Marbled Murrelet Landscape Management Plan for Zone 6

Editors

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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.

ACKNOWLEDGEMENTS

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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 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 photos[1].

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

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 map[2] 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 Murrelet[3]

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 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" (Golighty 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, 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	• 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	• 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	• 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	• 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	• 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.	• 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

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 is 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 Canyon[1]

	A-V Detections			Radar Detections		
Year	**Mean Total**	**S.D.**	**C.V.**	**Mean Total**	**S.D.**	**C.V.**
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

[1]For 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 fledgings 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).

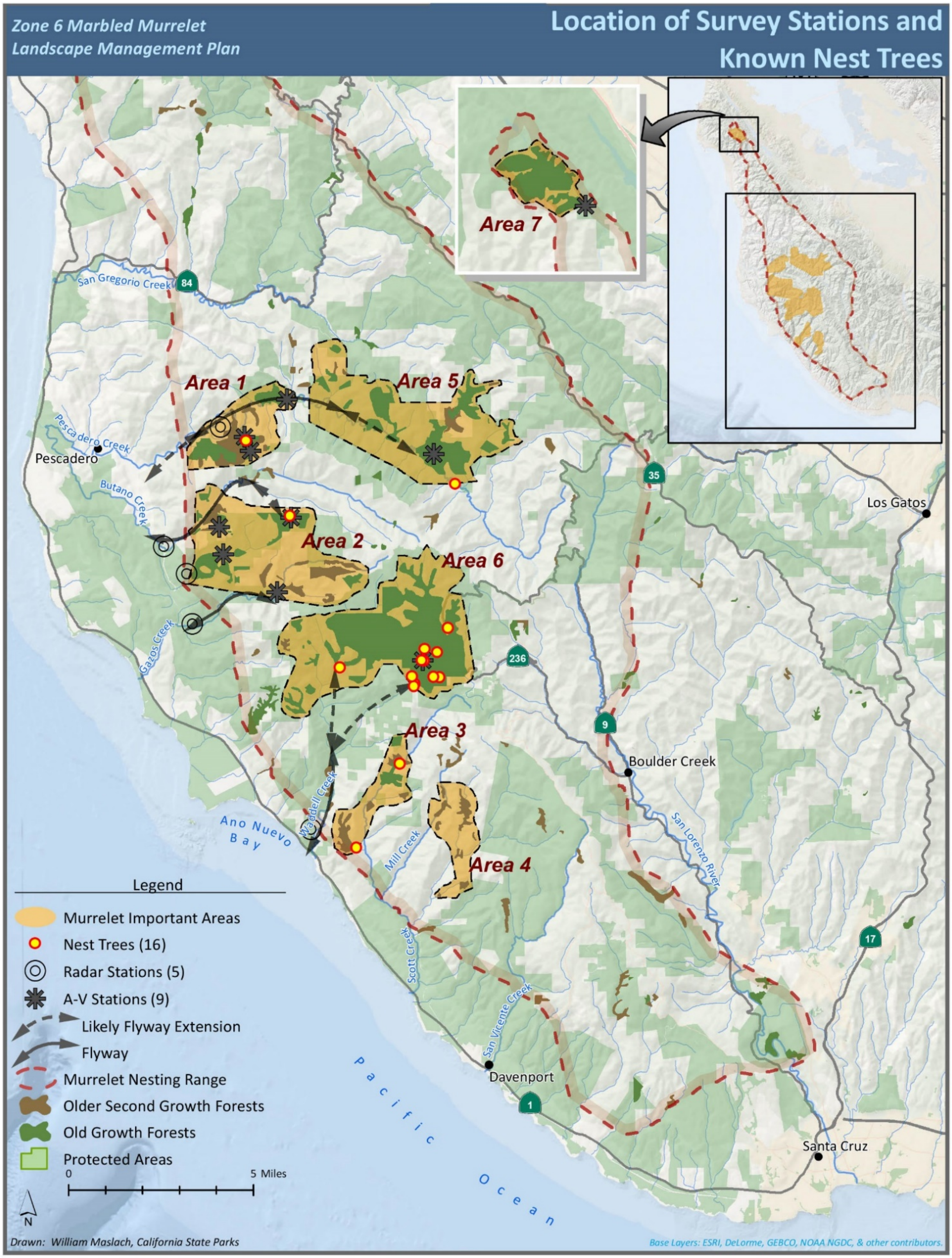

Figure 2-2.. Location of Survey Stations and Known Nest Trees

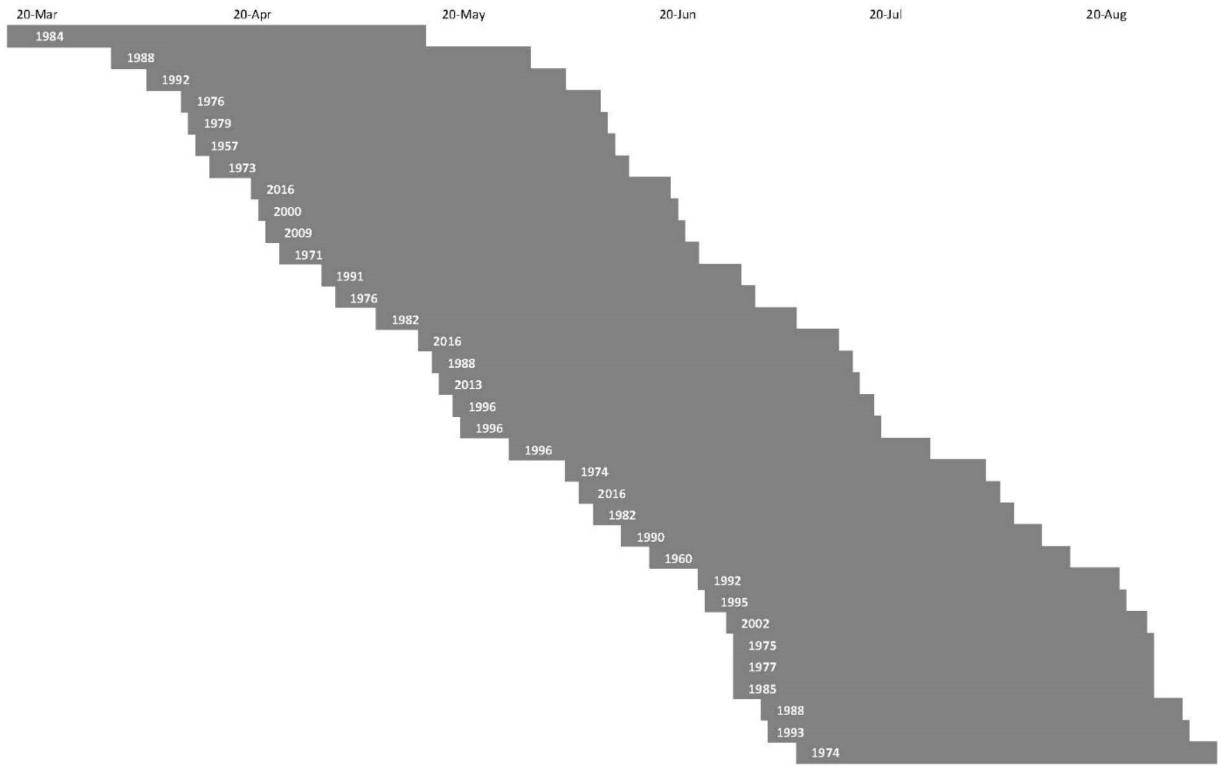

Figure 2-3. Nesting Chronology for Zone6 (Based on 30 grounded fledglings, 3 successful nests and 1 nest near completion.

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.

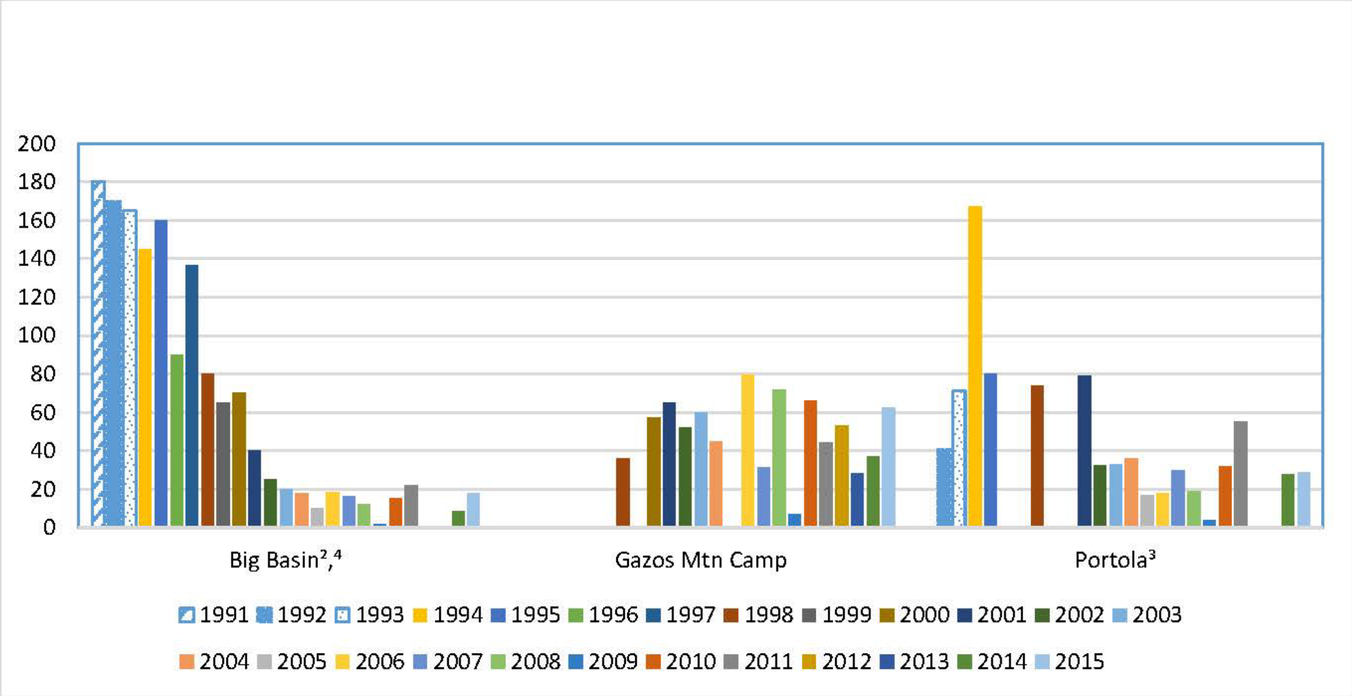

Figure 2-4. Mean Total A-V Detections from Long-term Monitoring

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 SITES[4]

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.

