2016). In addition, mixing models (see below) tend to attribute some proportion of all dietary sources considered to a consumer's diet, even rare or non-existent ones, in this case potentially overestimating the importance of murrelets in jay diets and thus underestimating more frequently consumed food sources (Parnell et al., 2008; Phillips et al., 2014). Samples were prepared using standard methods (West et al., 2016), and analyzed with a Costech 4010 elemental analyzer attached to a ThermoFinnigan DeltaPlus XP Continuous Flow Isotope Ratio Mass Spectrometer at the Stable Isotope Facility at the University of Wyoming. Results are provided as per mil (parts per thousand [‰]) ratios relative to the international standards of Pee Dee Belemnite (PDB; $\delta^{13}\text{C}$) and atmospheric nitrogen (AIR; $\delta^{15}\text{N}$) with calibrated internal laboratory standards. We adjusted prey isotopic signatures using isotopic correction factors for a passerine diet similar to that of wild Steller's Jays: $+1.8\text{‰}$ (SD = 0.66) for $\delta^{15}\text{N}$, and $+1.5\text{‰}$ (SD = 0.12) for $\delta^{13}\text{C}$ (Pearson et al., 2003). We grouped prey into three isotopically distinct and ecologically relevant source groups: mast/berries, invertebrates, and human foods (West et al., 2016). We used Bayesian mixing models in the software package SIAR (R Development Core Team, 2014) to quantify estimates of HY and AHY diet in terms of biomass assimilated. Bayesian mixing models provide estimates of diet as posterior distributions of likely solutions; we report the 95% credibility interval of these distributions.

2.4. Characterizing dispersal patterns and resource selection

We characterized seasonal dispersal movements of jays from their breeding sites in Big Basin campgrounds by tracking jays radio-marked in August until the following May from a fixed-wing aircraft flown over the Santa Cruz Mountains and surrounding area twice per month (mean number of relocations = 13.5). We employed an operational definition for dispersal where individuals were considered to have “dispersed” if they left old-growth forests surrounding capture sites. Our definition of dispersal was tied to the distribution of murrelet habitat (old growth forest) given one of our primary objectives was to determine how food subsidies in park campgrounds contributes to risk for murrelet populations at a broader spatial scales. Moreover, there was no clear break in the distances individual jays were located from the capture site during the non-breeding season, challenging the ability to classify jays as dispersers or non-dispersers based purely on movement distances. Natal and breeding dispersal were inferred if jays were located outside of murrelet nesting habitat in April and May of the year following radio-marking, a period that coincides with courtship and nesting behaviors in AHY jays and increased social activity among all age classes. In fact, several individuals tagged as HY individuals were observed in May of their second year engaging in nest building activities indicating that locations collected at this time were reasonable representative of natal dispersal movements. For HY individuals we defined *post-fledging dispersal* as the act of departing old-growth forests for non-breeding season

activities and *natal dispersal* (or conversely, *natal fidelity*) as the act of settling outside of old growth the following breeding season (April or May). For AHY individuals, we defined *post-breeding dispersal* as the act of departing a breeding sites in old-growth forests to conduct non-breeding season activities outside of old-growth and *breeding dispersal* (or conversely, *breeding fidelity*) as the act of establishing a breeding territory outside of old-growth the following breeding season.

We used a resource selection function under a use-availability design (Manly et al., 2010) to assess patterns of selection for human housing by HY jays over the August to May tracking period (we excluded AHY jays because these individuals generally remained in areas with low housing densities; see below). We quantified used habitat for each jay with 410-m circular buffers surrounding estimated jay locations, which represented the mean home range size of jays in the region (West et al., 2016). We defined the area available for use as the 95% minimum convex polygon (MCP) containing all individual locations and associated buffers. We generated an equal number of randomly distributed points within the MCP of available area and created 410-m circular buffers surrounding each of these points. We used spatial housing data for the Santa Cruz Mountains (Wilmers et al., 2013) to estimate the number of houses intersecting each used and available buffer within ArcGIS (ESRI, 2014). We performed habitat selection analyses separately for (i) each bi-monthly group and (ii) “dispersers” and “non-dispersers” using logistic regression models in R (R Development Core Team, 2014), where housing density (houses/km²) was the independent variable and jay versus random location was the dependent variable (coded as 1 and 0, respectively). Locational data were pooled into bimonthly periods to account for small sample sizes. Separate logistic regression analyses were conducted for “dispersers” and “non-dispersers”, as defined above, to characterize differences in habitat selection patterns between these two groups. Selection was inferred if the slope coefficient for housing density was positive and significantly greater than zero, whereas avoidance was inferred if the slope coefficient was negative and significantly less than zero.

2.5. Demographic assessment

We estimated monthly survival rates for HY and AHY jays radio-marked in August using known fate models (Pollock et al., 1989) based on individual fates (alive or dead) determined during relocations. For each stage class, we evaluated support for a suite of 9 models containing various additive combinations of sex, bi-monthly period, and year effects as well as a global model using program MARK (White and Burnham, 1999). We used AIC_C to select the most supported model (Burnham and Anderson, 2003). We estimated annual survival rates by raising monthly estimates to the 12th power and calculated sampling variances with the delta method (Seber, 1987). We estimated annual fecundity based on visual counts of the number of HY jays being provisioned by each of 36 AHY jays that were radio-marked in May, which were tracked and observed almost daily throughout the breeding season. Specifically, we divided the mean number of young observed per AHY female by two under the assumption of an even offspring sex ratio. We estimated the annual rate of population growth (λ) for Steller's jays in campgrounds using a two-stage (HY and AHY), female-based post-breeding matrix model (Caswell, 1989) assuming age-of-first breeding of 1 year (Brown, 1964):

$$\lambda = \begin{bmatrix} \varphi_{HY} & \varphi_{AHY} m_{AHY} \\ 0 & \varphi_{AHY} \end{bmatrix}$$

where φ_{HY} = annual HY survival, φ_{AHY} = annual AHY survival, and m = annual fecundity.

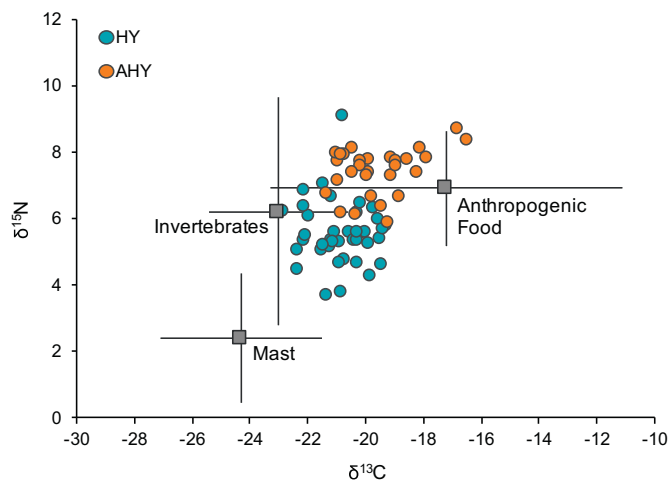


Fig. 1. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope ratios of radio-marked hatch-year (HY; $n = 39$) and after-hatch-year (AHY; $n = 29$) Steller's jays based on feather samples and potential diet sources, sampled during the breeding season (May–August) in Big Basin Redwoods State Park campgrounds, 2012–2013. Diet sources show mean isotopic values with error bars representing standard deviations.

3. Results

3.1. Consumption of human foods

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope signatures for HY and AHY feather samples fell within the mixing space of the three diet groups considered, suggesting that dietary sources were represented by our sampling of potential food sources (Fig. 1). As expected, $\delta^{13}\text{C}$ was greater for human food than for mast and invertebrates, allowing for discrimination between natural and human foods (Newsome et al., 2015). Human foods were estimated to constitute 46% (95% CI: 37–57%) and 57% (95% CI: 46–71%) of the diet of HY and AHY jays, respectively, based on three-source SIAR models (Supplementary Material Table S1).

3.2. Patterns of dispersal and resource selection

A high proportion of HY jays engaged in post-fledging dispersal from old-growth forest (28 of 39, Table 1, Fig. 2a), and dispersal was more frequent in females (19 of 21) than males (9 of 18, $\chi^2 = 5.9$, d.f. 1, $P = 0.01$, Table 1). HY post-fledging dispersal occurred from September to January (mean dispersal date: 12 November; range: 10 September–16 January). Many HY individuals (23 of 39, Table 1, Fig. 2b) exhibited natal fidelity in that they occurred within old-growth forest in April or May of their second year, including nearly half of HY individuals that initially dispersed from this area (13 of 28, Table 1, Fig. 2b). The remaining HY jays that engaged in post-breeding dispersal settled outside of old-growth within Big Basin (7 of 15) or in nearby residential areas outside the park (8 of 15). HY jays that left old-growth during the non-breeding season selected areas with greater housing

density from October to March after initially avoiding these areas in August and September (Fig. 3). HY jays that left old-growth avoided areas with greater housing density in April and May as some dispersers returned to old-growth habitat (Fig. 3). A smaller proportion of AHY jays engaged in post-breeding dispersal away from old-growth forests (5 of 29, Supplementary Material Fig. S1). AHY jays exhibited strong breeding site fidelity, as all individuals (29 of 29) occurred inside old-growth forest the following May near the campground at which they were originally radio-marked (Supplementary Material Fig. S2).

