Recovery Plan for the Marbled Murrelet (Washington, Oregon, and California Populations)

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

RECOVERY PLAN

for the

THREATENED MARBLED MURRELET
(*Brachyramphus marmoratus*)

in

WASHINGTON, OREGON, AND CALIFORNIA

Published by

Region 1
U.S. Fish and Wildlife Service
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PREFACE

The Regional Director, Region 1, U.S. Fish and Wildlife Service, Portland, Oregon, established the Marbled Murrelet Recovery Team in February 1993. The Team's direction was to develop this Marbled Murrelet Recovery Plan and assist in determining critical habitat for marbled murrelets. Affected Federal and state agencies were requested to provide nominations for participation on the Team as consultants. Agency participation was integral to the discussions of available information and development of this recovery plan. Based on work done by the Recovery Team and comments from the public, critical habitat was designated for the marbled murrelet on May 24, 1996.

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As consultants to the Team, the following individuals attended Recovery Team meetings, participated in the discussions and contributed to sections of this draft plan: Paula Burgess (Oregon Governor's Natural Resources Advisor), Esther Burkett (California Department of Fish and Game), Wayne Logan (Bureau of Land Management), Sarah Madsen (U.S. Forest Service), Carolyn Meyer (National Park Service), and Dave Renwald (Bureau of Indian Affairs). Their assistance in the recovery planning process, written portions of the plan, and review of this document were integral to producing a completed recovery plan. The Oregon Dept. of Forestry and Oregon Dept. of Fish and Wildlife, through the Oregon Governor's Forest Planning Team, also provided constructive comments on various drafts of the plan. The plan has also benefitted from the insights of, and many discussions with, numerous U.S. Fish and Wildlife Service biologists, especially Paul Henson. A special thanks to S. Kim Nelson (Oregon Cooperative Wildlife Research Unit) for all of her discussions, written documents, and sharing of knowledge of the species with the Team and to C.J. Ralph (U.S. Forest Service) for providing input while overseeing preparation of the Conservation Assessment for the marbled murrelet. Nadav Nur (Point Reyes Bird Observatory) provided valuable input on alcid demographics for Appendix B.

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G.J. McChesney and M. Casazza (U.S. Geological Survey) and Larry Reigel (U.S. Fish and Wildlife Service) assisted with several of the figure preparations. The cover and section divider illustration was drawn by John Megahan, and the marbled murrelet photographs (Figures 3 and 4) were taken by Gus van Vliet (Alaska Department of Environmental Conservation).

EXECUTIVE SUMMARY

Current Status: Marbled murrelets range along the Pacific coast from Alaska to California; the southern end of the breeding range is in central California. Their at-sea distribution becomes more discontinuous in California. Some wintering birds are found in southern California and as far south as northern Baja California, Mexico. Nesting behavior has been documented beyond 80 kilometers (50 miles) inland, though most nesting habitat likely occurs within 80 kilometers (50 miles) of shore throughout the breeding range. Currently, breeding populations are not distributed continuously throughout the forested portion of Washington, Oregon, and California (Pacific Northwest). Due to the substantial loss and modification of nesting habitat (older forest) and mortality from net fisheries and oil spills, the Washington, Oregon, and California vertebrate population segment was federally listed as threatened in September 1992. Critical habitat was designated for the species in May 1996. It is listed as endangered by California and as threatened in Washington and Oregon. It also is federally listed as threatened in Canada.

Habitat Requirements and Limiting Factors: Marbled murrelets use forests that primarily include typical old-growth forests (characterized by large trees, a multistoried stand, and moderate to high canopy closure), but also use mature forests with an old-growth component. Trees must have large branches or deformities for nest platforms, with the occurrence of suitable platforms being more important than tree size alone. Throughout the Pacific Northwest the amount of older forests have decreased substantially due to timber harvest, fires, and windthrow. The earliest possible recovery time for nesting habitat, once lost, is generally 100–200 years. Specific nesting habitat requirements and life-history strategy, a low reproductive rate, a low current breeding success and recruitment rate (based on juvenile:adult ratios) are likely to yield a decreasing population, which cannot easily recover should numbers be further depleted by additional catastrophic events. Because marbled murrelets feed primarily on fish and invertebrates in nearshore marine waters, they require nearshore marine habitats with sufficient prey resources.