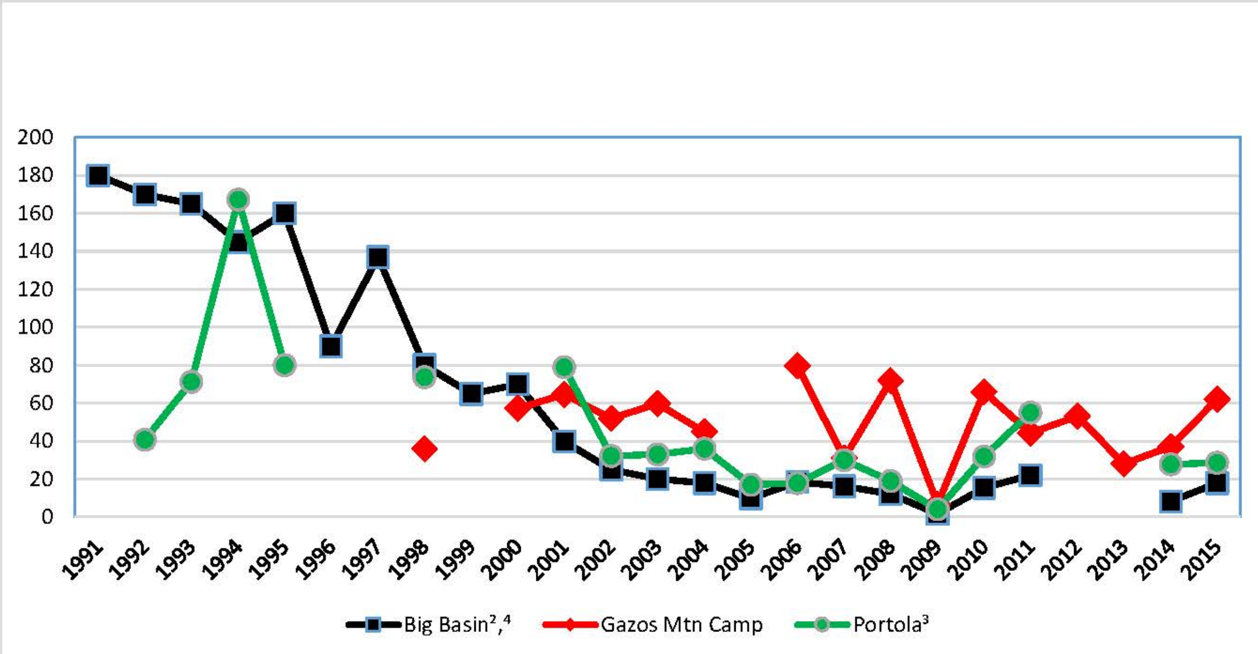

Figure 2-6. Mean Total A-V Detections from Long-term Monitoring

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

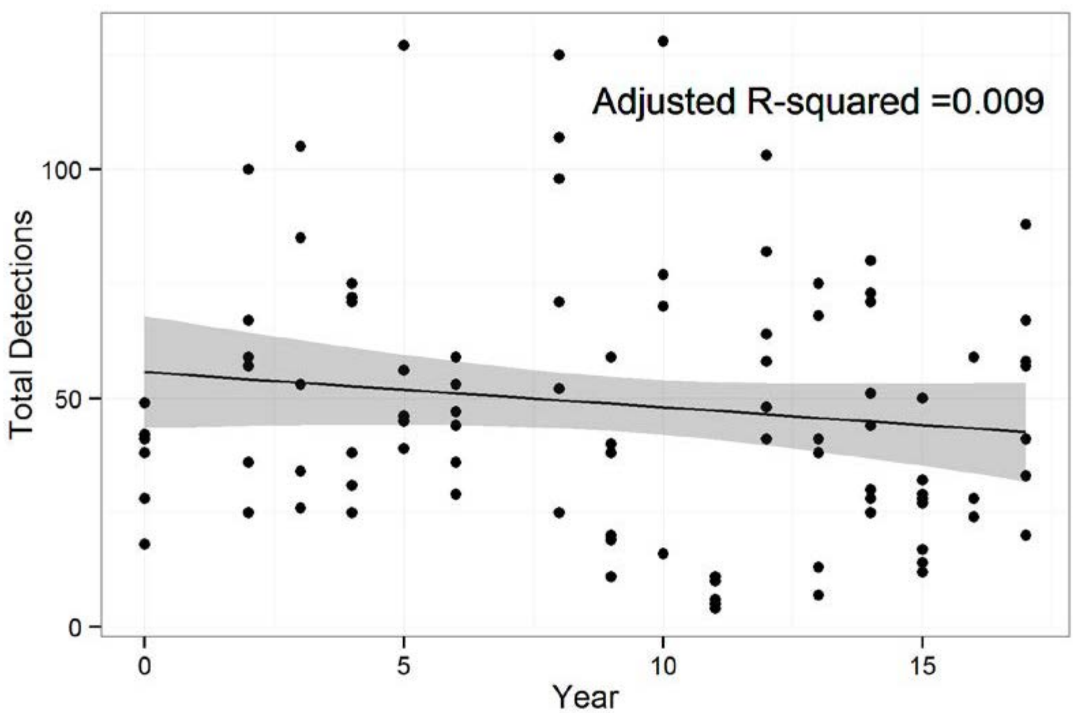

Figure 2-5. Daily A-V Detections, Gazos Mountain Camp, 1998-2015

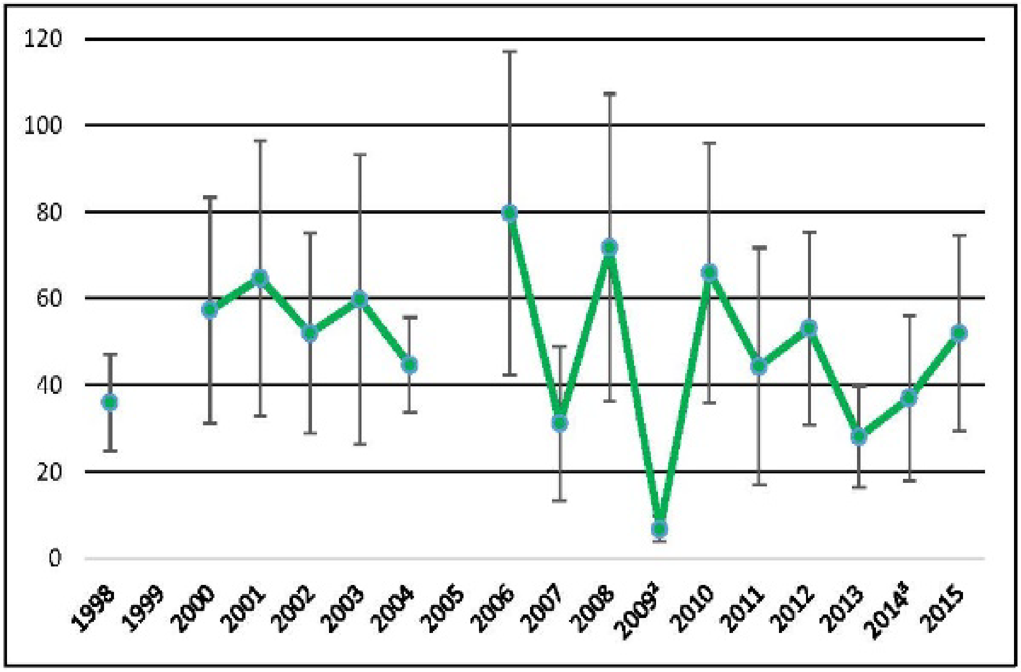

Figure 2-7. A-V Detection Means, with Error Bars, Gazos Mountain Camp, 1998-2015

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

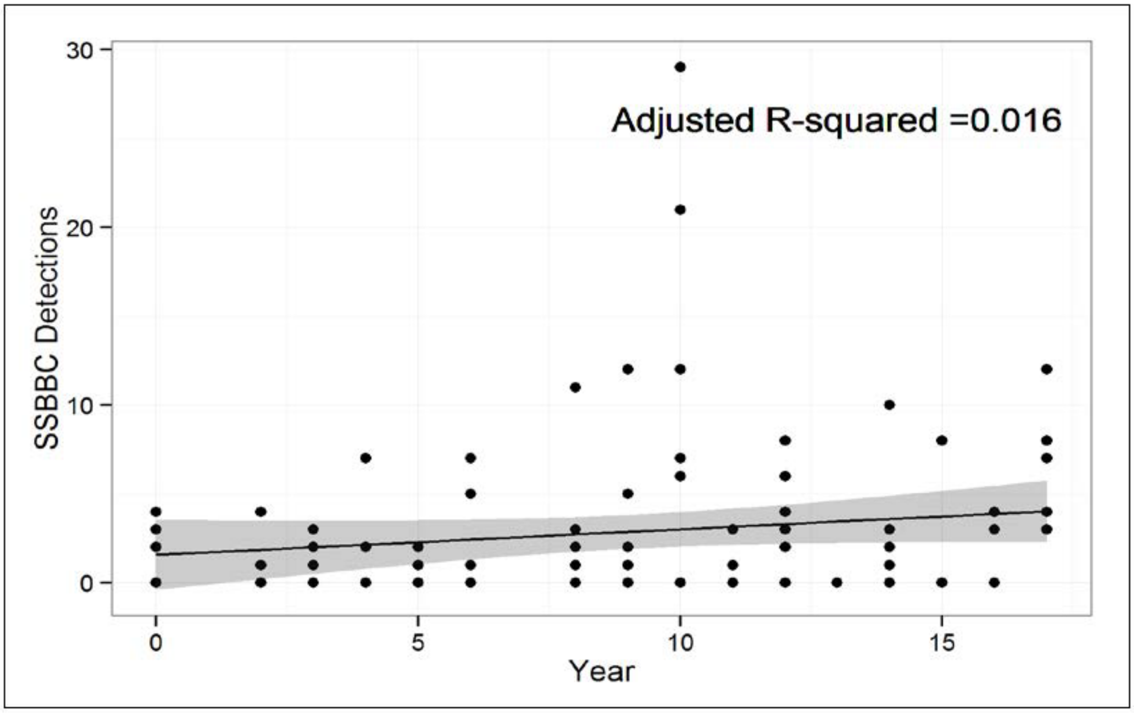

Figure 2-8. Daily SSBBC Detections, Linear Model, Gazos, 1998-2015
(Note: SSBBC=Single silent birds below on canopy)

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

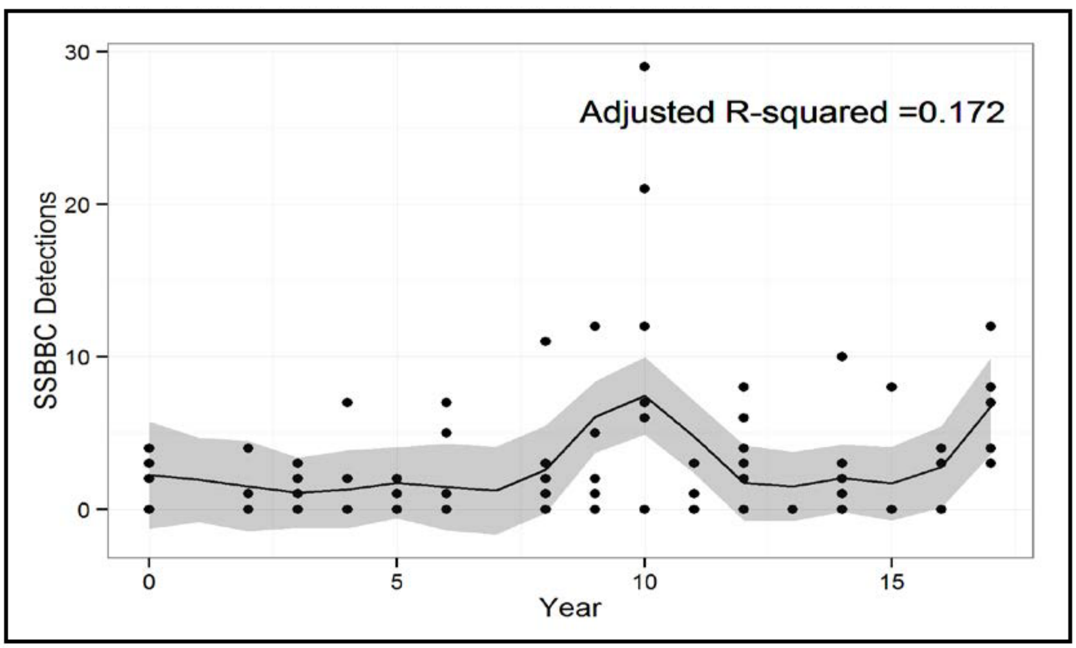

Figure 2-9. Daily SSBBC Detections, GAM Model, Gazos, 1998-2015

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

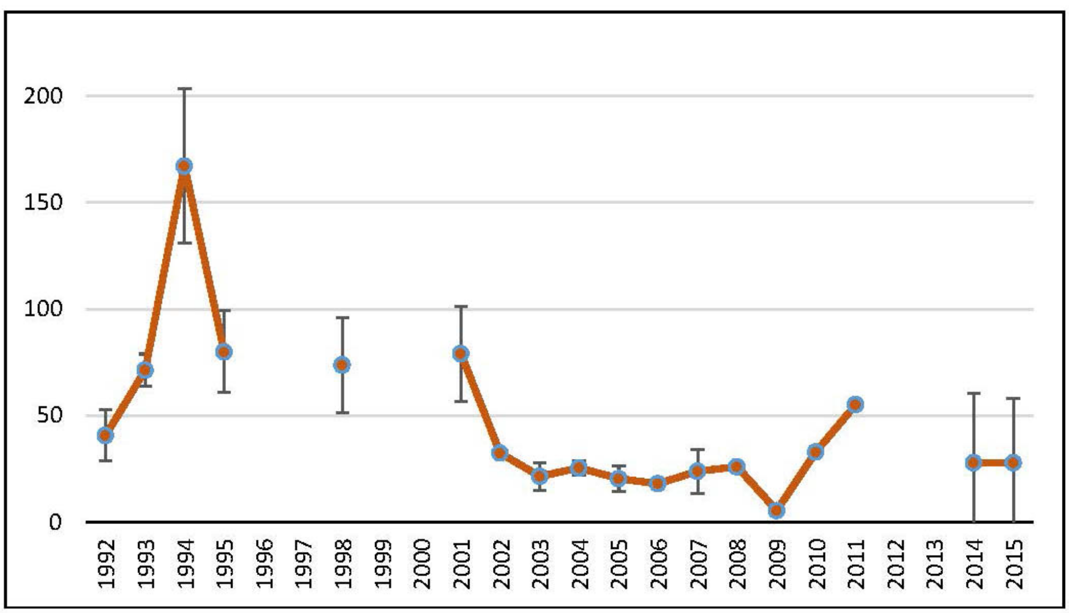

Figure 2-10. Mean Total A-V Detections, Portola State Park, 1992-2015

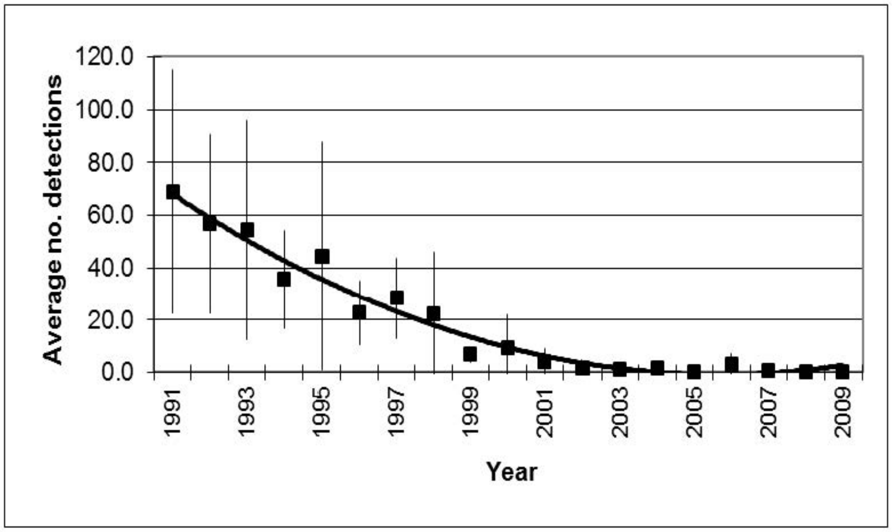

Figure 2-11. Mean Total A-V Detections, Big Basin, 1991-2009 (data from D.L. Suddjian)

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,

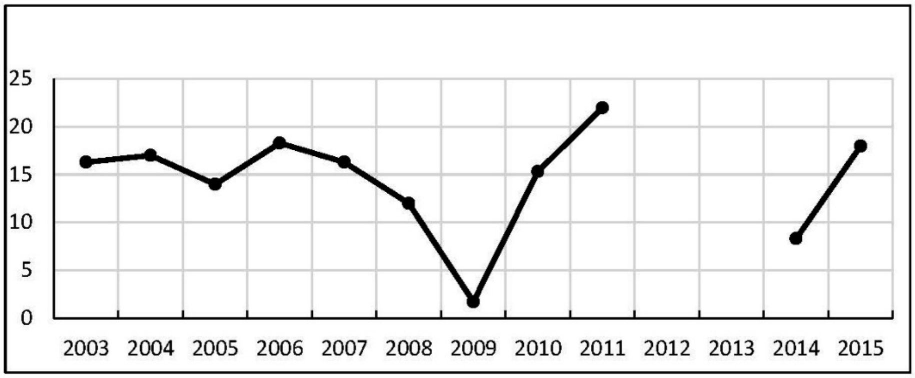

Figure 2-12. Mean Total A-V Detections, Big Basin, 2003-2015

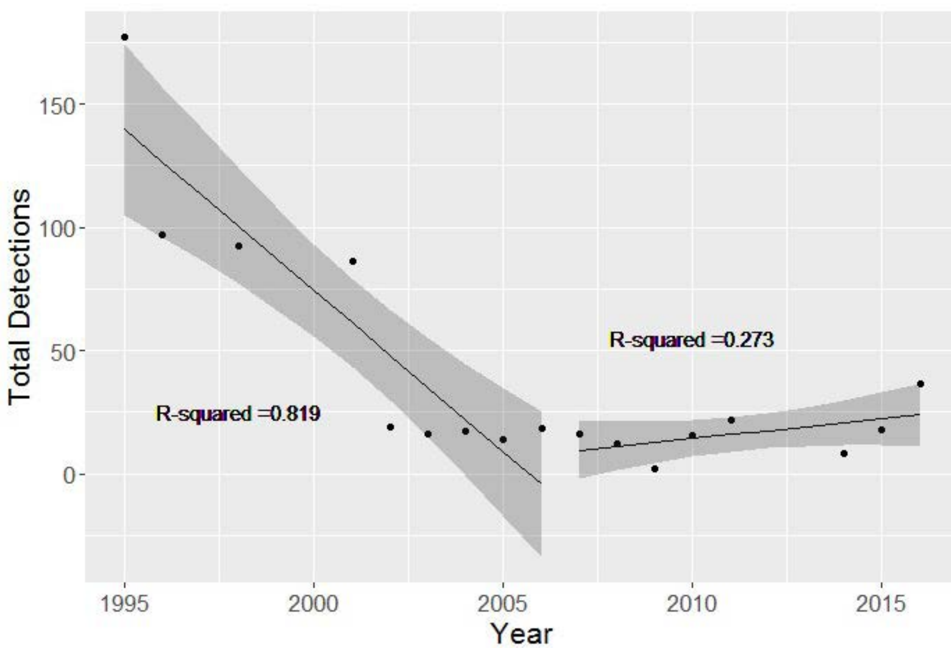

Figure 2-13. Trends in total A-V detections at Big Basin State Park both before and after the onset of efforts to control corvid numbers in 2006. The trend line from 1995 to 2006 is statistically significant ($F_{1,7}$ = 31.57, $p<0.001$). The trend line from 2007 to 2016 is not (Comfort 2017).