3.3. Demography

Eight of 49 (16%) HY jays died, all before December, and only two of 31 (6%) AHY jays died during the tracking period. We found most support for the effect of month on HY survival ($w = 0.45$, Table 2). Monthly HY survival was lower during the first two bi-monthly periods (August–September and October–November) than the latter three bi-monthly periods (Fig. 4). We found most support for the effect of sex on monthly AHY survival ($w = 0.35$, Table 2), with males having higher survival than females (males: 1.000; females: 0.984, 95% CI: 0.962–1.00, Fig. 4). Annual survival calculated from monthly estimates derived from intercept only models was 0.742 (95% CI: 0.604–0.879) and 0.924 (95% CI: 0.826–1.00) for HY and AHY jays, respectively. The mean number of young produced per radio-marked female was 1.58 (95% CI: 1.39–1.78, $n = 36$), yielding a fecundity estimate of 0.79. Based on this and the aforementioned HY and AHY annual survival estimates, we estimated that $\lambda = 1.25$, which represents a positive annual population growth rate of 25% and translated to an expected 9-fold increase in abundance over a 10-year period based on an exponential growth model.

4. Discussion

Our study suggests that heavily-visited sites in a protected area promoted a source population of an overabundant nest predator that “seeded” the surrounding landscape within the park with recruiting breeders, potentially exacerbating risk to a threatened species that is at the heart of the park's conservation mission. The benefits provided by these temporally-pulsed, local subsidies, however, appeared to be augmented by more stable, landscape-scale subsidies provided in developed areas outside of parks—a process facilitated by nonbreeding dispersal to these areas. To the best of our knowledge, our integrative study linking stable isotopes, regional-scale tracking of dispersal behavior, and demographic analyses, provides the first clear example of how resources provided in protected areas can benefit populations of overabundant species at broader spatial scales—and how effects of these subsidies can be augmented by human development outside of parks. This phenomenon, however, may not be unique to this system as food subsidies at heavily-visited sites in protected areas have the potential to benefit a host of human commensals including mice, squirrels, raccoons, possums, and other corvids that prey on native species (Bradley et al., 2003; Marzluff and Neatherlin, 2006).

These findings, in conjunction with our previous work, indicate that

Table 1

Dispersal and fidelity in male and female radio-marked hatch-year (HY) and after-hatch-year (AHY) Steller's jays tracked during the 2012–2013 and 2013–2014 non-breeding seasons. n = sample size.

Age class	Proportion post-fledging (HY) or post-breeding (AHY) dispersal (n)	Proportion dispersers returning to old-growth forest (n)	Proportion natal (HY) or breeding (AHY) fidelity (n)
Hatch-year	0.72 (39)	0.46 (28)	0.59 (39)
Females	0.90 (21)	0.32 (19)	0.38 (21)
Males	0.50 (18)	0.78 (9)	0.83 (18)
After-hatch-year	0.17 (29)	1.00 (5)	1.00 (29)
Females	0.25 (12)	1.00 (3)	1.00 (12)
Males	0.12 (17)	1.00 (2)	1.00 (17)

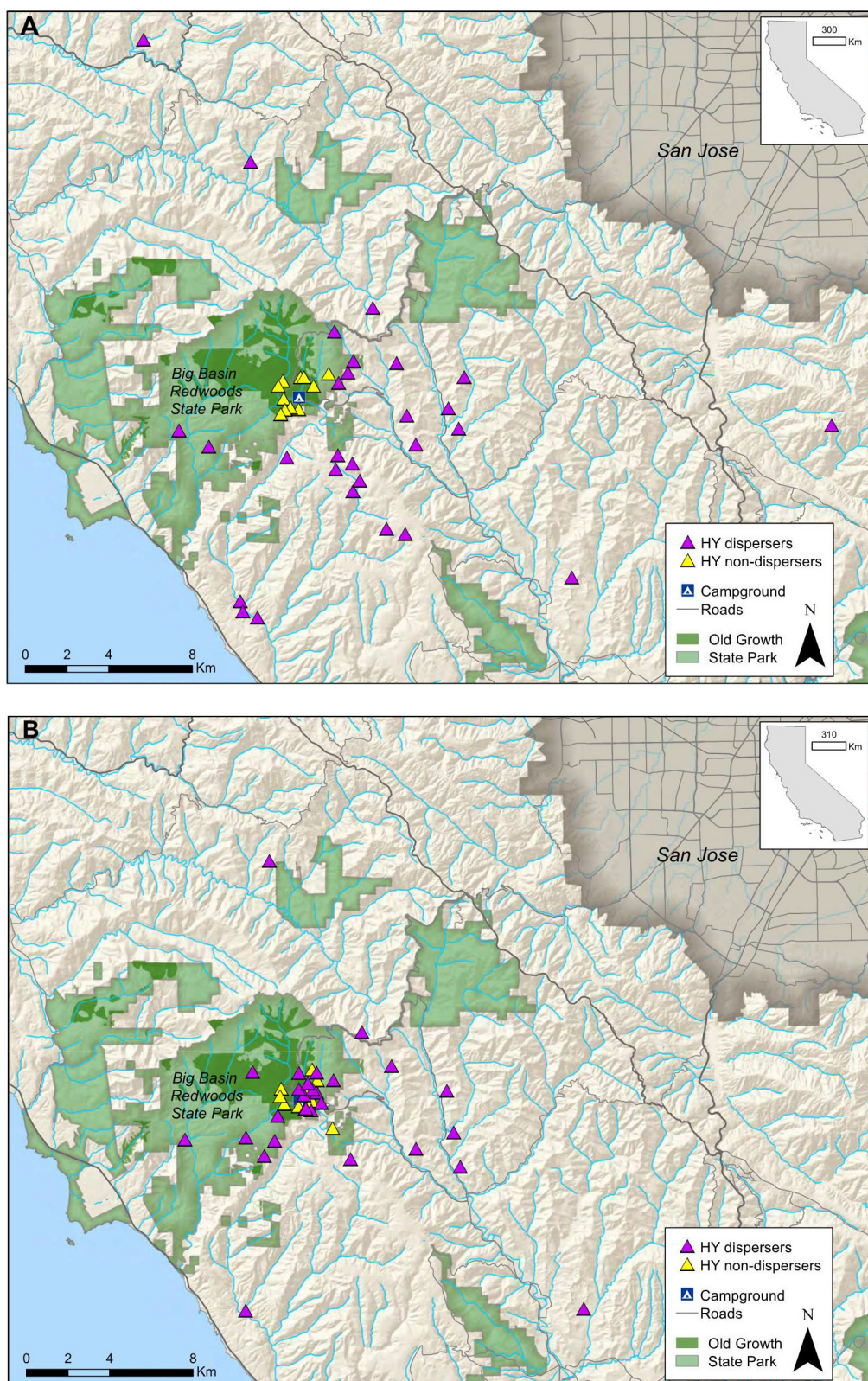


Fig. 2. a) Dispersal movements and b) settlement locations of radio-marked hatch year (HY; $n = 39$) Steller's jays during the non-breeding season (August 2012–May 2013 and August 2013–May 2014). Dispersal was defined as movements made out of old-growth habitat. All jays were radio-marked in campgrounds in Big Basin Redwoods State Park campgrounds.

food subsidies contributed to the rapid projected population growth (25% increase annually) of jays in campgrounds. Adults relied heavily on human foods to provision their young as our estimate of 46% human foods consumed by HYs individuals was derived from flight feathers

sampled prior to fledging, and the isotopic ratio of carbon in consumer tissues predictably reflect those in their diets during tissue growth (DeNiro and Epstein, 1978). Sampling was limited to campgrounds for logistical reasons, and we were unable to compare the estimates of HY

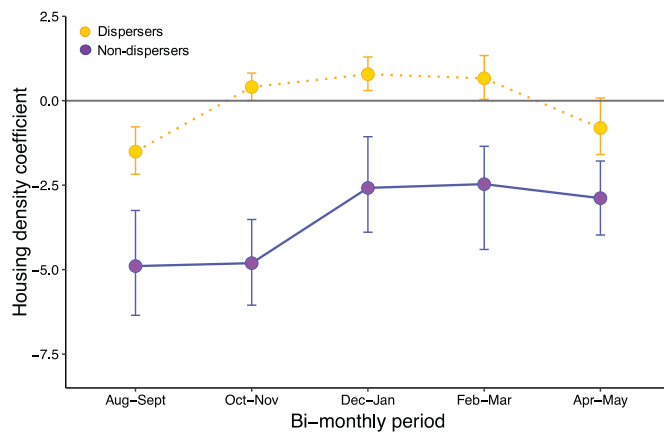


Fig. 3. Housing density logistic regression coefficients predicting used versus random locations for HY Steller's jays ($n = 68$) during the non-breeding period in the Santa Cruz Mountains, CA, USA. Error bars represent 95% confidence intervals.