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 Surveys[1]

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

[1]*Excluding 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 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

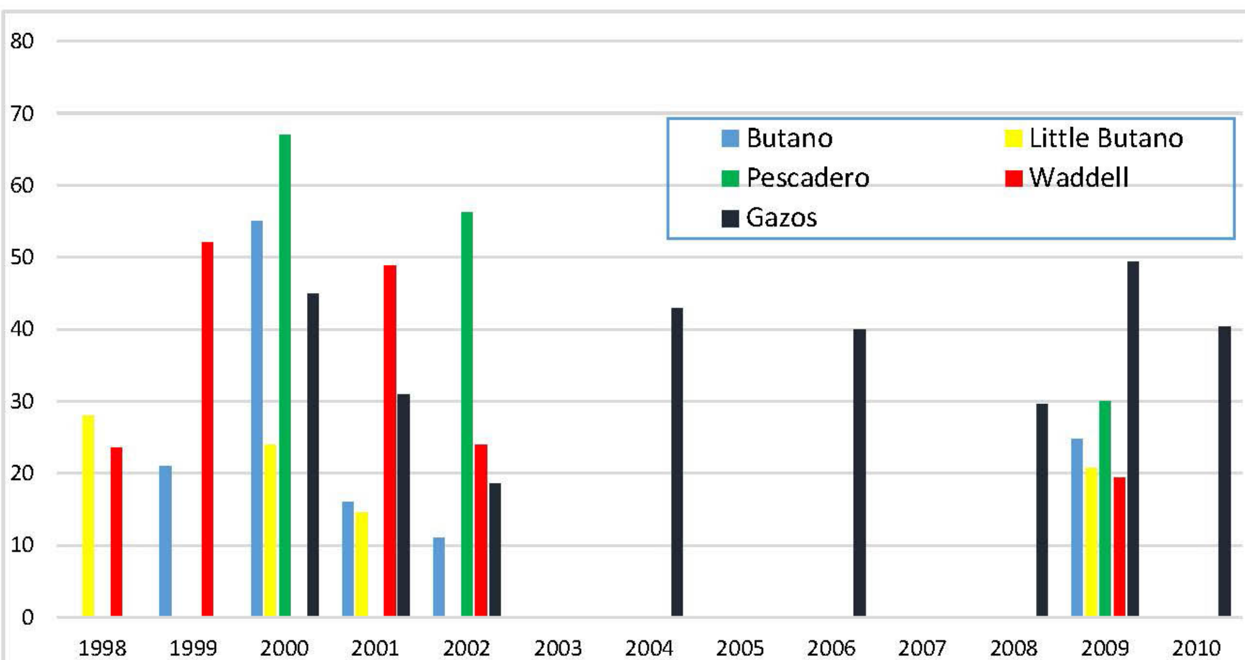

Figure 2-14. Means-Total Radar Detections at Five Stations

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 WATERSHED[5]

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.

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

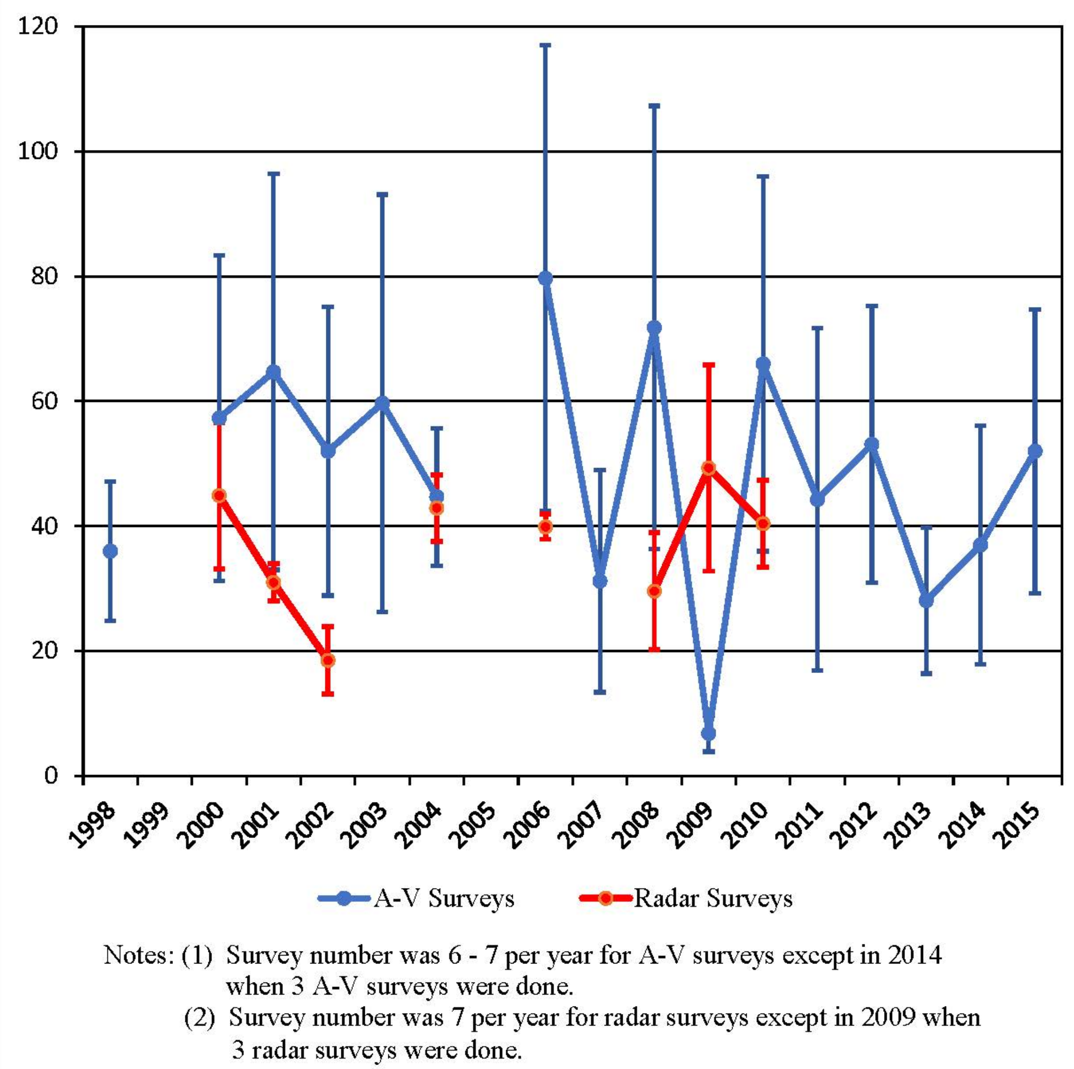

Figure 2-15. Radar and A-V Results with Standard Deviation for Gazos, 1998 - 2015

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 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

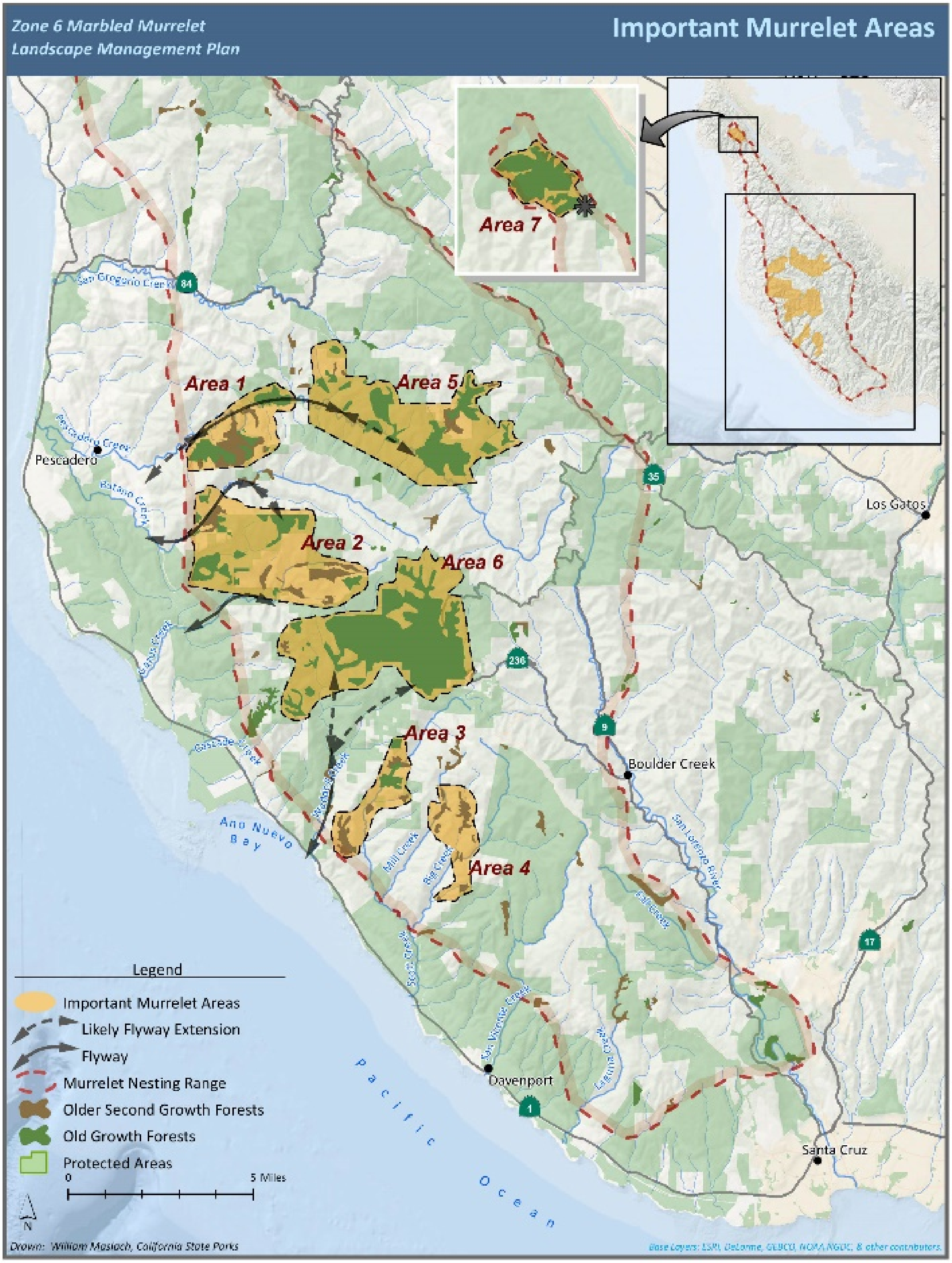

Figure 2-16. Important Murrelet Areas

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

TABLES

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence[1,2]

Type of Evidence	Map ID	Date Discovered	General Location	Specific Location if known	Comment
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 Hucklberry & 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	

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence[1,2]

Type of Evidence	Map ID	Date Discovered	General Location	Specific Location if known	Comment
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	

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence[1,2]

Type of Evidence	Map ID	Date Discovered	General Location	Specific Location if known	Comment
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	

Table 2-4 Nesting Occurrences of the Marbled Murrelet in Zone 6 Based on Conclusive Evidence[1, 2]

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

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

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

[1]Nest 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.

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 down-stream 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.

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.	1995-2001: n=4 surveys/yr. TD=133 (86-177). OB=33 (8-64). 1991-2001 Suddjian set: n= 7-11 surveys/yr. TD = 118 (83-325). OB= 32 (12-166). 2002-2011: n=10 surveys/yr. TD=15 (1.7-22). OB=2 (0-9). 2002-2009 Suddjian set: n= 14-18 surveys/yr. TD= 11 (9-134). OB= 1 (0.2-1.6) 2015: 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.	1998-2001: n=5-7surveys/yr. TD=53 (18-105). OB=15 (3-43). 2002-2011: n= 7surveys/yr. TD=51 (4-128). OB=13 (0-48). 2012-2015: n=7surveys/yr. TD=38 (14-88). OB=10 (0-56). 2015: 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: 2002: n=4 surveys. TD=28 (4-59). OB=5 (1-10). 2011: n=7 surveys. TD=6 (2-9). OB=<1 (0-2). 2002, 2007-2011: 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.	2003-2011: n=3 surveys/yr. TD=40 (18-68). OB= 8 (2-22). 2014: n=3 surveys. TD=78 (36-42). OB= 29 (23-34). 2015: 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.	1992-2001: Inside Park: 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.

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 1993-2001: 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 1993-2001: 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.	1993: 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 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.	2003-2011 (n=3/yr). TD=3 (1-11). OB=<1 (0-1). 2014: 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.	Dark Gulch station: 2015: 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.

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. 1991: 15 surveys. TD=9. OB=1. 2001: 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. 2001: 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.	2015: 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.

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

*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

*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

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

*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

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

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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

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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-growths stands in Big Basin State Park. Grounded fledgling found in watershed in 2016.	CDFG, SVP records	OB	None
TOTAL		**n = 67 stands**			**3117.89**					

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 whichl drains into the South Fork of Butano Creek. Park also has significant amounts of Older 2G forest.	NEST

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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)

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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

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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 residental 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

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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

Watershed Unit	Remaining Potential Habitat (acres)	Flyway Identi-fied?	Most Important Breeding Sites, Their Status[1] and Size	Research & Monitoring Needs
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.

Table 2-10 Watersheds with the Most Remaining Habitat

Watershed Unit	Remaining Potential Habitat (acres)	Flyway Identi-fied?	Most Important Breeding Sites, Their Status[1] and Size	Research & Monitoring Needs
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.

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

[2]Plus 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.

*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.

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 circum-stantial 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 mal-adaptive 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 brachyrhyncus*) 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,

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 subsides 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-Auger et al. 1990) and urban/suburban areas (Chamberlain-Auger 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.

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

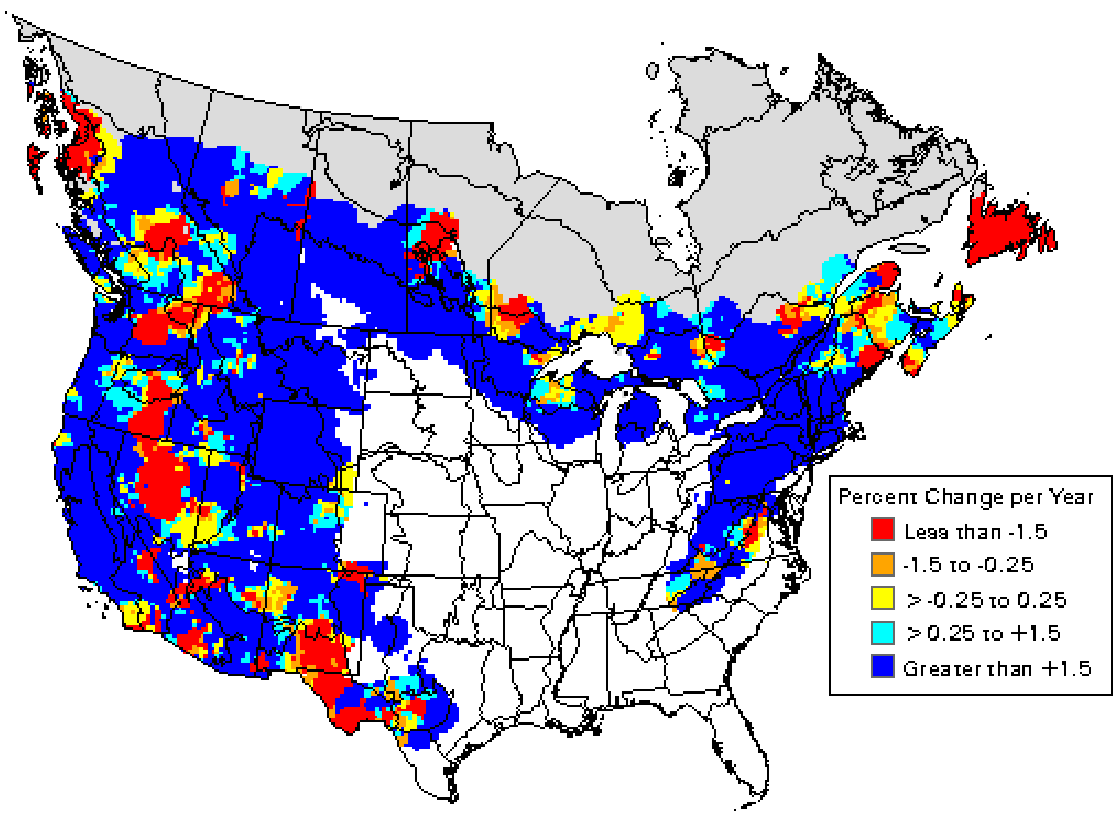

Figure 3-1. Trend map for ravens generated from BBS survey data from the time period 1966–2013.

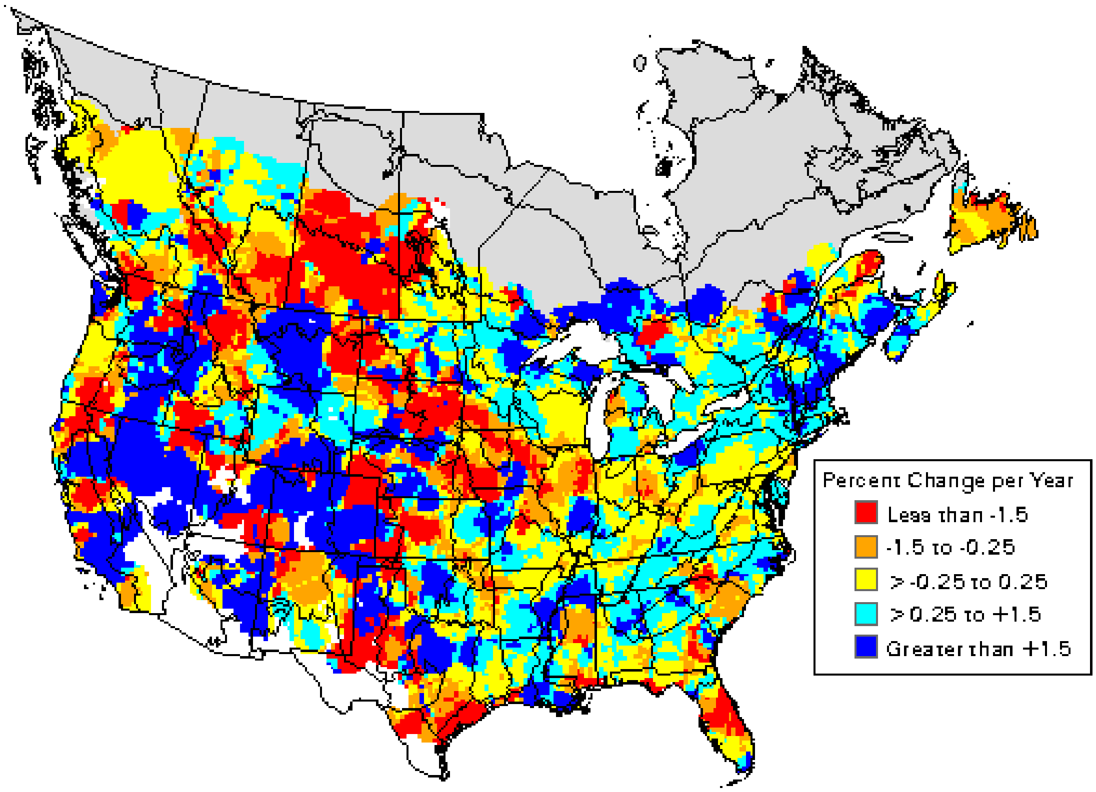

Figure 3-2. Trend map for crows generated from BBS survey data from the time period 1966–2013.

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).

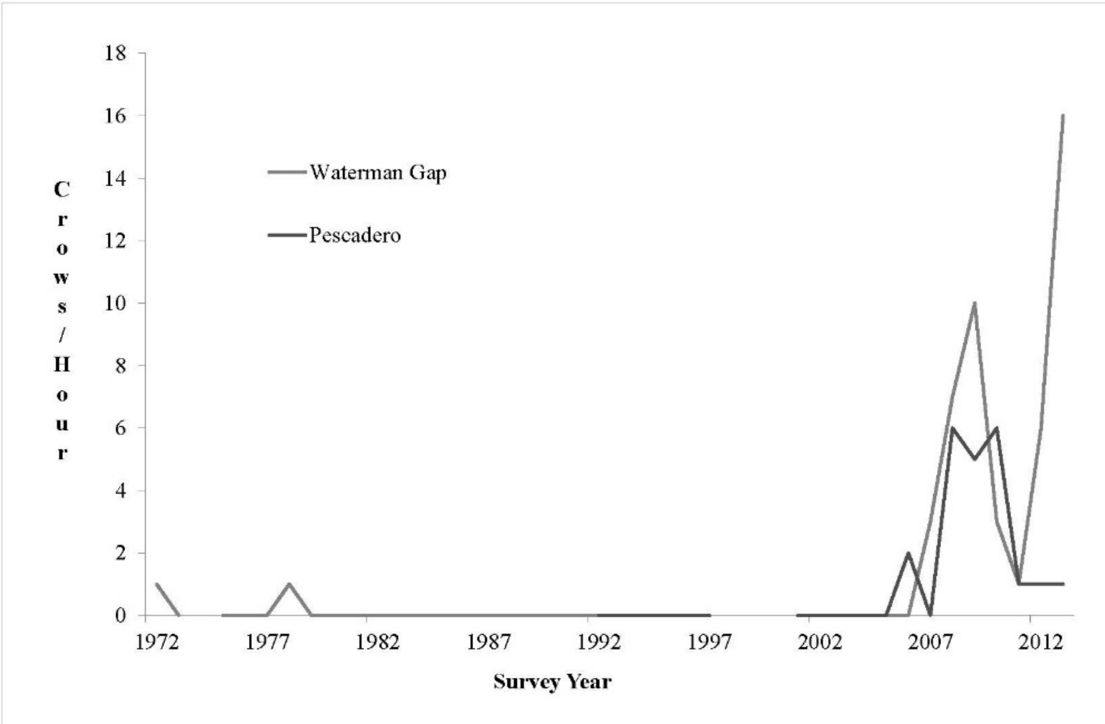

Figure 3-3. Number of crows observed on the two Breeding Bird Survey routes in the Santa Cruz Mountains between 1972 -2014. Gaps in the lines represent years in which surveys did not occur.

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 theses 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 item 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*

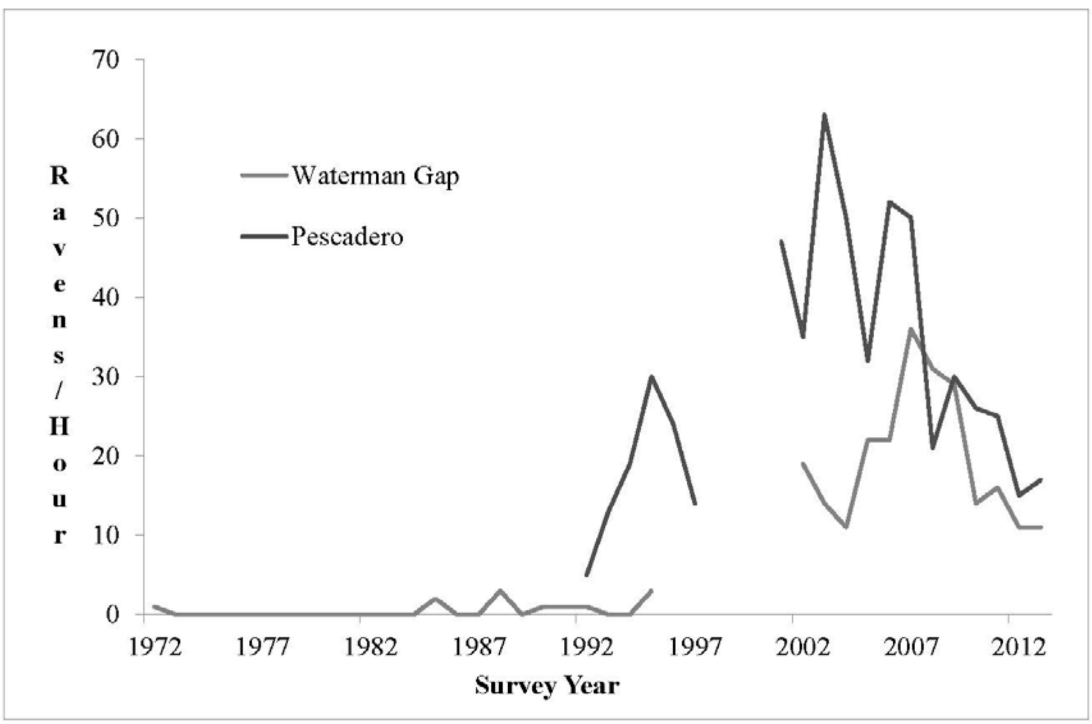

Figure 3-4. Number of ravens observed on the two Breeding Bird Survey routes in the Santa Cruz Mountains between 1972 -2014.

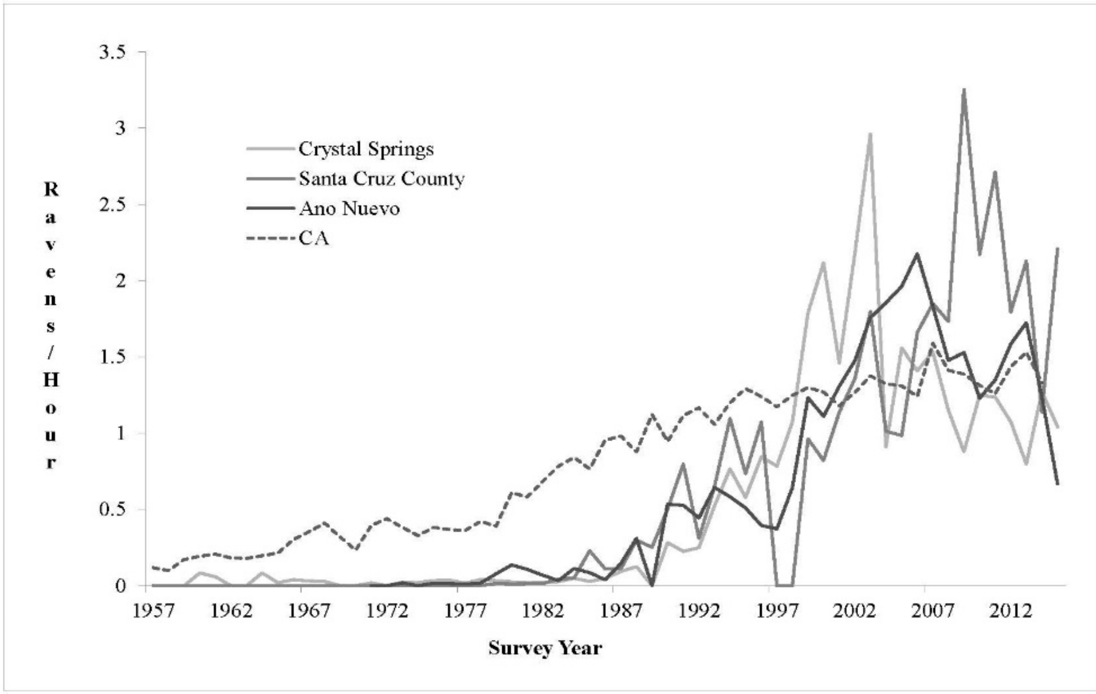

Figure 3-5. Number ravens observed per party hour from Audubon Society's Christmas Bird Counts, 1956-2015 Data are from statewide averages and the three closest census sites to the forested portions of the Santa Cruz Mountains: Crystal Springs, Santa Cruz County and Ano Nuevo.