Table 2

Results of known fates survival models for radio-marked hatch-year and after-hatch-year Steller's jays in central California, 2012–2014. AIC_C = Akaike information criterion adjusted for sample size, ΔAIC_C = difference in AIC_C between model and the most highly ranked mode, k = number model parameters, w = AIC_C weight.

Model	AIC_C	ΔAIC_C	K	w
Hatch-year				
Month	85.68	0.00	5	0.58
Sex + month	87.36	1.69	6	0.25
Sex + month + year	88.77	3.09	7	0.12
Year + month	91.16	5.49	6	0.04
Intercept	95.89	10.21	1	0.00
Year	97.08	11.41	2	0.00
Sex	97.58	11.90	2	0.00
Sex + year	98.91	13.24	3	0.00
Sex * year * month	155.85	70.17	40	0.00
After-hatch-year				
Sex	24.55	0.00	2	0.35
Sex + year	25.48	0.93	3	0.22
Intercept	26.11	1.56	1	0.16
Sex + month	26.22	1.67	6	0.15
Year	26.73	2.18	2	0.12
Month	85.68	61.13	5	0.00
Sex + month + year	104.36	79.81	7	0.00
Year + month	105.98	81.43	6	0.00
Sex * year * month	195.76	171.22	40	0.00

survival, AHY survival, and fecundity to vital rates estimated for unsubsidized populations in this study. However, previous work indicated that subsidized jays breeding in campgrounds were in better body condition than unsubsidized jays breeding in surrounding forests and that indices of productivity were nearly three times greater in campgrounds than forests (West and Peery, 2017). Consumption of human food subsidies very likely support high jay reproductive rates in campgrounds—and likely survival rates (see below)—which contribute to high project population growth rates. The strategies that these large numbers of HY jays use to exploit resources during the post-breeding season and the extent to which they settle in campgrounds in old-growth forests the following breeding season become key questions for minimizing jay impacts to marbled murrelets.

Many HY jays appeared to respond to declines in human-provided foods at their natal site following peak park visitation in August by dispersing to more developed areas during the non-breeding season. This hypothesis is supported by the observation that dispersing HY individuals tended to select areas with greater housing density from October to March. These individuals were likely taking advantage of

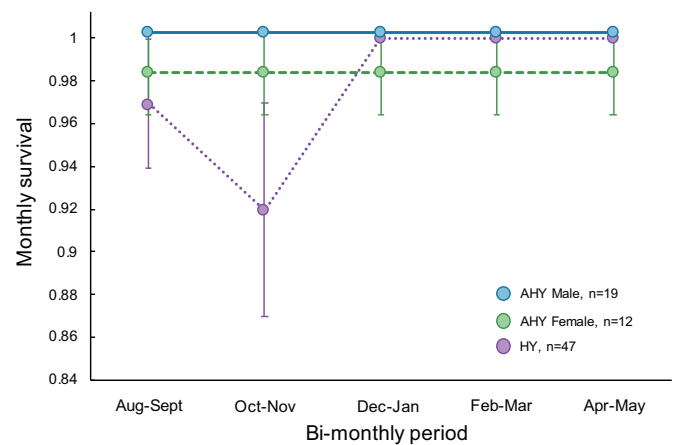


Fig. 4. Monthly survivorship, using survivorship estimates from the top-ranked model, for hatch year (HY; month model) and after-hatch-year (AHY; sex model) Steller's jays, 2012–2014, radio-marked in the Santa Cruz Mountains. Error bars represent 95% confidence intervals.

opportunities to forage on seasonally-stable human food sources as they were commonly seen feeding at refuse from residential areas and bird feeders. Thus, seasonally-available human resources in parks appear to have interacted with more stable resources in the surrounding landscape to promote HY survival rates that contributed to high jay population growth. Indeed, other studies have shown that food provisioning from bird feeders can improve survival and contribute to population growth in some species (Brittingham and Temple, 1988; Robb et al., 2008). In contrast, a much lower proportion of AHY jays dispersed from old-growth forest in the non-breeding season, perhaps because of greater familiarity with local foraging resources during periods of scarcity and territory maintenance (Piper, 2011).

Post-breeding dispersal behavior and habitat selection patterns appeared to contribute to high survival rates in the first year of life, a period that typically incurs relatively high mortality in birds, as no dispersing HY jays died in this study. Nevertheless, natal fidelity was high in the sense that many HY jays that dispersed during the non-breeding season returned to areas near their natal site in parks in the subsequent breeding season. The pattern of high natal fidelity suggests that stable, year-round food subsidies in more developed landscapes surrounding parks can support populations of synanthropic species that disperse from protected areas during periods of scarcity, which in turn may threaten sensitive species whose habitat is restricted to these protected areas. Thus, our results add to the growing body of literature indicating that housing development, agricultural and other human activities adjacent to protected areas can spillover inside them, potentially threatening biodiversity (DeFries et al., 2007; Hansen and DeFries, 2007; Newsome et al., 2014; Wood et al., 2014). We demonstrate a novel mechanism by which developed areas surrounding parks can increase risk to sensitive species within parks, namely by subsidizing synanthropic species when HY individuals would typically experience periods of resource scarcity (low human visitation) in parks. Importantly, some of the jays that returned to old-growth forests and were thus considered to exhibit natal fidelity settled a short distance from campgrounds, yet still within marbled murrelet habitat (Fig. 2). Heavily-visited campgrounds, then, appeared to act as source habitats at both local and broader spatial scales, both processes apparently facilitated by landscape-scale land-use patterns.

Ours was the first study to estimate survival rates for Steller's jays of any age class and indicates that annual HY survival was very high (0.742), particularly after most individuals had dispersed from natal territories in campgrounds (Fig. 4). Interestingly, all HY mortalities occurred prior to December and all but one was attributable to predation inside old-growth habitat. The fact that most mortalities were

caused by predators is consistent with previous studies on avian predation caused by raptors (Anders et al., 1997; Webb et al., 2004; Yackel Adams et al., 2006). *Accipiter* spp. were likely jay predators; they were commonly observed in the study area and are generally important predators of juvenile birds, particularly during the months after fledging (Anders et al., 1997; King et al., 2006; Naef-Daenzer et al., 2001; Newton and Marquis, 1982) when young birds may lack the ability to escape due to limited flying ability or be less vigilant than adults. Our finding of high annual survival in HY jays is in contrast to the relatively low rate of survival of other passerines at this age that have been previously reported (Cohen et al., 2004; Kershner et al., 2004; Snow, 1958; Sullivan, 1989; Yackel Adams et al., 2006). However, high HY jay survival in our study mirrored a similar pattern in subsidized HY American Crows (*Corvus brachyrhynchos*) and Common Ravens (*Corvus corax*; Marzluff and Neatherlin, 2006). The fact that some HY jays did not disperse from Big Basin and others delayed dispersal movements may indicate continued dependence on parents through later summer and early fall, or simply a reliance on food resources—natural or human-derived—in the park during this period. Even though all HY jays do not appear to be drawn to areas with greater housing density during the post-fledging period, sufficient dispersal into these areas may be a response by jays to seasonally-stable human food resources after natural food resources such as berries and mast diminish in the fall. We believe dispersal to these areas promoted higher overall survival, and may maintain a large jay population at broader spatial scales. Indeed, as generalist omnivores, jays also appear to be relatively flexible in terms of their use of habitat during the post-fledging period and we suspect that this flexibility may be adaptive in heterogeneous landscapes, ultimately promoting survival.

Point sources of supplemental human foods contribute to increases in Steller's jay reproductive output and population density inside heavily-visited campgrounds in state parks (West and Peery, 2017), and improve survival in these areas and at broader spatial scales (this study). These results point to the collective effect of food subsidies inside protected areas and those from the surrounding landscape on synanthropic predators that occurred despite well-intentioned campaigns to reduce subsidies including improved trash management, visitor education, and enforcement of park policies (West and Peery, 2017). Reducing point sources of food subsidies inside parks through improved refuse management coupled with increased visitor education and greater enforcement of park policies could be effective strategies for reducing jay populations as similar efforts have been successful in limiting other synanthropic species in parks (Craighead et al., 1995; Hopkins et al., 2014). Yet, changing human behavior can be challenging (John et al., 2011) and removing heavily-visited recreational sites from old-growth forests may be a more effective long-term strategy. This approach poses its own challenges however, given the dual mandate of many U.S. parks and natural areas to preserve biodiversity and also provide the public with recreational opportunities. This issue is not unique to the U.S., as protected areas around the world are increasingly tasked with social and economic objectives in addition to nature conservation (Watson et al., 2014), posing political challenges for park managers.

An archetype of synanthrope expansion, corvid abundance and distribution in many protected areas in the U.S. undoubtedly results in significant predation pressure on a host of sensitive and non-sensitive species (Bradley et al., 2003; Marzluff and Neatherlin, 2006), which may in turn have indirect effects on food webs and ecosystems (Newsome et al., 2014). Our findings underscore the importance of understanding the extent to which food subsidies in protected areas can alter predator behavior and potential top-down impacts on prey. Given the continued expansion of developed areas in many landscapes and concurrent increases in the availability of human food subsidies for synanthropic predators, maintaining protected areas as refugia for sensitive species within these regions will also require management actions on private lands and at larger spatial scales. Reducing access to

subsidies outside of protected areas will be challenging and would require long-term regional planning, public outreach, and education. This is particularly relevant, as human activities and expanding exurban development will undoubtedly continue to influence synanthrope behavior and demography through access to spatially and temporally stable food subsidies, with potentially cascading negative influences on sensitive species. Rather than a management response after the decline of sensitive species is identified, a more prudent approach would be to manage those features that draw predators to undesirable areas in developed landscapes. For instance, development and implementation of best management practices that improve waste management and increase efforts to educate the public about issues associated with feeding wildlife could reduce access to human food subsidies by synanthropic predators and should reduce local predator population growth rates by reducing reproduction and survivorship and causing mobile predators like corvids to disperse. Similarly, habitat alterations such as buffers between natural and residential areas could be used to reduce the movement of both predators and prey into areas featuring high human densities. Ultimately, however, there will be ecological interactions in human-dominated landscapes, regardless of management strategies, including some that will be detrimental to sensitive species and may require management actions that are unpopular with the public. Consequently, managers interested in reducing the risk of nest predation will need to include members of the public in decision-making about what developed ecosystems should feature and whether public tolerance can adapt along with wildlife.

5. Conclusions

Greater insight into how dispersal influences the population dynamics of synanthropic species will improve decision making intended to reduce their negative impacts on threatened species and biological communities. Indeed, our results indicated that human-influenced landscapes that encompass or border large protected areas are capable of supporting synanthropes, and increasing development pressures may threaten the sensitive species inside parks and recreation areas. In addition, flexibility in dispersal behavior can allow synanthropic predators to take advantage of interactions between local, ephemeral resources in protected areas and permanent resources in surrounding landscapes. Our findings indicate the importance of controlling food sources in areas of management concern, as well as those at substantial distances from these areas at broader spatial scales. As anthropogenic influences expand, studies like ours that integrate molecular, behavioral, and demographic approaches can help elucidate the response of synanthropic species to spatial and temporal patterns in human food subsidies to better inform management and public outreach.

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Role of the funding source and declaration of conflicts of interest

The funders played no part in the study design, analysis, interpretation of data, writing of the paper or decision to submit for publication.

Declaration of competing interest

The authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.biocon.2019.108220>.

References

- Anders, A.D., Dearborn, D.C., Faaborg, J., Iii, F.R.T., 1997. Juvenile survival in a population of neotropical migrant birds. *Conserv. Biol.* 11, 698–707. <https://doi.org/10.1046/j.1523-1739.1997.95526.x>.
- Bearhop, S., Waldron, S., Votier, S.C., Furness, R.W., 2002. Factors that influence assimilation rates and fractionation of nitrogen and carbon stable isotopes in avian blood and feathers. *Physiol. Biochem. Zool.* 75, 451–458. <https://doi.org/10.1086/342800>.
- Bradley, J.E., Marzluff, J.M., Thompson III, F.R., 2003. Rodents as nest predators: influences on predatory behavior and consequences to nesting birds. *Auk* 120, 1180–1187. [https://doi.org/10.1642/0004-8038\(2003\)120\[1180:RANPIO\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2003)120[1180:RANPIO]2.0.CO;2).
- Brand, L.A., George, T.L., 2001. Response of passerine birds to forest edge in coast redwood forest fragments. *Auk* 118, 678–686. [https://doi.org/10.1642/0004-8038\(2001\)118\[0678:ROPBTF\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2001)118[0678:ROPBTF]2.0.CO;2).
- Brittingham, M.C., Temple, S.A., 1988. Impacts of supplemental feeding on survival rates of black-capped chickadees. *Ecology* 69, 581–589. <https://doi.org/10.2307/1941007>.
- Brown, J.L., 1964. The evolution of diversity in avian territorial systems. *Wilson Bull.* 76, 160–169.
- Buehler, D.A., Fraser, J.D., Fuller, M.R., McAllister, L.S., Seegar, J.K.D., 1995. Captive and field-tested radio transmitter attachments for bald eagles. *J. Field Ornithol.* 66, 173–180.
- Burnham, K.P., Anderson, D.R., 2003. *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. Springer-Verlag, New York, NY, USA.
- Carwardine, J., O'Connor, T., Legge, S., Mackey, B., Possingham, H.P., Martin, T.G., 2012. Prioritizing threat management for biodiversity conservation. *Conserv. Lett.* 5, 196–204. <https://doi.org/10.1111/j.1755-263X.2012.00228.x>.
- Caswell, H., 1989. *Matrix Population Models*. Sinauer Assoc. Inc, Sunderland, MA.
- Chamberlain, D.E., Cannon, A.R., Toms, M.P., Leech, D.I., Hatchwell, B.J., Gaston, K.J., 2009. Avian productivity in urban landscapes: a review and meta-analysis. *Ibis* 151, 1–18.
- Cohen, E.B., Lindell, C.A., Stouffer, P.C., 2004. Survival, habitat use, and movements of fledgling white-throated robins (*Turdus assimilis*) in a Costa Rican agricultural landscape. *Auk* 121, 404–414. [https://doi.org/10.1642/0004-8038\(2004\)121\[0404:SHUAMO\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2004)121[0404:SHUAMO]2.0.CO;2).
- Craighead, J.J., Sumner, J.S., Mitchell, J.A., 1995. *The Grizzly Bears of Yellowstone: Their Ecology in the Yellowstone Ecosystem, 1959–1992*, Fourth. ed. Island Press, Washington, D.C., USA.
- DeFries, R., Hansen, A., Turner, B.L., Reid, R., Liu, J., 2007. Land use change around protected areas: management to balance human needs and ecological function. *Ecol. Appl.* 17, 1031–1038. <https://doi.org/10.1890/05-1111>.
- DeNiro, M.J., Epstein, S., 1978. Influence of diet on the distribution of carbon isotopes in animals. *Geochim. Cosmochim. Acta* 42, 495–506. [https://doi.org/10.1016/0016-7037\(78\)90199-0](https://doi.org/10.1016/0016-7037(78)90199-0).
- ESRI, 2014. *ArcGIS 10.2*. ESRI, Redlands, California, USA.
- Gabriel, P.O., Golightly, R.T., 2014. Aversive conditioning of Steller's jays to improve marbled murrelet nest survival. *J. Wildl. Manag.* 78, 894–903. <https://doi.org/10.1002/jwmg.725>.
- Griffiths, R., Double, M.C., Orr, K., Dawson, R.J.G., 1998. A DNA test to sex most birds. *Mol. Ecol.* 7, 1071–1075.
- Gutzwiller, K.J., Riffell, S.K., 2008. Does repeated human intrusion alter use of wildland sites by red squirrels? Multiyear experimental evidence. *J. Mammal.* 89, 374–380. <https://doi.org/10.1644/07-MAMM-A-122R1.1>.
- Halbert, P., Singer, S.W. (Eds.), 2017. *Marbled Murrelet Landscape Management Plan for Zone 6*.
- Hansen, A.J., DeFries, R., 2007. Ecological mechanisms linking protected areas to surrounding lands. *Ecol. Appl.* 17, 974–988. <https://doi.org/10.1890/05-1098>.
- Hobson, K.A., Clark, R.G., 1992. Assessing avian diets using stable isotopes II: factors influencing diet-tissue fractionation. *Condor* 189–197.
- Hopkins, J.B., Koch, P.L., Ferguson, J.M., Kalinowski, S.T., 2014. The changing anthropogenic diets of American black bears over the past century in Yosemite National Park. *Front. Ecol. Environ.* 12, 107–114. <https://doi.org/10.1890/130276>.
- John, F.A.V.S., Edwards-Jones, G., Jones, J.P.G., 2011. Conservation and human behaviour: lessons from social psychology. *Wildl. Res.* 37, 658–667. <https://doi.org/10.1071/WR10032>.
- Kershner, E.L., Walk, J.W., Warner, R.E., Haukoos, D.A., 2004. Postfledging movements and survival of juvenile eastern meadowlarks (*Sturnella magna*) in Illinois. *Auk* 121, 1146–1154. [https://doi.org/10.1642/0004-8038\(2004\)121\[1146:PMASOJ\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2004)121[1146:PMASOJ]2.0.CO;2).
- King, D.I., Degraaf, R.M., Smith, M.-L., Buonaccorsi, J.P., 2006. Habitat selection and habitat-specific survival of fledgling ovenbirds (*Seiurus aurocapilla*). *J. Zool.* 269, 414–421. <https://doi.org/10.1111/j.1469-7998.2006.00158.x>.
- Laurance, W.F., Carolina Useche, D., Rendeiro, J., Kalka, M., Bradshaw, C.J.A., Sloan, S.P., Laurance, S.G., Campbell, M., Abernethy, K., Alvarez, P., Arroyo-Rodriguez, V., Ashton, P., Benítez-Malvido, J., Blom, A., Bobo, K.S., Cannon, C.H., Cao, M., Carroll, R., Chapman, C., Coates, R., 2012. Averting biodiversity collapse in tropical forest protected areas. *Nature* 489, 290–294. <https://doi.org/10.1038/nature11318>.
- Luginbuhl, J.M., Marzluff, J.M., Bradley, J.E., Raphael, M.G., Varland, D.E., 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. *J. Field Ornithol.* 72, 556–572.
- Manly, B.F., McDonald, L., Thomas, D., McDonald, T.L., Erickson, W.P., 2010. *Resource Selection by Animals: Statistical Design and Analysis for Field Studies*, 1st ed. Springer Science & Business Media, Springer, Netherlands.
- Marzluff, J.M., Neatherlin, E., 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biol. Conserv.* 130, 301–314. <https://doi.org/10.1016/j.biocon.2005.12.026>.
- Marzluff, J.M., Millsapugh, J.J., Hurvitz, P., Handcock, M.S., 2004. Relating resources to a probabilistic measure of space use: forest fragments and Steller's jays. *Ecology* 85, 1411–1427. <https://doi.org/10.1890/03-0114>.
- McCarthy, D.P., Donald, P.F., Scharlemann, J.P.W., Buchanan, G.M., Balmford, A., Green, J.M.H., Bennun, L.A., Burgess, N.D., Fishpool, L.D.C., Garnett, S.T., Leonard, D.L., Maloney, R.F., Morling, P., Schaefer, H.M., Symes, A., Wiedenfeld, D.A., Butchart, S.H.M., 2012. Financial costs of meeting global biodiversity conservation targets: current spending and unmet needs. *Science* 338, 946–949. <https://doi.org/10.1126/science.1229803>.
- Mcdonald, R.L., Kareiva, P., Forman, R.T.T., 2008. The implications of current and future urbanization for global protected areas and biodiversity conservation. *Biol. Conserv.* 141, 1695–1703. <https://doi.org/10.1016/j.biocon.2008.04.025>.
- Monz, C.A., Pickering, C.M., Hadwen, W.L., 2013. Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts. *Front. Ecol. Environ.* 11, 441–446. <https://doi.org/10.1890/120358>.
- Naef-Daenzer, B., Widmer, F., Nuber, M., 2001. Differential post-fledging survival of great and coal tits in relation to their condition and fledging date. *J. Anim. Ecol.* 70, 730–738. <https://doi.org/10.1046/j.0021-8790.2001.00533.x>.
- Nelson, S.K., 1997. *Marbled Murrelet (Brachyramphus marmoratus)*, version 2.0. In: Poole, A.F., Gill, F.B. (Eds.), *The Birds of North America*. Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bna.276>.
- Newsome, T.M., Dellinger, J.A., Pavey, C.R., Ripple, W.J., Shores, C.R., Wirsing, A.J., Dickman, C.R., 2014. The ecological effects of providing resource subsidies to predators. *Glob. Ecol. Biogeogr.* 24, 1–11. <https://doi.org/10.1111/geb.12236>.
- Newsome, S.D., Garbe, H.M., Wilson, E.C., Gehrt, S.D., 2015. Individual variation in anthropogenic resource use in an urban carnivore. *Oecologia* 1–14. <https://doi.org/10.1007/s00442-014-3205-2>.
- Newton, N., Marquiss, M., 1982. Food, predation and breeding season in Sparrowhawks (*Accipiter nisus*). *J. Zool.* 197, 221–240. <https://doi.org/10.1111/jzo.1982.197.2.221>.
- Orell, M., 1989. Population fluctuations and survival of Great Tits *Parus major* dependent on food supplied by man in winter. *Ibis* 131, 112–127. <https://doi.org/10.1111/j.1474-919X.1989.tb02750.x>.
- Parnell, A., Inger, R., Bearhop, S., Jackson, A.L., 2008. *SIAR: Stable Isotope Analysis in R*. R Package Version 3.
- Pearson, S.F., Levey, D.J., Greenberg, C.H., Rio, C.M. del, 2003. Effects of elemental composition on the incorporation of dietary nitrogen and carbon isotopic signatures in an omnivorous songbird. *Oecologia* 135, 516–523.
- Peery, M.Z., Henry, R.W., 2010. Recovering marbled murrelets via corvid management: a population viability analysis approach. *Biol. Conserv.* 143, 2414–2424. <https://doi.org/10.1016/j.biocon.2010.04.024>.
- Peery, M.Z., Beissinger, S.R., Newman, S.H., Burkett, E.B., Williams, T.D., 2004. Applying the declining population paradigm: diagnosing causes of poor reproduction in the marbled murrelet. *Conserv. Biol.* 18, 1088–1098. <https://doi.org/10.1111/j.1523-1739.2004.00134.x>.
- Phillips, D.L., Newsome, S.D., Gregg, J.W., 2005. Combining sources in stable isotope mixing models: alternative methods. *Oecologia* 144, 520–527.
- Phillips, D.L., Inger, R., Bearhop, S., Jackson, A.L., Moore, J.W., Parnell, A.C., Semmens, B.X., Ward, E.J., 2014. Best practices for use of stable isotope mixing models in food-web studies. *Can. J. Zool.* 92, 823–835. <https://doi.org/10.1139/cjz-2014-0127>.
- Piper, W.H., 2011. Making habitat selection more “familiar”: a review. *Behav. Ecol. Sociobiol.* 65, 1329–1351. <https://doi.org/10.1007/s00265-011-1195-1>.
- Pollock, K.H., Winterstein, S.R., Bunck, C.M., Curtis, P.D., 1989. Survival analysis in telemetry studies: the staggered entry design. *J. Wildl. Manag.* 53, 7–15. <https://doi.org/10.2307/3801296>.
- Pyle, P., Howell, S.N.G., Yunick, R.P., DeSante, D.F., 1997. *Identification Guide to North American Passerines*. Braun-Brumfield. Slate Creek Press, Bolinas, California.
- R Development Core Team, 2014. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing.
- Radeloff, V.C., Stewart, S.I., Hawbaker, T.J., Gimmi, U., Pidgeon, A.M., Flather, C.H., Hammer, R.B., Helmers, D.P., 2010. Housing growth in and near United States protected areas limits their conservation value. *PNAS* 107, 940–945. <https://doi.org/10.1073/pnas.0910130107>.