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

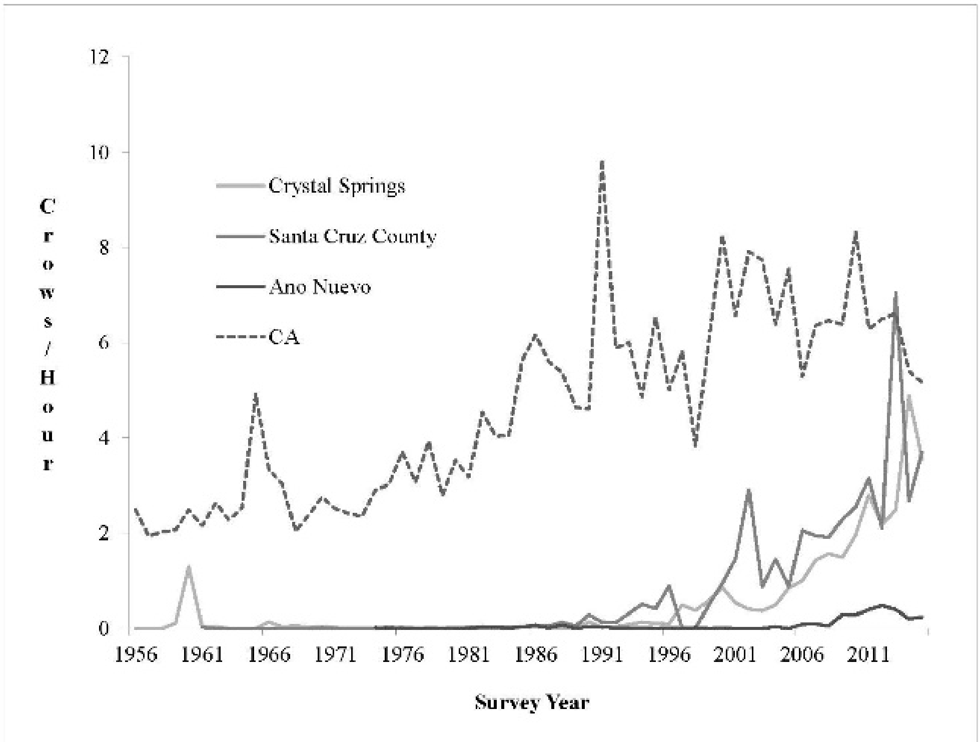

Figure 3-6. Number of crows per party hours observed during Audubon Society's Christmas Bird Counts, 1956-2015 Data include statewide averages and from the three closest census sites to the forested portions of the Santa Cruz Mountains: Crystal Springs, Santa Cruz County and Ano Nuevo.

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 predating 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

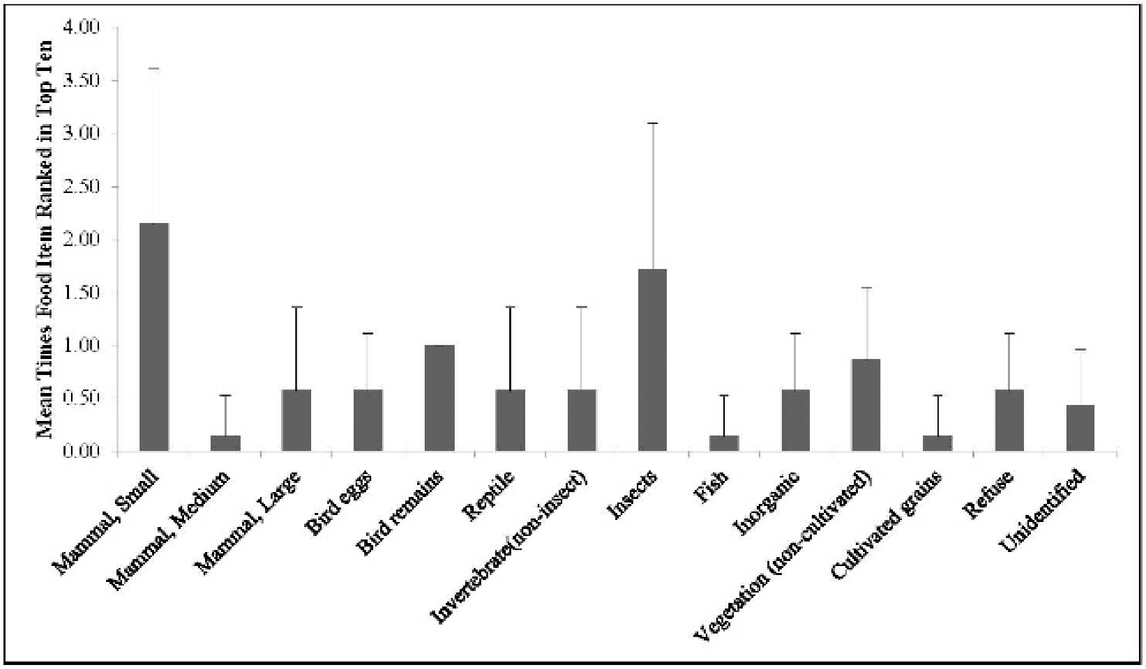

Figure 3-8. Results of a diet metanalysis from seven studies of raven pellets or stomach contents. Displayed are the mean number of times a food item (from the top ten most frequently consumed in each study) fell into a particular dietary category. Plotted are the mean and standard deviation (error bars).

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

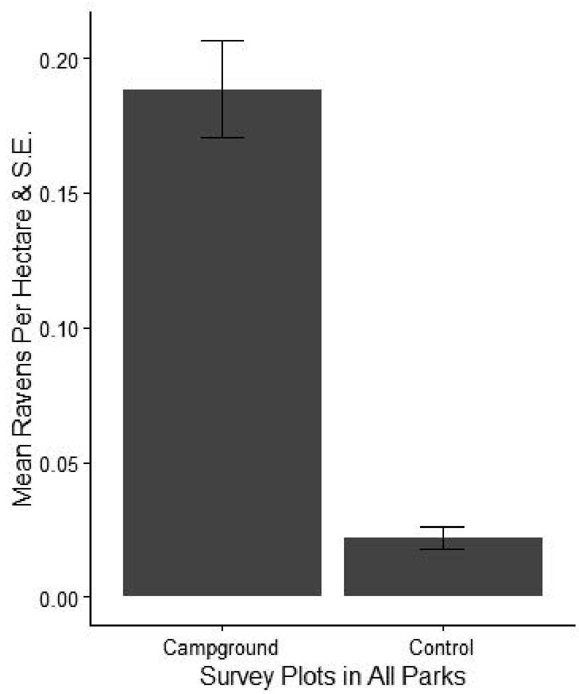

Figure 3-7. Raven density in campgrounds compared to control sites observed during corvid surveys. Data are from (Halbert 2012) , which includes surveys conducted 2003-2008 and 2012.

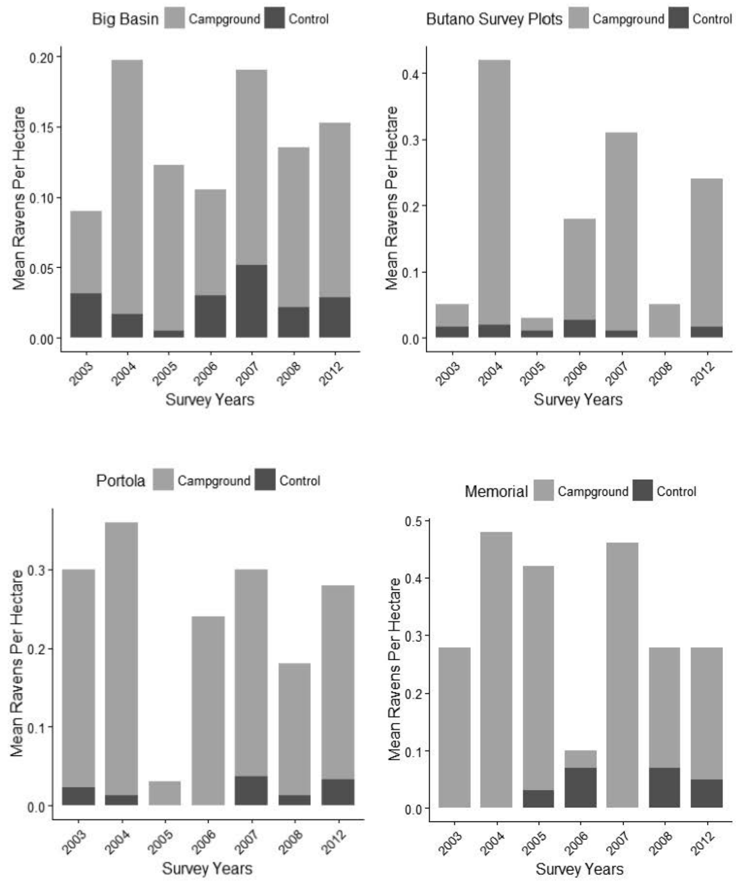

Figure 3-9. Raven density in campgrounds and control sites at all four parks. Data are from (Halbert 2012), which includes surveys conducted 2003-2008 and 2012. Note: Light gray bars are not stacked but intended to extend beneath the dark gray bars.

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 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.

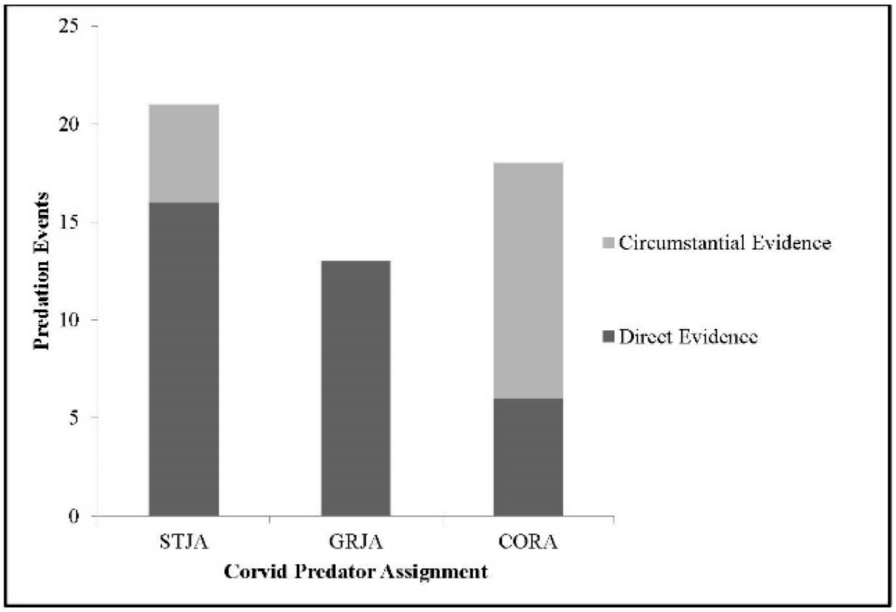

Figure 3-10. The number of predation events attributed to steller's jays (STJA), Gray Jays (GRJA) and ravens (CORA) from the 52 predation events of real or simulated murrelet nests assigned to corvids. Assignments determined by circumstantial evidence are colored light grey, and assignments observed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

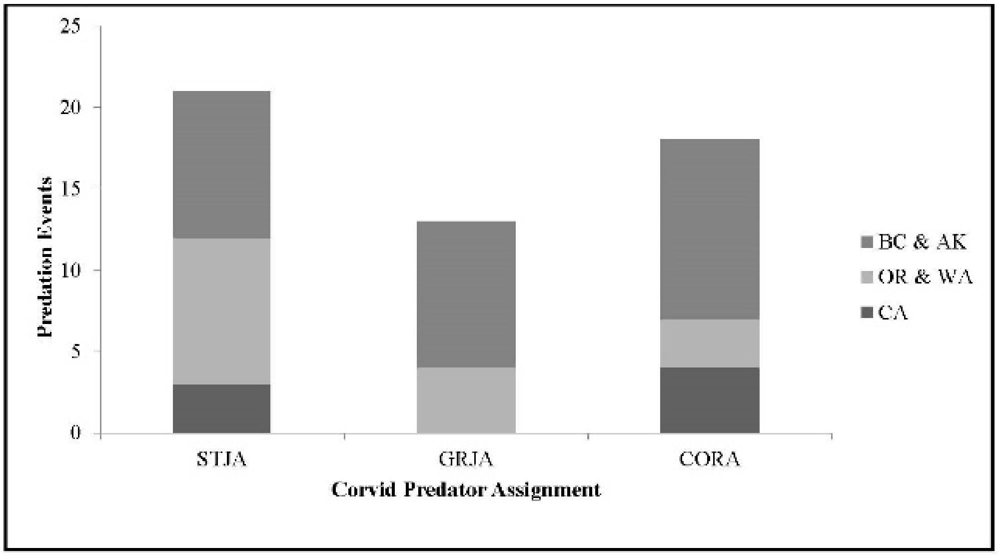

Figure 3-11. The number of predation events attributed to steller's jays (STJA), Gray Jays (GRJA) and ravens (CORA) from the 52 predation events of real or simulated murrelet nests assigned to corvids. Predation events for each predator are divided by political jurisdictions: California (CA); dark grey; 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

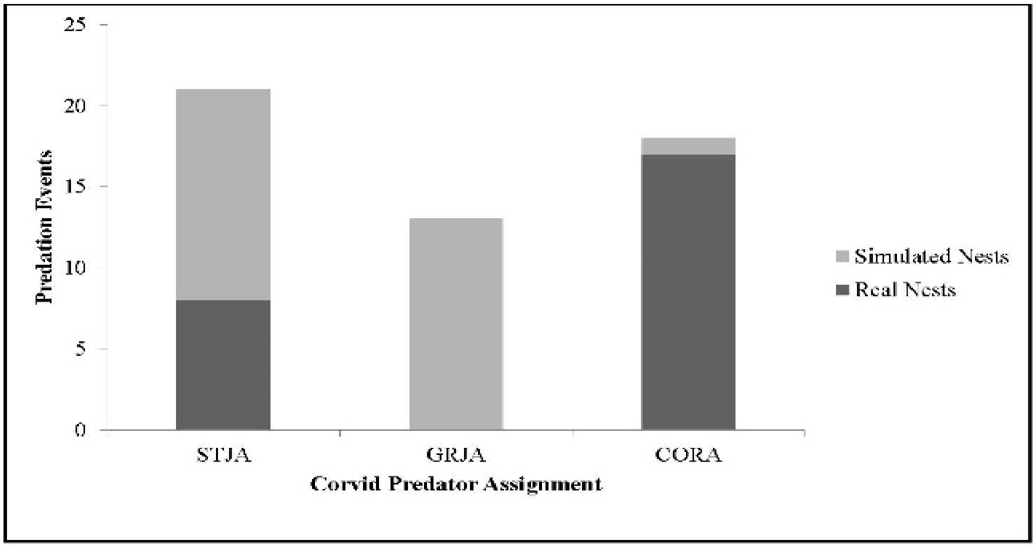

Figure 3-12. The number of predation events for simulated (light grey) and real nests (dark grey) attributed to steller's jays (STJA), Gray Jays (GRJA) and ravens (CORA) from the 52 predation events of real or simulated murrelet nests assigned to corvids.