- 1073/pnas.0911131107.
- Raphael, M.G., Mack, D.E., Marzluff, J.M., Luginbuhl, J.M., 2002. Effects of forest fragmentation on populations of the marbled murrelet. *Stud. Avian Biol.* 25, 221–235.
- Robb, G.N., McDonald, R.A., Chamberlain, D.E., Bearhop, S., 2008. Food for thought: supplementary feeding as a driver of ecological change in avian populations. *Front. Ecol. Environ.* 6, 476–484. <https://doi.org/10.1890/060152>.
- Seber, G.A.F., 1987. *The Estimation of Animal Abundance*. Oxford University Press, Oxford, England, UK.
- Sieving, K.E., Willson, M.F., 1998. Nest predation and avian species diversity in north-western forest understory. *Ecology* 79, 2391–2402. [https://doi.org/10.1890/0012-9658\(1998\)079\[2391:NPAASD\]2.0.CO;2](https://doi.org/10.1890/0012-9658(1998)079[2391:NPAASD]2.0.CO;2).
- Snow, D.W., 1958. The breeding of the blackbird *Turdus merula* at Oxford. *Ibis* 100, 1–30. <https://doi.org/10.1111/j.1474-919X.1958.tb00362.x>.
- Sullivan, K.A., 1989. Predation and starvation: age-specific mortality in juvenile juncos (*Junco phaeotus*). *J. Anim. Ecol.* 58, 275–286. <https://doi.org/10.2307/5000>.
- Vigallon, S.M., Marzluff, J.M., 2005. Is nest predation by Steller's jays (*Cyanocitta stelleri*) incidental or the result of a specialized search strategy? *Auk* 122, 36–49.
- Walker, L.E., Marzluff, J.M., 2015. Recreation changes the use of a wild landscape by corvids. *Condor* 117, 262–283. <https://doi.org/10.1650/CONDOR-14-169.1>.
- Watson, J.E.M., Dudley, N., Segan, D.B., Hockings, M., 2014. The performance and potential of protected areas. *Nature* 515, 67–73. <https://doi.org/10.1038/nature13947>.
- Webb, W.C., Boarman, W.I., Rotenberry, J.T., 2004. Common raven juvenile survival in a human-augmented landscape. *Condor* 106, 517–528. <https://doi.org/10.2307/4151049>.
- West, E.H., Peery, M.Z., 2017. Behavioral mechanisms leading to improved fitness in a subsidized predator. *Oecologia* 1–12. <https://doi.org/10.1007/s00442-017-3898-0>.
- West, E.H., Henry, W.R., Goldenberg, W., Peery, M.Z., 2016. Influence of food subsidies on the foraging ecology of a synanthropic species in protected areas. *Ecosphere* 7, 1–15. <https://doi.org/10.1002/ecs2.1532>.
- White, G.C., Burnham, K.P., 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46, S120–S139. <https://doi.org/10.1080/00063659909477239>.
- Wilmers, C.C., Wang, Y., Nickel, B., Houghtaling, P., Shakeri, Y., Allen, M.L., Kermish-Wells, J., Yovovich, V., Williams, T., 2013. Scale dependent behavioral responses to human development by a large predator, the puma. *PLoS One* 8, e60590. <https://doi.org/10.1371/journal.pone.0060590>.
- Wood, E.M., Pidgeon, A.M., Radeloff, V.C., Hesters, D., Culbert, P.D., Keuler, N.S., Flather, C.H., 2014. Housing development erodes avian community structure in U.S. protected areas. *Ecol. Appl.* 24, 1445–1462. <https://doi.org/10.1890/12-1992.1>.
- Yackel Adams, A.A., Skagen, S.K., Savidge, J.A., 2006. Modeling post-fledging survival of lark buntings in response to ecological and biological factors. *Ecology* 87, 178–188. <https://doi.org/10.1890/04-1922>.



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December 1, 2025

Santa Cruz District, California Department of Parks and Recreation
303 North Big Trees Park Road
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Contact: Will Fourt
Reimagining.BigBasin@parks.ca.gov

RE: Big Basin Redwoods State Park General Plan Supplemental EIR

Dear Mr. Fourt and California Department of Parks and Recreation,

The Pacific Seabird Group (PSG) is a society of professional seabird researchers and managers dedicated to the study and conservation of seabirds. PSG was incorporated as a 501c3 non-profit in the state of California in 1972 and has an international membership from countries throughout the Pacific Basin and beyond. The principal goals of PSG are to: 1) increase the quality and quantity of seabird research by facilitating the exchange of information, 2) identify and assess the importance of threats to seabird populations, and 3) provide government agencies and others with expert advice on managing threats and populations. Over the last several decades, PSG members have provided Marbled Murrelet population status information, standardized monitoring protocols for at-sea and forest-based monitoring, and assessed management alternatives for state and federal agencies and other constituents.

Marbled Murrelets nesting in central California have a small population (Felis et al. 2020), specific nesting habitat requirements (Baker et al. 2006), and may be habitat limited (Raphael 2006, California Department of Parks and Recreation 2017), particularly after habitat loss resulting from the 2020 CZU Lightning Complex Fire (CZU fire, Potter 2023). We urge the California Department of Parks and Recreation to take full advantage of this unique opportunity to protect remaining old-growth forest, Marbled Murrelets and other species relying on this habitat while rebuilding infrastructure and providing valuable visitor experiences. As we stated

ORG4-01

in our 18 July 2025 letter, we support the many facets of the proposed Plan to relocate most facilities out of the remaining old-growth forest portion of Big Basin Redwoods State Park (Park). This alone may provide much needed conservation benefits to the Marbled Murrelet. However, there are aspects of the proposed Plan that require additional information and analysis to more fully consider and analyze potential impacts to Marbled Murrelets and methods to mitigate those impacts. Given the large-scale damage to Marbled Murrelet breeding habitat and likely long-term impacts to the small central California population from the CZU fire, protection of remaining potential breeding habitat and nesting birds is of the utmost importance. Below, we provide several suggestions to improve the SEIR to best assure that protection of the remaining Marbled Murrelet population and their terrestrial habitat in the Park is maximized to the fullest extent possible.

ORG4-01
cont.

1. As also stated in our July 18 letter, we found it difficult to assess current conditions in the Park and where proposed infrastructure will be in relation to remaining lightly burned old-growth refugia habitat, as well as to isolated unburned trees possessing appropriate crown structures, which still contain potential Marbled Murrelet breeding habitat. This information is critical to properly locate proposed infrastructure and to analyze potential impacts to Marbled Murrelets. As most of the information on habitat conditions provided in section 3.2 *Existing Conditions* was based on sampling conducted prior to the CZU fire, much of this information may no longer be relevant. For example, we found no mention of the large-scale replacement of the Park's forest understory with *Ceanothus thyrsiflorus*, a species also found in chaparral habitats. In our July 18 letter, we recommended that "remaining late successional and old-growth habitat should be quantified to precisely identify unburned refugia areas that are still suitable for murrelet nesting. Additionally, burned areas with potential to develop into nesting habitat in the coming decades should be identified." Further, we provided a map showing approximate locations of remaining old-growth stands in the Plan area that still contain potential Marbled Murrelet habitat. We did not find this information in the Draft SEIR, so we have provided the map below for your reference. Not shown on this map, but needing investigation, is an additional possible refuge area located west of Middle Ridge, north of Gazos Creek Road, and south of Johansen Road. It appears as a lightly burned area on remote sensing imagery from October 2021 included in Potter (2023). Inclusion of a more thorough assessment of this remaining habitat along with maps and descriptions of the proposed Plan areas would substantially aid the planning and evaluation processes.

ORG4-02

2. We appreciate the review of Marbled Murrelet literature for the 2012-2025 period provided in Appendix D. However, this review omitted the Pacific Seabird Group's *Terrestrial Habitat Management Recommendations for Marbled Murrelets* (Pacific Seabird Group 2024; <https://pacificseabirdgroup.org/psg-publications/technical-publications/>). We also found no reference to this relevant document in the main body of the Draft SEIR despite our reference to it in our July 18 letter. Murrelet habitat recommendations from this document that we strongly suggest for inclusion in the Draft SEIR include:

ORG4-03

- a. no campgrounds, trails, waste management areas, or other public facilities be located within 0.8 km (0.5 mi) of murrelet breeding habitat;

ORG4-04

b. signs be posted in existing campgrounds or public facilities located in habitat, saying no feeding of wildlife, no excessive noise (particularly around dawn and dusk), and no eating while hiking on trails;	ORG4-05
c. use of existing campgrounds or recreation facilities be re-evaluated if existing habitat located within 0.8 km becomes occupied by nesting murrelets;	ORG4-06
d. long-term monitoring of predator densities be conducted at campgrounds and facilities near occupied habitat areas and, if necessary, mitigation measures be put in place along with development of an adaptive management plan;	ORG4-07
e. wildlife-proof trash cans be used in all campgrounds and picnic areas and wildlife-proof food lockers installed at all campsites;	ORG4-08
f. dishwashing stations be installed in all campgrounds;	ORG4-09
g. hazard trees in or near habitat be evaluated and treated in consultation with a wildlife biologist;	ORG4-10
h. trees proposed for removal or pruning in or near habitat be reviewed by a qualified forest health protection pathologist or a certified arborist;	ORG4-11
i. human infrastructure threatened by hazard trees be considered for removal, relocation, and/or seasonal closure before removing the tree;	ORG4-12
j. removal of active or historic marbled murrelet nest trees be avoided;	ORG4-13
k. removal of large branches that may later support nests or nest sites or contribute to habitat characteristics be avoided wherever possible;	ORG4-14
l. impacts to surrounding trees when felling hazard trees be avoided or minimized;	ORG4-15
m. potential hazard trees be trimmed to create snag habitat, rather than felled entirely;	ORG4-16
n. all visual disturbance, sudden noises, novel noises, and noises > 90 dB associated with construction and other activities be avoided near nest sites throughout the breeding season and during dawn and dusk activity periods year-round;	ORG4-17
o. burning not be conducted near murrelet nesting habitat during the nesting season.	ORG4-18
3. We have concerns about certain proposed visitor use facilities in the old-growth area, including the Sequoia Group Camp, visitor kiosk, backpacker camp sites, picnic areas, parking lots, and amphitheater. Following the measures outlined in the Pacific Seabird Group's <i>Terrestrial Habitat Management Recommendations for Marbled Murrelets</i> for reduction of predation risk (see above), we recommend placing infrastructure as far from remaining potential Marbled Murrelet habitat as possible and avoiding placement of recreational features within 0.8 km (0.5 mi) of murrelet breeding habitat. This recommendation applies to infrastructure such as	

campgrounds, picnic areas, off-highway vehicle staging areas, trailheads, and trails. This should not be confused with the separate recommendation for harvest activities of “no-cut” buffers of 100 m around murrelet habitat. These measures will help protect Marbled Murrelets from human disturbance, and, more importantly, from predators such as Steller’s Jays (*Cyanocitta stelleri*) and Common Ravens (*Corvus corax*) that can be attracted to human visitors and the food they leave behind.

ORG4-18
cont.

4. Nest predation is a significant factor limiting Marbled Murrelet nest success across the breeding range (USFWS 2024) with corvids (crows, ravens, and jays) being the primary nest predators (Nelson 2020). Corvid populations have been shown to benefit from human food sources such as garbage and food scraps, resulting in increased densities (West and Peery 2017) and likelihood of predation (Peery and Henry 2010). Given the documented success of the “Crumb Clean” campaign in reducing predator densities in Big Basin State Park (Brunk et al. 2021), we strongly support the Park’s plan to continue the “Crumb Clean” campaign in combination with other measures to minimizing predator impacts (see Comment #2, above). We suggest strengthening the Crumb Clean campaign by integrating outreach materials into parking or shuttle reservation websites and documentation and verbally communicating the importance of the campaign to visitors when arriving at parking areas, visitor facilities, and campgrounds. Park docents could help with public outreach and education regarding this important conservation topic. Finally, we recommend continuing existing corvid management efforts within the Park.