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 it 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.

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 Malhuer 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 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 subsides 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).

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

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

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

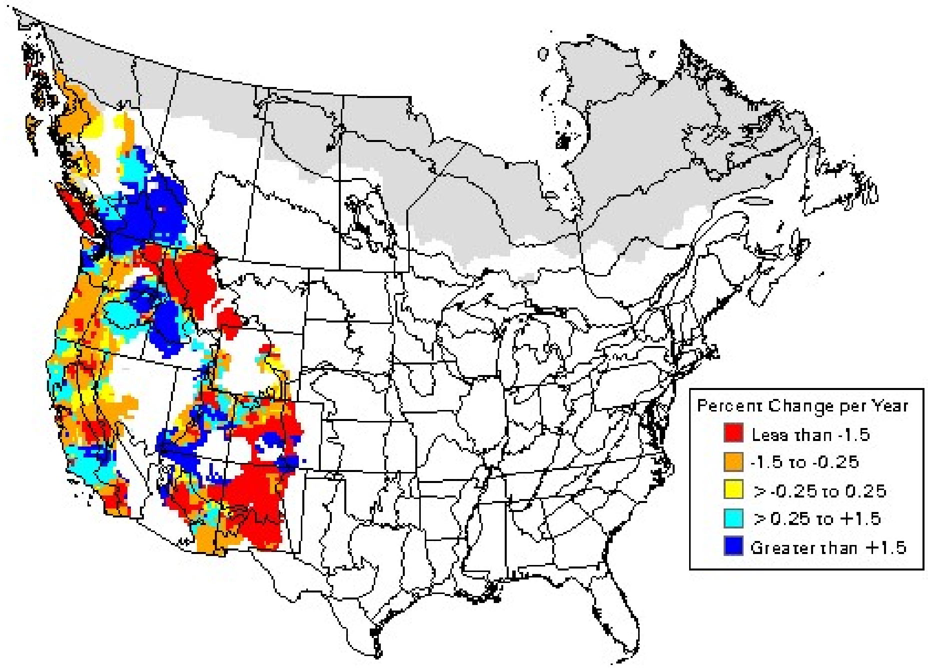

Figure 3-13. Trend map for steller's jays generated from BBS survey data from the time period 1966–2015 showing percent change per year.

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

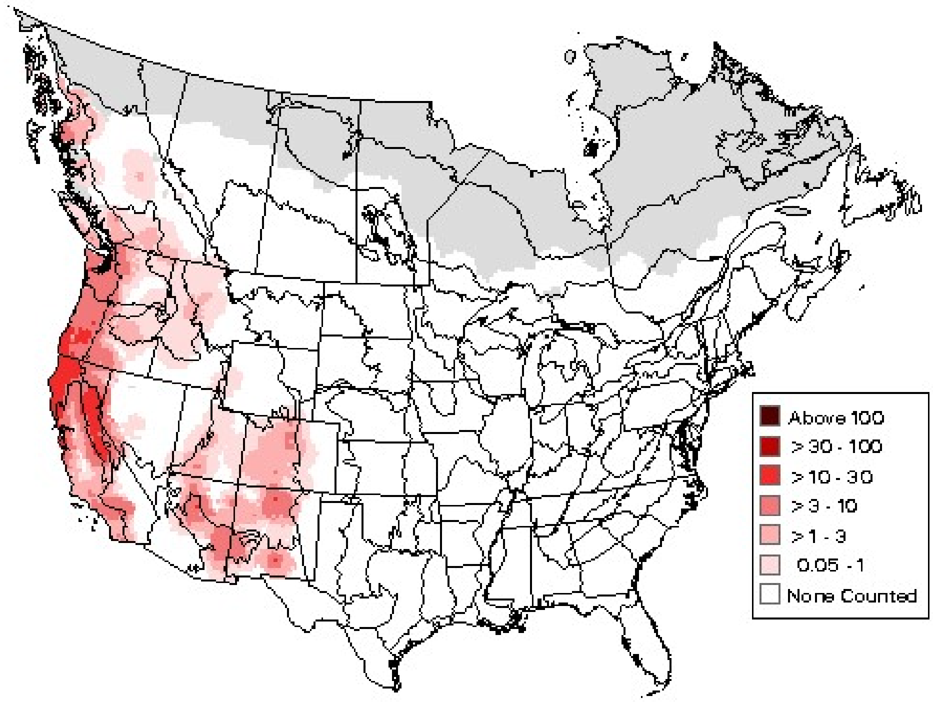

Figure 3-14. Trend map for steller's jays generated from BBS survey data showing relative abundance during summer, estimated over the interval 2011-2015.

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 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

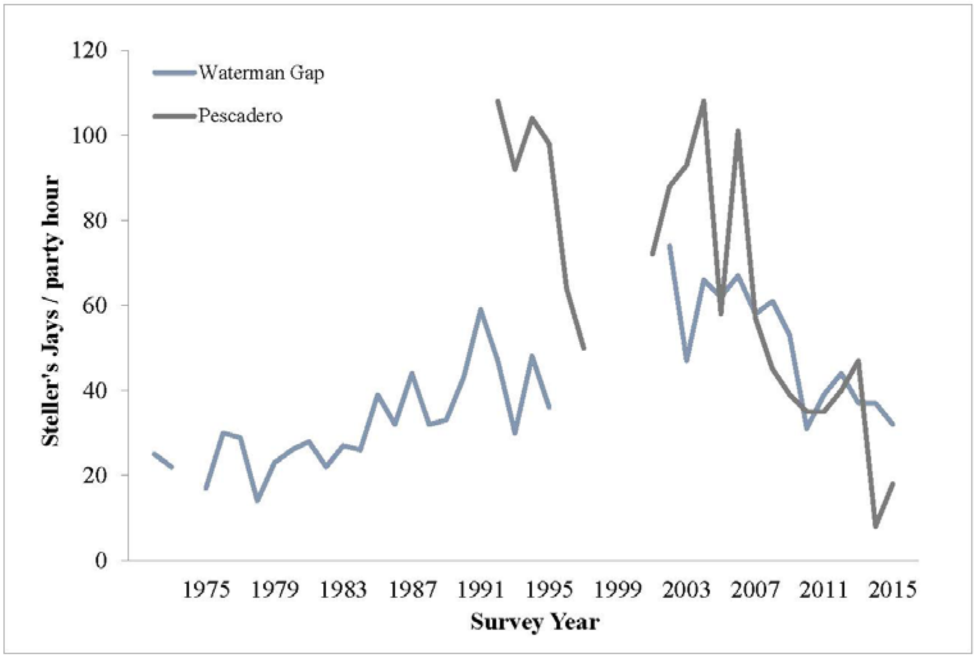

Figure 3-17. Number of steller's jays observed on the two Breeding Bird Survey routes in the Santa Cruz Mountains between 1972–2015. Gaps in the lines represent years in which surveys did not occur.

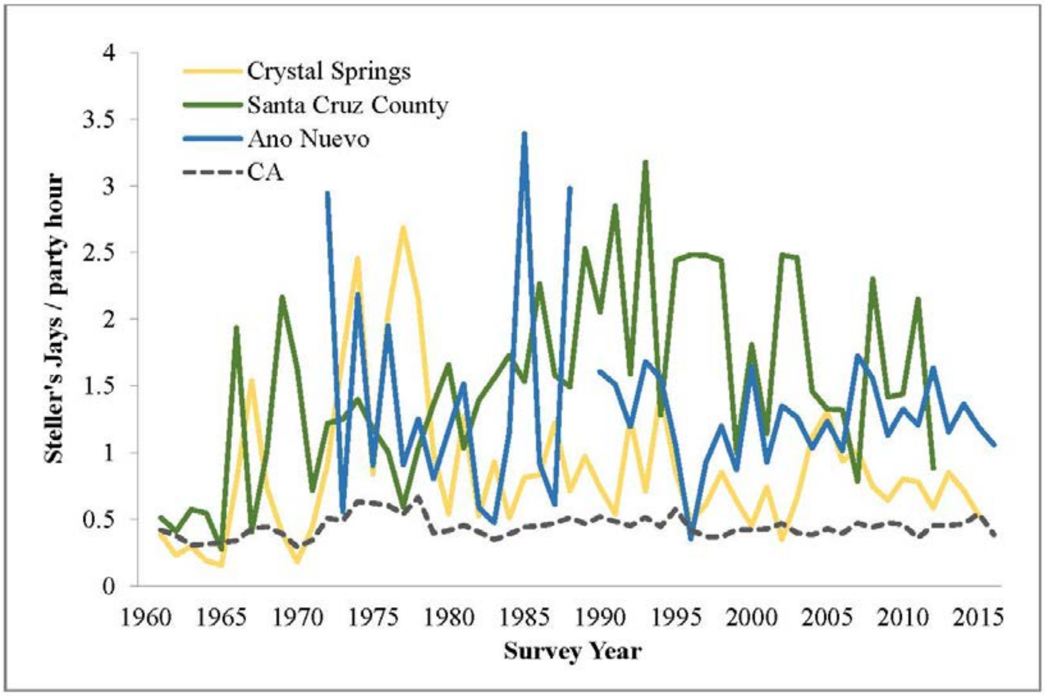

Figure 3-15. Number of Steller's jays observed per party hour from Audubon Society's Christmas Bird Counts, 1961-2015. Data are from statewide averages and the three closest census sites to the forested portions of the Santa Cruz Mountains: Crystal Springs, Santa Cruz County and Año Nuevo.

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

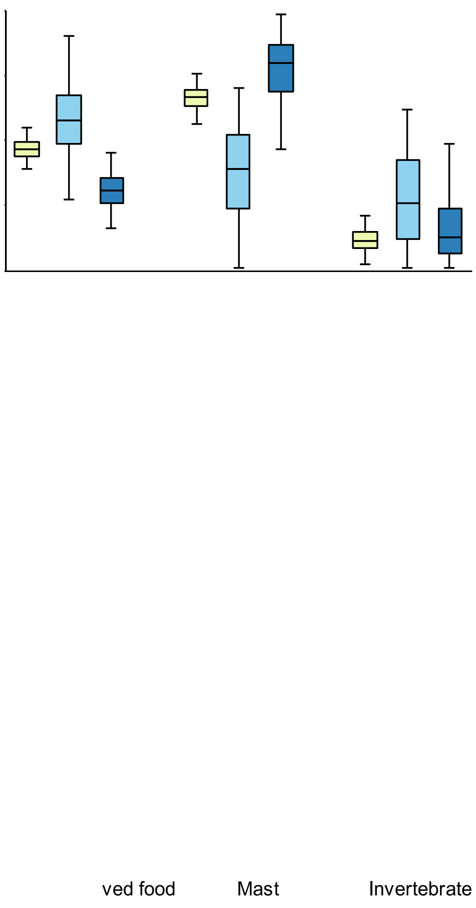

Figure 3-18. Stable isotope model results for Steller's jays in (a) Jedediah Smith Redwoods and Prairie Creek Redwoods State Parks, 2011, which were merged due to small sample sizes (n = 45), (b) Big Basin Redwoods State Park, 2011–2013 (n = 197) and (c) Butano State Park, 2012–2013 (n = 53). Boxes show 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 jays/ha ± 0.91) compared to forest sites (0.70 jays/ha ± 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 jays/ha ± 0.82) in August than at forest sites (0.18 jays/ha ± 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

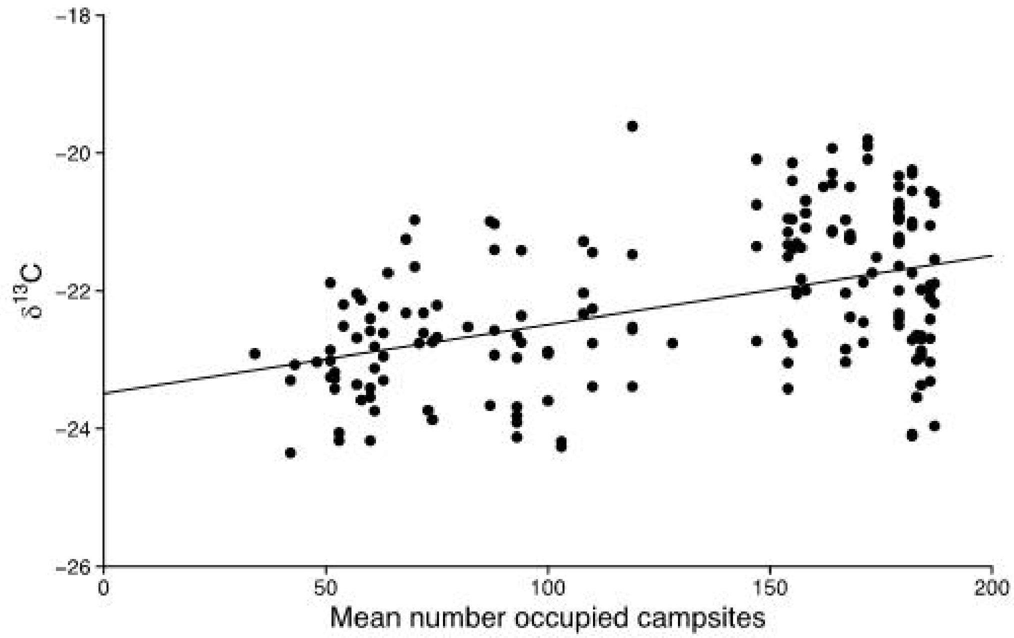

Figure 3-19. Relationship between carbon-isotope ratios ($\delta^{13}C$) of blood samples obtained from Steller's jays in campgrounds during the breeding period (April–August) 2011–2013 (n = 179) and human presence (mean number occupied campsites) in Big Basin Redwoods State Park. The solid line represents 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 $\delta^{13}C$ 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 ($^{15}N/^{14}N$, noted $\delta^{15}N$) and carbon ($^{13}C/^{12}C$, noted $\delta^{13}C$) 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 $\delta^{13}C$ (Jahren et al. 2006). This $\delta^{13}C$ 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