ORG4-19

5. As stated in section 3.4 *Project Impact Analysis* of the Draft SEIR, the Park’s *General Plan Guideline Murrelet 9* calls for formalizing “...existing State Parks marbled murrelet management team for Big Basin Redwoods State Park and develop formal marbled murrelet adaptive management plan for the park.” We strongly support this initiative, which has not yet been implemented. Before park planning goes further, we recommend formalizing the marbled murrelet management team and developing a marbled murrelet adaptive management plan that includes regular monitoring of murrelet activity levels and uses a combination of both visual and acoustic surveys to maximize detection of murrelets. PSG could offer a member of the Marbled Murrelet Technical Committee to participate with the Park on this management team.

ORG4-20

6. To further reduce impacts to the Park’s Marbled Murrelet population, we offer the following additional recommendations:

- a. We suggest studies be conducted to examine movements and use of anthropogenic food subsidies by the Park’s Common Ravens, including in areas outside the Park. Common Ravens are opportunistic foragers and scavengers and can have extensive home ranges; thus, ravens found in the Park likely also forage extensively on both natural and anthropogenic resources outside the Park’s boundaries. Large sources of food waste, such as waste distribution centers and landfills, typically attract large numbers of scavengers such as ravens and gulls and can help inflate populations of these species. For example, in a study of Western Gulls (*Larus occidentalis*) breeding at Año Nuevo Island on the San Mateo County coast near Big Basin Redwoods State Park, Shaffer et al. (2017) found the City of Santa Cruz Resource Recovery Facility to be a major food source for those gulls. This facility is about 24 km from the old-growth area of the

ORG4-21

Park, or nearly the same distance as Año Nuevo Island to the facility. Research on movements of ravens occurring within the Park could help identify key measures and external partnerships to help curb the Park's raven population.

- b. We recommend also reducing impacts to Marbled Murrelets at other Santa Cruz Mountains state parks. Impacts to murrelets, including from habitat loss, avian predation, and human disturbance, are similar at other parks. Measures to reduce impacts to murrelets, including moving campgrounds and picnic areas away from murrelet habitat, could help mitigate this Plan's impacts on the Santa Cruz Mountains murrelet population. One suggested action would relocate the campground at Butano State Park away from the old-growth forest.

Thank you for your consideration of our comments. If you have any questions about these comments or seek additional information about Marbled Murrelets, please contact the co-chairs of the PSG Marbled Murrelet Technical Committee, Lindsay Adrean ladrean@abcbirds.org and Bill McIver bill_mciver@fws.gov

Sincerely,



Daniel Barton, PhD
PSG 2025 Chair

ORG4-21
cont.

ORG4-22

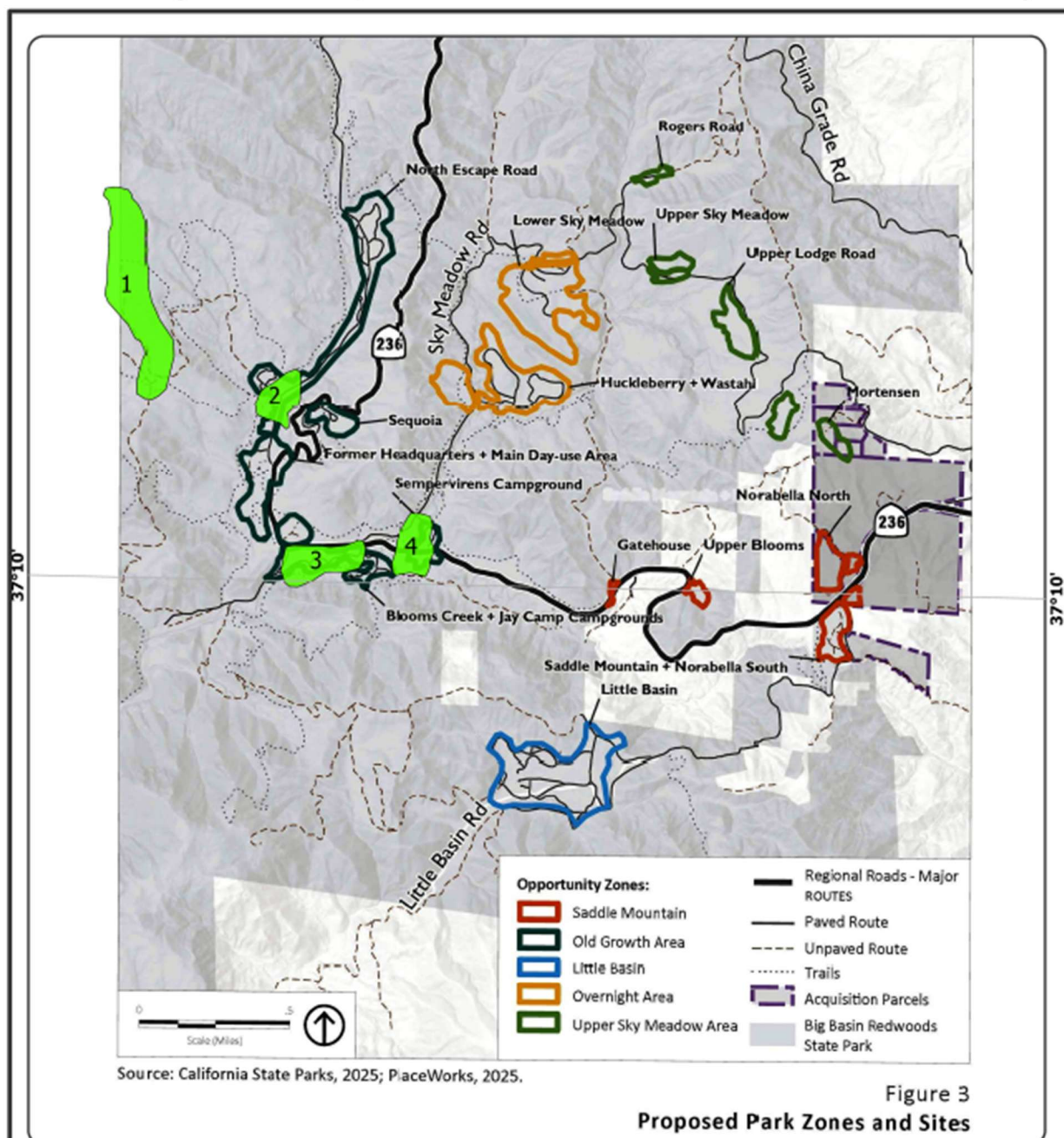
ORG4-23

Literature cited:

- Baker, L. M., Peery, M. Z., Burkett, E. E., Singer, S. W., Suddjian, D. L., & Beissinger, S. R. (2006). Nesting Habitat Characteristics of the Marbled Murrelet in Central California Redwood Forests. *The Journal of Wildlife Management*, 70(4), 939–946. [https://doi.org/10.2193/0022-541X\(2006\)70%255B939:NHCOTM%255D2.0.CO;2](https://doi.org/10.2193/0022-541X(2006)70%255B939:NHCOTM%255D2.0.CO;2)
- Brunk, K. M., West, E. H., Peery, M. Z., & Pidgeon, A. M. (2021). Reducing anthropogenic subsidies can curb density of overabundant predators in protected areas. *Biological Conservation*, 256, 109081. <https://doi.org/10.1016/j.biocon.2021.109081>
- California Department of Parks and Recreation, 2017. Marbled Murrelet Management Plan for Zone 6. 223 pp. Available at www.parks.ca.gov.
- Felis, J.J., Kelsey, E.C., Adams, J., Horton, C., and White, L., 2020. Abundance and productivity of marbled murrelets (*Brachyramphus marmoratus*) off central California during the 2019 breeding season. *U.S. Geological Survey Data Series* 1123, 13 p., <https://doi.org/10.3133/ds1123>.
- Nelson, S. K. (2020). Marbled Murrelet (*Brachyramphus marmoratus*), version 1.0. *Birds of the World*. <https://doi.org/10.2173/bow.marmur.01>
- Pacific Seabird Group. 2024. Terrestrial habitat management recommendations for Marbled Murrelets. *Pacific Seabird Group Technical Publication Number 7*. 38p. Available at <https://pacificseabirdgroup.org/psg-publications/technical-publications/>
- Peery, M.Z., Henry, R.W., 2010. Recovering marbled murrelets via corvid management: a population viability analysis approach. *Biological Conservation*, 143, 2414–2424.
- Potter, C. 2023. Impacts of the CZU Lightning Complex Fire of August 2020 on the Forests of Big Basin Redwoods State Park. *California Fish and Wildlife Journal* 109:109e1.
- Raphael, M.G. 2006. Conservation of the Marbled Murrelet under the Northwest Forest Plan. *Conservation Biology*, 20(2), 297-305.
- Shaffer, S. A., S. Cockerham, P. Warzybok, R. W. Bradley, J. Jahncke, C. A. Clatterbuck, M. Lucia, J. A. Jelincic, A. L. Cassell, E. C. Kelsey and J. Adams. 2017. Population-level plasticity in foraging behavior of western gulls (*Larus occidentalis*). *Movement Ecology* 5:27. DOI 10.1186/s40462-017-0118-9.
- USFWS 2024. Marbled Murrelet (*Brachyramphus marmoratus*) CA, OR, WA DPS. 5-year review: Summary and Evaluation. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, WA. 21 p.
- West, E.H., Peery, M.Z., 2017. Behavioral mechanisms leading to improved fitness in a subsidized predator. *Oecologia*, 184, 787–798.