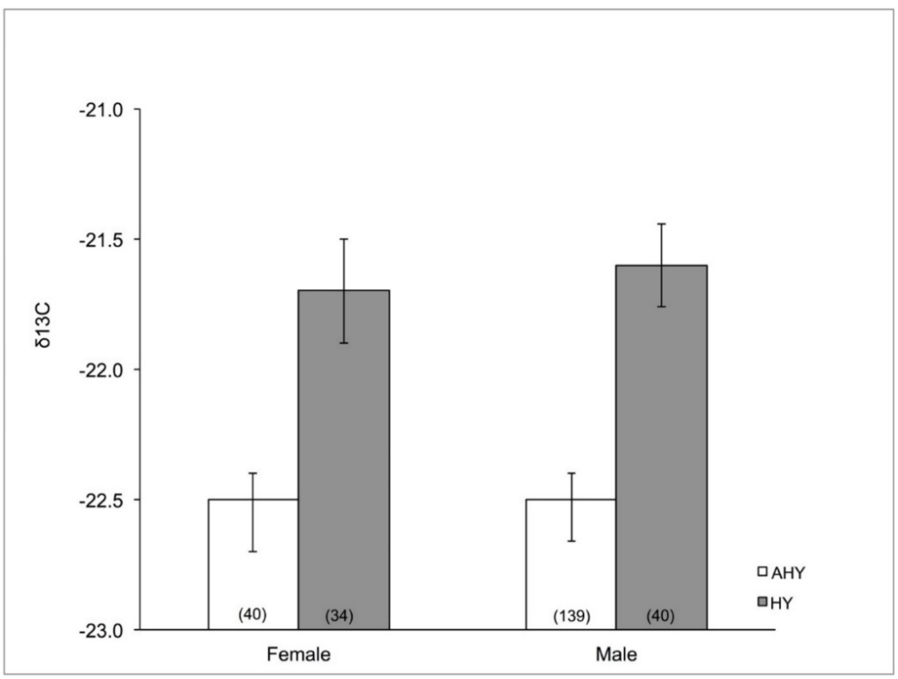

Figure 3-20. Mean carbon-isotope ratios ($\delta^{13}C$) of blood samples obtained from Steller's jays during the breeding period (April–August) 2011–2013 in Big Basin Redwoods and Butano state parks grouped by age and sex classes. Data are means ± SE for $\delta^{13}C$. Sample

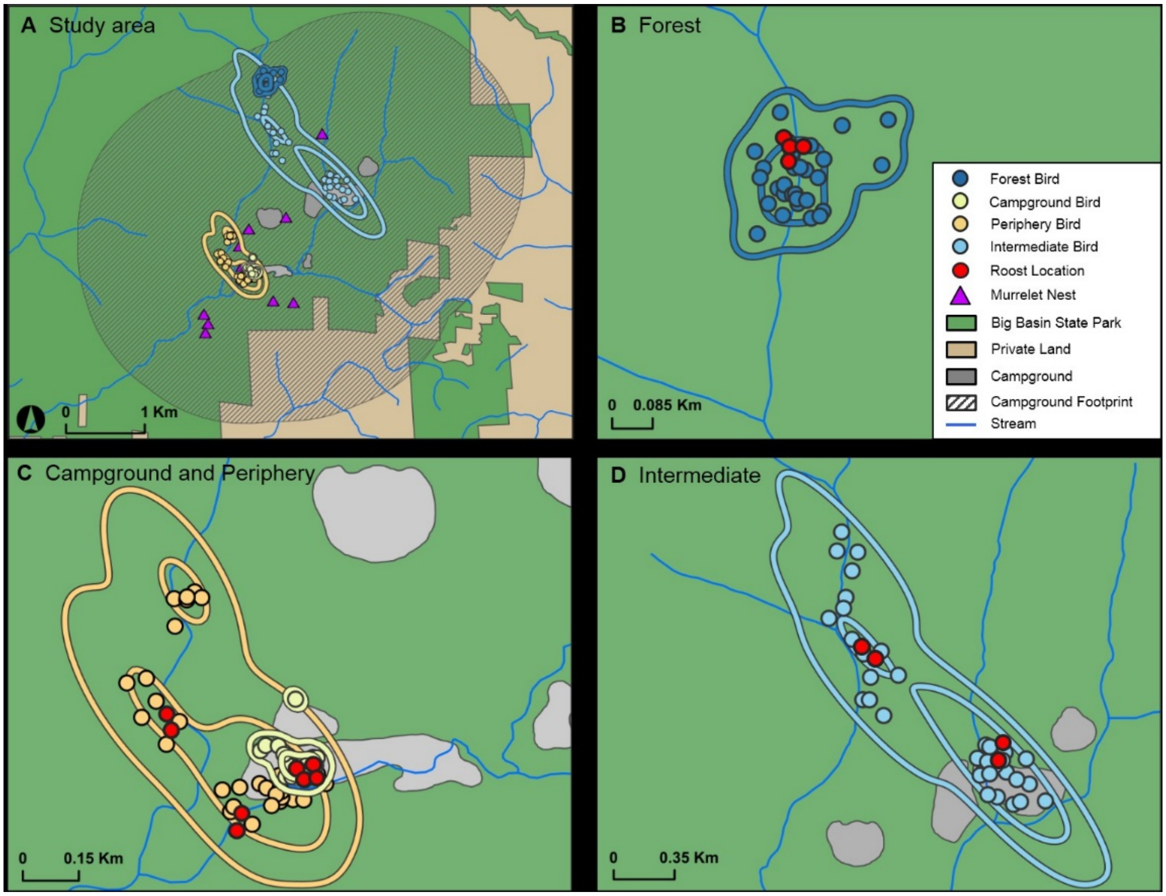

Figure 3-21. Representative core areas and home ranges (50% and 95% utilization distributions, respectively) for male forest, campground, periphery, and intermediate Steller's jays radio-marked in Big Basin Redwoods State Park in 2011. Also shown in (a) is the estimated 2 km "ecological footprint" of 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 $\delta^{13}C$ (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 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 murrerelet 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 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

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 carbacol-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.

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).

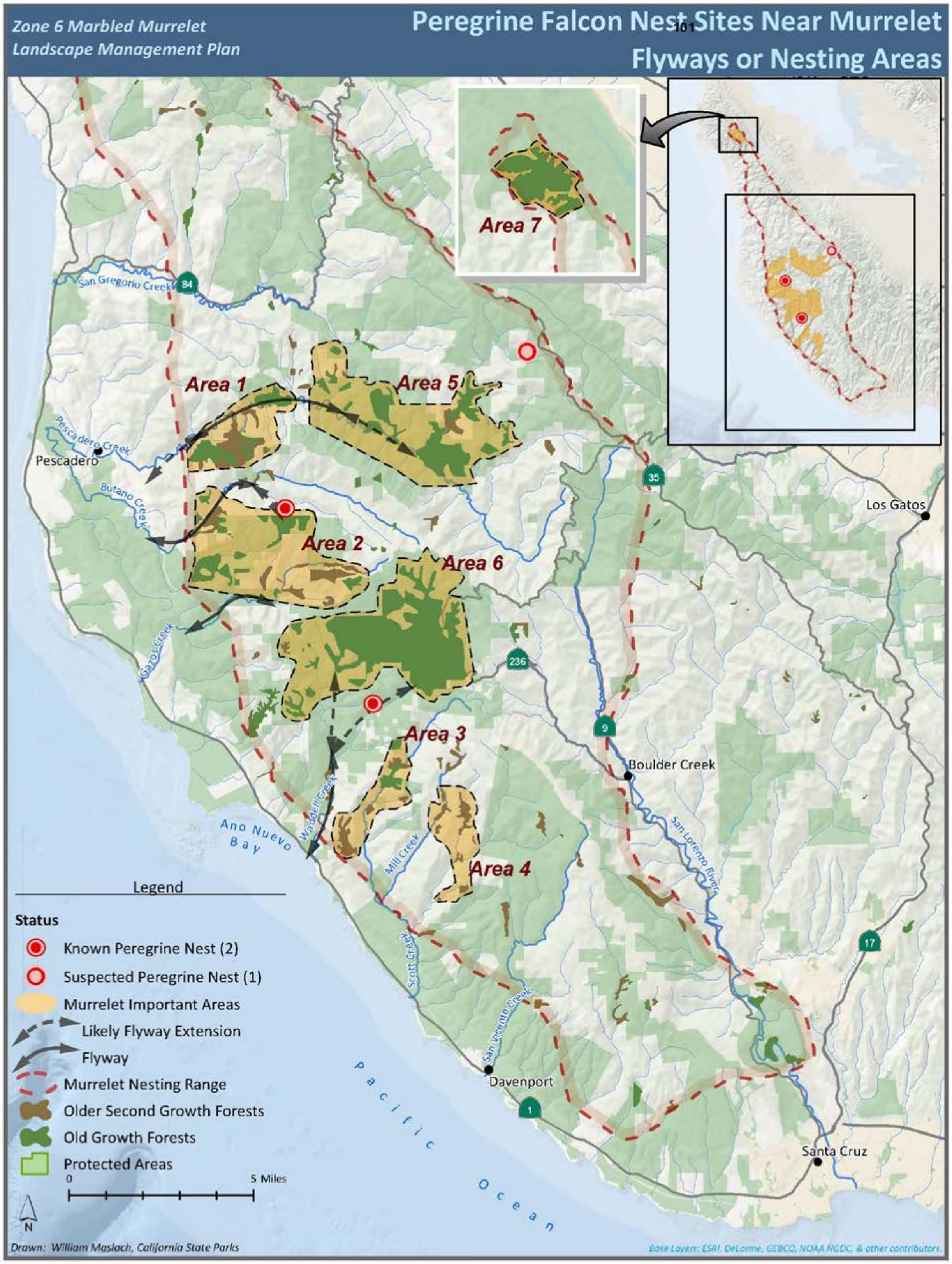

Figure 4-1. Peregrine Falcon Nest Sites Near Murrelet Flyways or Nesting Areas

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 Kittzlitz'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.

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 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 matting 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 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 it's 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 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 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 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 Jure 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 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

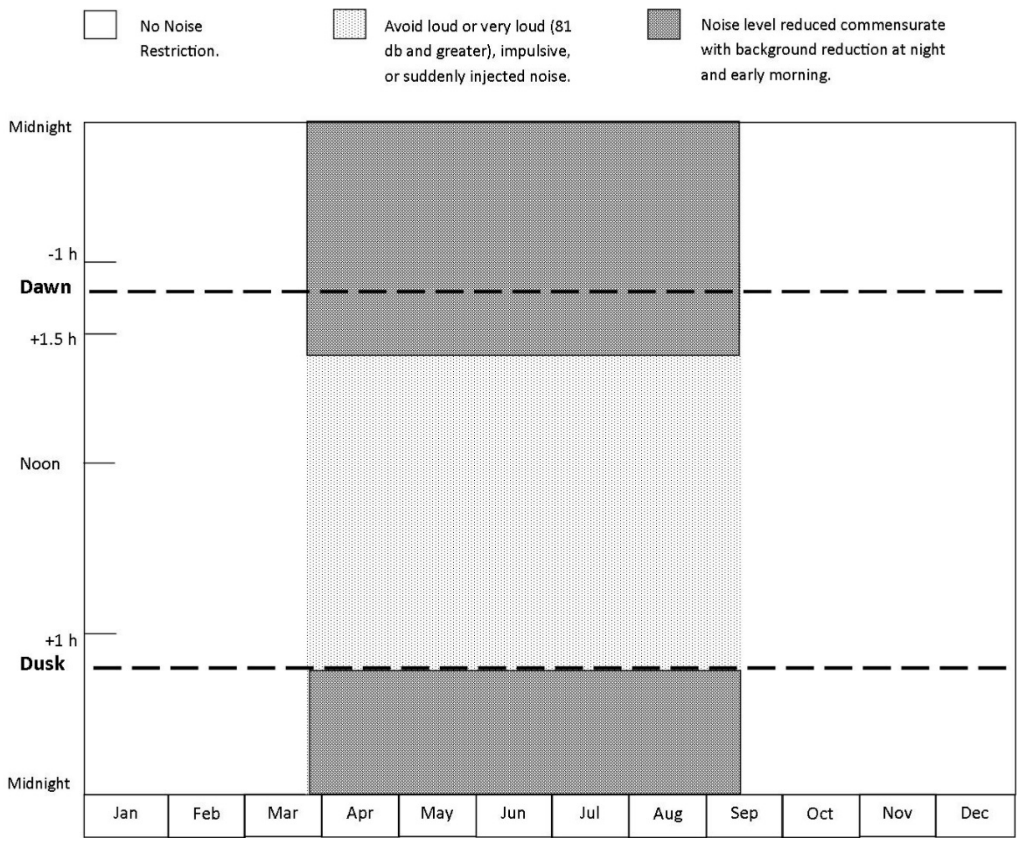

Figure 5-1. Schematic diagram of the existing temporal variation in timing anthropogenic-noise avoidance for Marbled murrelets in the Santa Cruz Mountains. Times are relative to dawn and dusk and are for schematic purposes only (they do not reflect the changing clock-time of dawn and dusk through the 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

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

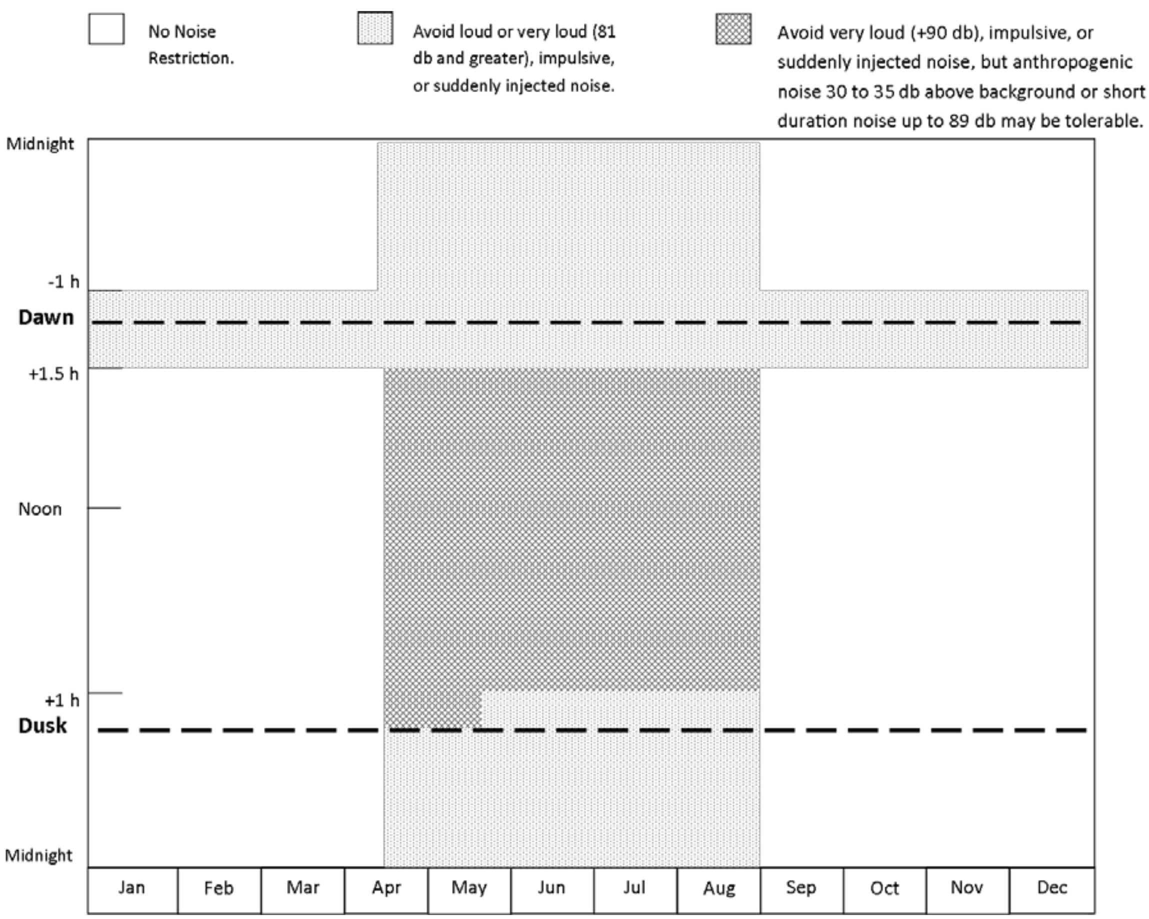

Figure 5-2. Schematic diagram of temporal variation in timing potential anthropogenic noise avoidance for marbled murrelets in the Santa Cruz Mountains if all potential alterations of noise restrictions considered here were adopted. Times are relative to dawn and dusk and are for schematic purposes only (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 murres, 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 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 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 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