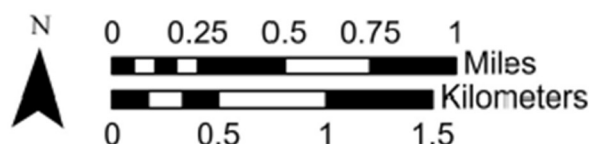
Location of Refugia Relative to Proposed Park Zone and Sites

July 2025

**Legend**

 Unburned Refugia

County of Santa Clara, MSinger
(Singer pers. comm. 2023)
Figure 3 (Parkworks 202)





Supplemental EIR

From Leslie Keedy <lkeedy505@gmail.com>
Date Fri 10/17/2025 7:00 PM
To Reimagining Big Basin <reimagining.bigbasin@parks.ca.gov>

This EIR study and its content information has not adequately addressed potentially significant impacts to adjacent private property, including environmental impacts, increased trespass and foot traffic, vehicle traffic - despite shuttles, noise pollution, light pollution, groundwater, and increased physical trash from patron use, and other adverse impactful ecological activities resulting from increased public use.

IND1-01

The currently low state staffing levels and resources levels will limit response to neighbor concerns and limit park oversight. The plan implementation will further significantly impact immediate neighbors. Emails and messages are currently not returned.

Roads such as upper Bloom Grade have not been adequately protected with park signage and gating to limit trespass and stop lost people and vehicles from trespass onto private property.

IND1-02

A greater effort should be made towards funding the Sempervirens fund to purchase adjoining privately owned burned acreage properties that are now forever changed in desirability and character because of the new park headquarters location. Many people are interested in selling to the state and Sempervirens fund and inquiries have been rejected for purchase by Sempervirens fund stating limited funds for land acquisition and stated higher priorities.

My specific property at 505 upper Bloom Grade is now completely surrounded on three sides by State Park property limiting its serenity and privacy. Initially Sempervirens fund stated said they would purchase my property and then they never followed up or responded to my messages and then when I finally was in contact with them they told me they were no longer interested ..however this property will be directly adversely impacted by unpermitted uses and trespass and people cutting across the private land to get to trails and roads, etc. It is no longer desirable as a private residence. This property should be purchased and acquired at fair market value and made part of the saddle mountain trail system as it features scenic views, and an existing loop trail already in place from previous logging.

IND1-03

Due to acquisition of all surrounding lands by the state my adjoining property is virtually surrounded by public use, the property no longer retains its character, privacy and serenity that it had prior to the 2020 CZU wildfires and the greater state acquisitions.

IND1-04

The road that accesses my land upper bloom grade which I am solely responsible for financially has been adversely impacted by unauthorized vehicles and the state has offered no funding or support to maintain or repair this road from increased unsolicited vehicle use. Although the uphill side land is now owned by Sempervirens fund to center line of the road, there has been no maintenance of the road or management of the encroachment of invasive plant material, nor addressing drainage and erosion impacting the road.

IND1-05

This project was inadequately vetted by the immediate neighbors. There was little inclusion, complete

IND1-06

10/20/25, 10:49 AM

Mail - Hammack, Garret@Parks - Outlook

dismissal of mitigating impacts of neighbors concerns, no inclusion of suggestions, neighbors comments were dismissed. The rural neighborhood is no longer what it was because of the saddle Mountain headquarters proposal. This plan and change in public use was thrust upon us immediate neighbors with little input and leaving neighbors no recourse.

Leslie keedy
505 upper bloom grade
Boulder creek

Sent from my iPhone

**IND1-06
cont.**

To: Mr. Will Fourn, CDPR
Re: Big Basin Redwoods State Park
General Plan Supplemental EIR

December 1, 2025

The SEIR for the Facilities Management Plan and General Plan Amendments is well thought out and presented. I support the proposed project in general.

IND2-01

I offer the following comments for consideration:

The Sequoia Group Camp within the Old Growth Area is still troubling. It is a difficult call since much of the infrastructure remains post-fire. However, I lean towards abandonment and restoration for the following reasons. There appears to be Old Growth^(OG) connectivity with the Core Old Growth area. This connectivity is especially evident along the beginning portion of the access road and in redwood clumps within and surrounding the camp area. Fair post-fire canopy exists, which will improve with time, and there appear to be trees with potential Marbled Murrelet nesting platforms.

IND2-02

The Sequoia Camp would be the only

(2)

Camping facility proposed that is topographically connected to the Core OG area. A ridge East of Sequoia separates the OG area from the Overnight and Upper Sky Meadow Areas. Camping and access vehicle sounds will likely carry to the Core OG area, as will smoke from campfires and BBQ's. Campground use may also attract Corvids to the OG Area. On my recent visit I saw and heard no Corvids there (Sequoia).

IND2-02
cont.

The access road to Sequoia is steep and narrow and will need repair and ongoing maintenance. This is possible, but OG habitat connectivity may be more important.

IND2-03

Restoring Sequoia appears to potentially further reduce impacts to marbled murrelets (MAMV). Perhaps the Overnight and Upper Sky Meadows could accommodate the group camps instead.

IND2-04

The Gazos East and West group picnic areas are also of concern. This area has been identified as unburned MAMV refugia (Singer pers. comm. 2025) as referenced by Pacific Seabird Group comments (July 18, 2025). The North Escape Road would be partially reopened to recreational parking and traffic to access the picnic areas. The picnic

IND2-05

③

area could also attract crowds to this Core OG area. Removing recreational vehicular access, parking, and picnic sites would likely further reduce potential impacts to MAMV at this location.

IND2-05
cont.

On my recent ~~visit~~ visit there were numerous families, from toddlers to great-grandparents walking the North Escape Road. It was peaceful and families had room to spread out. As it is (closed to ^{vehicular} access) the North Escape Road may be the most pedestrian/ADA friendly pathway within the OG area. It is a small, easily accessed "Avenue of the Giants." Car access, parking, and group picnic areas would diminish the existing OG experience in my view.

IND2-06

If a picnic area were still desired here (Gazos), I would recommend no vehicular access/parking. Perhaps wagons could be available for guests as part of the reservation. It is a short, flat, paved walk in.

I also noted that there was no smoke, smell of campfires and BBQ's in the OG area as there was in the past. I could smell the forest! This enhanced my visitor experience. I recommend that

IND2-07

(4)

any cooking within the OG area be
limited to cooking stoves, no BBQ's.
BBQ's could be provided elsewhere.

IND2-07
cont.

Special Animals Section 4 of the SEIR
discusses that culverts would be sized for
fish Passage. This is good, but there
is only an emphasis on culverts. Full
span bridges may be preferable for fish
passage and should be included in this
section.

IND2-08

In conclusion, I appreciate the
huge level of work and thought
involved by DPR staff and consultants
in this effort. My comments are
respectfully submitted. In my mind they
are maybe fine tuning, the bulk of
the big issues have been well considered
already. For this reason I support
approval of the SEIR.

IND2-09

Sincerely,

Matt Baldzikowski
Santa Cruz, CA

Fourt, Will@Parks

From: Susan Kirks <susankirks@sbcglobal.net>
Sent: Monday, December 1, 2025 4:33 PM
To: Reimagining Big Basin
Subject: Big Basin Redwoods State Park General Plan Supplemental EIR

You don't often get email from susankirks@sbcglobal.net. [Learn why this is important](#)

There should be no camping ground or camping activity in the area of habitat for Marbled Murrelet. As you know, active nesting birds and their nests are protected by the federal Migratory Bird Treaty Act and the CA Fish and Game Code. For any human activity in the area of the trees that comprise the Murrelet's nesting habitat, buffer zones should be established and demarcated to prevent any human encroachment into the area where the Murrelets are nesting. Marbled Murrelets are asynchronous nesters, but generally the regulations apply to nesting birds February 15 to early September. That would mean all of Spring and Summer.

So, no camping activity should be allowed in the area of the trees where the Murrelets nest. If other active nesting birds are identified, those habitat areas should also be protected, with no human encroachment.

Susan Kirks
Past President, Madrone Audubon, Sonoma County
Naturalist, Bay Area and California
707-241-5548

IND3-01