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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 el. 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 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 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 km^2 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

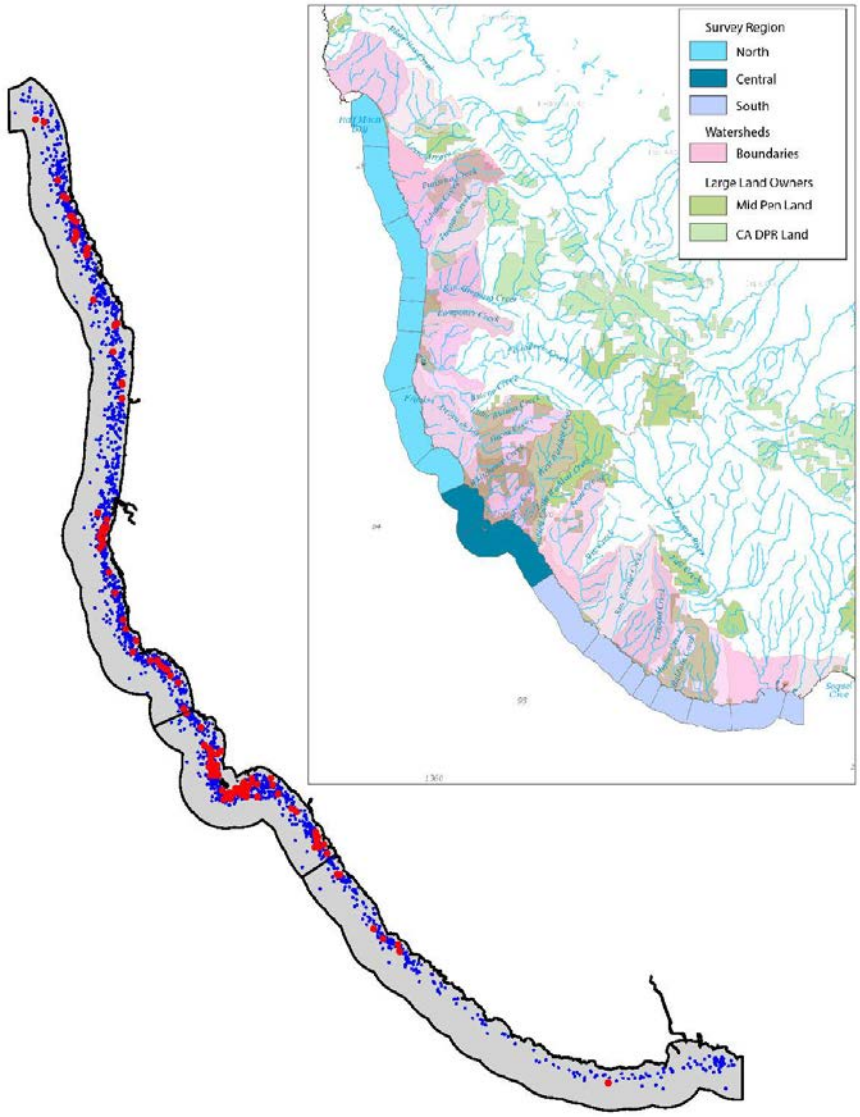

Figure 7-1. Inset map showing the North, Central, and South areas within the Region 6 at sea survey area. Locations of Marbled Murrelet adults (blue) and juveniles (red) detected during at sea surveys in central California during all zig-zag surveys from 1996-2016.

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

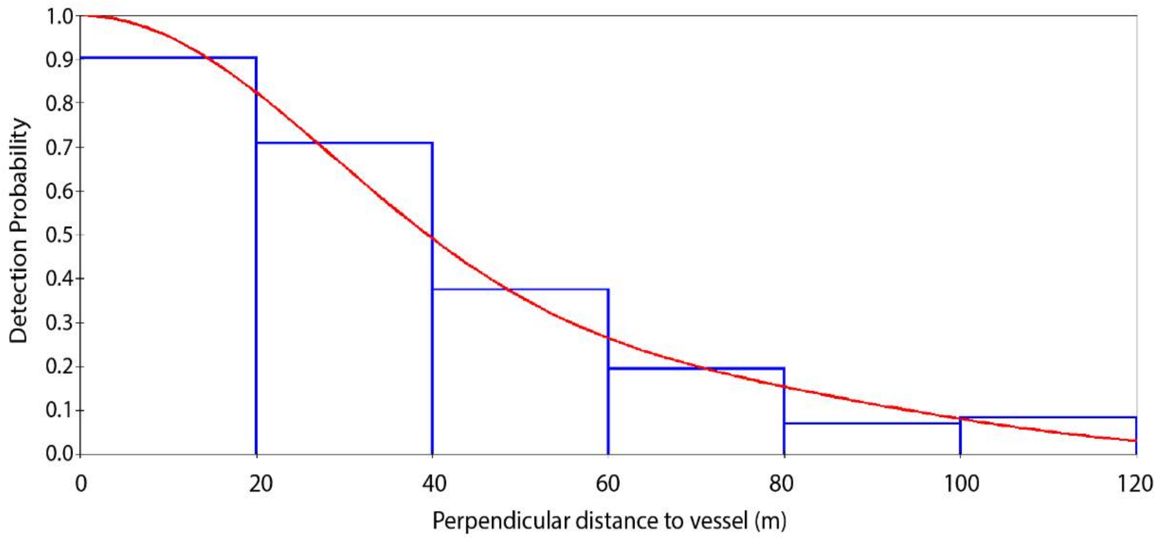

Figure 7-2. Example of detection probabilities for Marbled Murrelet surveys conducted in central California. Representative data are for during the 2015 breeding season ($\chi 2$ = 2.02, df = 3, P *= 0.57).*

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, R2 = 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, R2 = 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, x= 572.6, SD=74.5) than after (2009-2016, 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 (x=481, SD=37.4) were only marginally significantly lower than those of 1999-2003 (x= 572.6, SD=74.5), (t(6)=2.39, p = 0.062).

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 ($F(1,16)=10.25$, $p=0.006$, $R2 = 0.3904$), prior to corvid control (1996-2003, $F(1,6)=13.75$, $p<0.001$, $R2 = 0.6962$), and after implementation of corvid control in 2006 (2007-2016, $F(1,8)=5.895$, $p=0.041$, $R2 = 0.4243$).

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

	Both Directions			North			South		
Year	***N***	**95% CL**	***n***	***N***	**95% CL**	***n***	***N***	**95% CL**	***n***
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

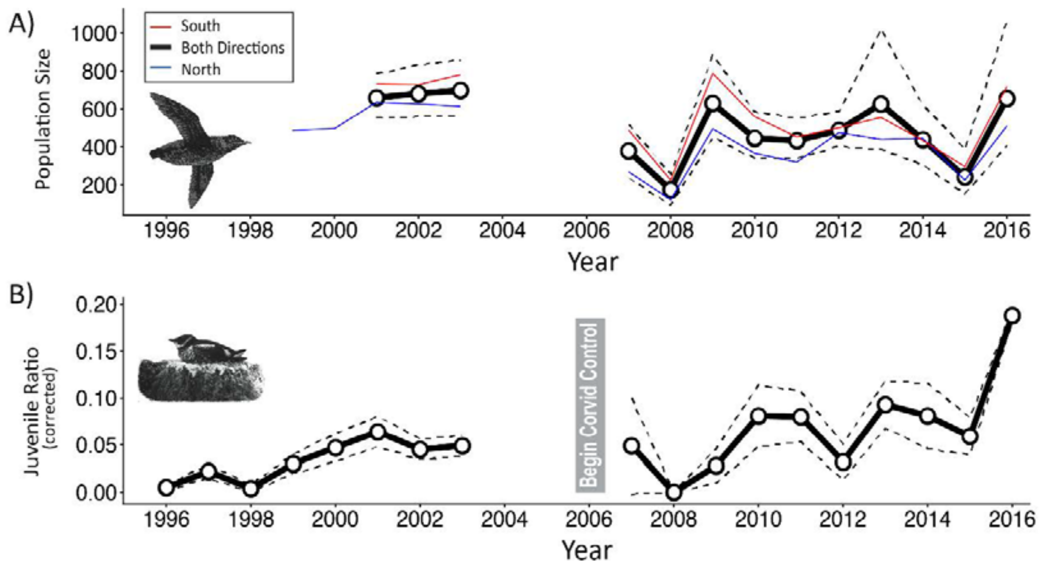

Figure 7-3. A) Abundance estimates for the central California population of marbled murrelets based on at sea surveys, 1999-2016 (dashed lines 95% confidence intervals for surveys drawn in Both directions). Data absent from years 2004-2006. Zig-zag surveys were not conducted prior to 1999 and from 2004-2006.
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 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 (Sadinops 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.

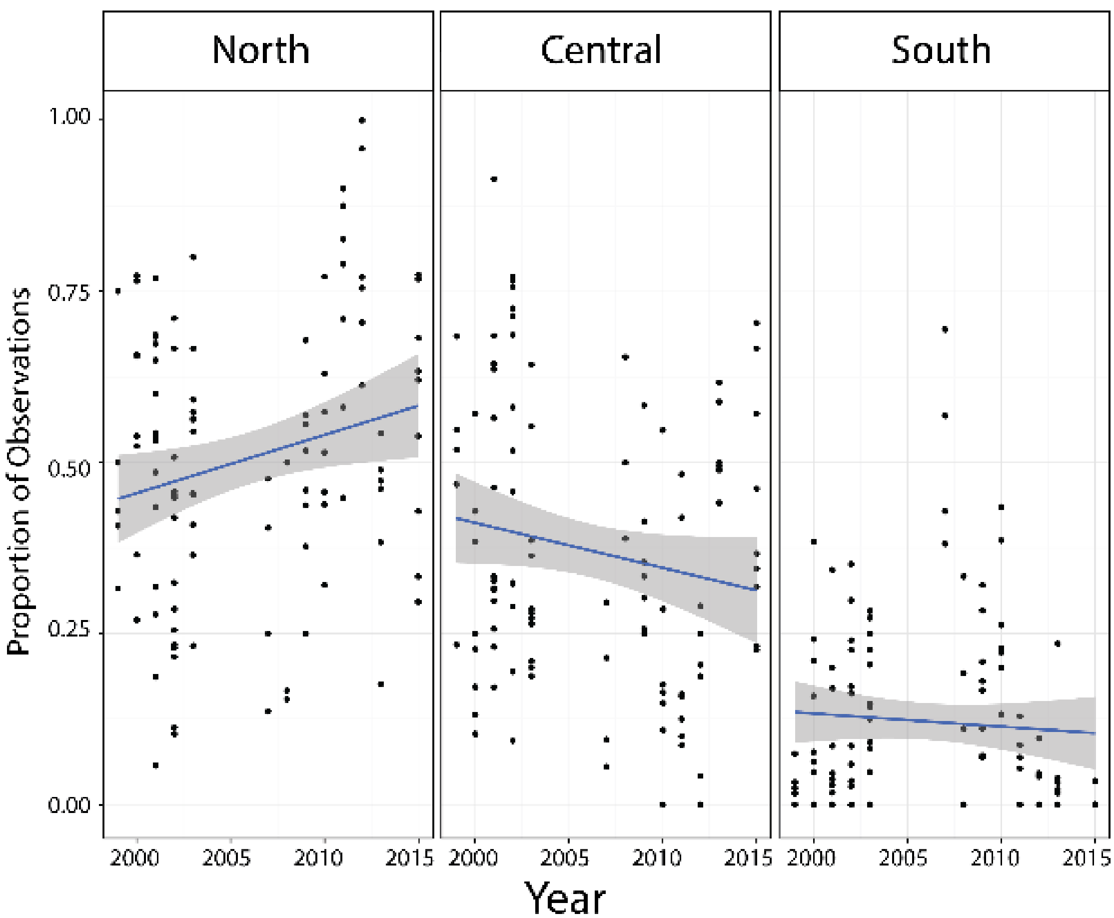

Figure 7-4. Trends for the relative abundance of all murrelets observed over time (1999-2016) in the North, Central, and South Zones of Region 6.

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 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; Gibble 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 el. 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

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

	Uncorrected		Corrected				
Year	*R* (SE)		*R* (SE)		n_{hy}	n_{inds}	$n_{surveys}$
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 ($R^{corrected}$ x=0.05048, 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 (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.

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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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).

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 ouglas-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 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 the 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 sparred. 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 surveyer 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 stands 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 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 surveys in this area, included 9 surveys per year in both 2009 and 2010 have found **p**resence 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 **R**edwood 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 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 be 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

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, 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 Opens 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).

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.

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

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.

- 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 <u>not</u> been surveyed for over 10 years. New A-V or ARU surveys are needed to confirm continued use of these areas.

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

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

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 jays/ha ± 0.91) compared to forest sites (0.70 jays/ha ± 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.

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

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 ($F(1,13)= 3.152$, $p=0.09924$, $R2 = 0.1332$). The trend for results using estimates from 2001 to 2016 using transects drawn from both directions is also negative but not significant. ($F(1,11)= 1.644$, $p=0.2262$, $R2 = 0.13$).
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, x=409.75, SD=98.3) than before (1999-2003, 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).

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 (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 ($F(1,16)=10.25$, $p=0.006$, $R2 = 0.3904$) and 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), ($t(13.2) = -2.90$, $p = 0.012$).
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 sandlance (*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.