Recovery Priority: 3 (indicating a subspecies with a high degree of threat and high recovery potential).

Recovery Objective: The interim objective of this recovery plan is to stabilize population size at or near current levels by (1) maintaining and/or increasing productivity of the population as reflected by changes in total population size, the adult:juvenile ratio, and nesting success by maintaining and/or increasing marine and terrestrial habitat and by (2) removing and/or minimizing threats to survivorship, including mortality from gill-net fisheries and oil spills.

Delisting Criteria: Specific delisting criteria can be developed when completion of some recovery tasks provides necessary information about marbled murrelets and their biological requirements. Interim delisting criteria include:

(1) Trends in estimated population size, densities and productivity have been stable or increasing in four of the six zones over a 10-year period, which should encompass at least one to two El Niño events.

(2) Management commitments, including protection and monitoring in marine and terrestrial habitats, have been implemented to provide adequate protection of marbled murrelets in the six Marbled Murrelet Conservation Zones for at least the near future (50 years).

Actions Needed:

1. Establish six Marbled Murrelet Conservation Zones (Zones) and develop landscape-level management strategies for each Zone.

2. Identify and protect terrestrial and marine habitat areas within each Marbled Murrelet Conservation Zone.

3. Monitor marbled murrelet populations and habitat and survey potential breeding habitat to identify potential nesting areas.

4. Implement short-term actions to stabilize the marbled murrelet population.

5. Implement long-term actions to stop population decline and increase marbled murrelet population growth.

6. Initiate research on survey and monitoring protocols, population estimates, limiting factors, disturbance effects, and additional life history data.

7. Establish a Regional West Coast Data Center.

Costs: ($1,000s)

Year	Priority 1	Priority 2	Priority 3	Total
1997	1285	160	80	1,525
1998	1285	210	380	1,875
1999	1260	150	415	1,825
2000	1175	150	415	1,740

Recovery costs over the next 10 years:

8,405	940	3,350	12,695

Recovery costs, as summarized above, are only projected for the next 10 years. A revision to the final recovery plan is expected in the next 5-10 years as new information about the species becomes available.

Date of Recovery: A delisting target date cannot be projected at this time.

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PART I. INTRODUCTION

"...You take my life when you do take the means whereby I live."
- William Shakespeare, *The Mechant of Venice*

I. INTRODUCTION

A. Brief Overview

The marbled murrelet (*Brachyramphus marmoratus*) is a small diving seabird that breeds along the Pacific coast of North America from the Aleutian Archipelago and southern Alaska south to central California. In the Pacific Northwest (Washington, Oregon, and California) (Figure 1), it forages almost exclusively in the nearshore marine environment (mainly within a few kilometers of shore), but flies inland to nest in mature conifers. Behavior indicative of marbled murrelet nesting has been documented to occur beyond 80 kilometers (50 miles) inland from the marine environment, though most nesting habitat likely occurs within 80 kilometers (50 miles) of shore throughout the breeding range. The most inland occupied site in the Pacific Northwest was located 84 kilometers (52 miles) from marine waters in Washington.

The Washington, Oregon, and California population segment of the marbled murrelet was federally listed as threatened on September 28, 1992 (U.S. Fish and Wildlife Service 1992a) due to the high rate of nesting habitat loss and fragmentation, and mortality associated with net fisheries and oil spills. The U.S. Fish and Wildlife Service recognized the marbled murrelet population in Washington, Oregon, and California as a distinct vertebrate population segment, which is included in the Endangered Species Act's definition of a "species" [16 U.S.C. 1532 (6)]. Critical habitat for the marbled murrelet was designated on May 24, 1996 (U.S. Fish and Wildlife Service 1996; see Appendix A for maps of the Critical Habitat Units). The species is state listed as endangered in California, threatened in Washington, and threatened in Oregon. Canada has officially listed the marbled murrelet as a threatened species. The primary threat discussed was the harvest of old-growth forest nesting habitat (Rodway and the Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 1990). To date, the marbled murrelet has not been listed in Alaska.

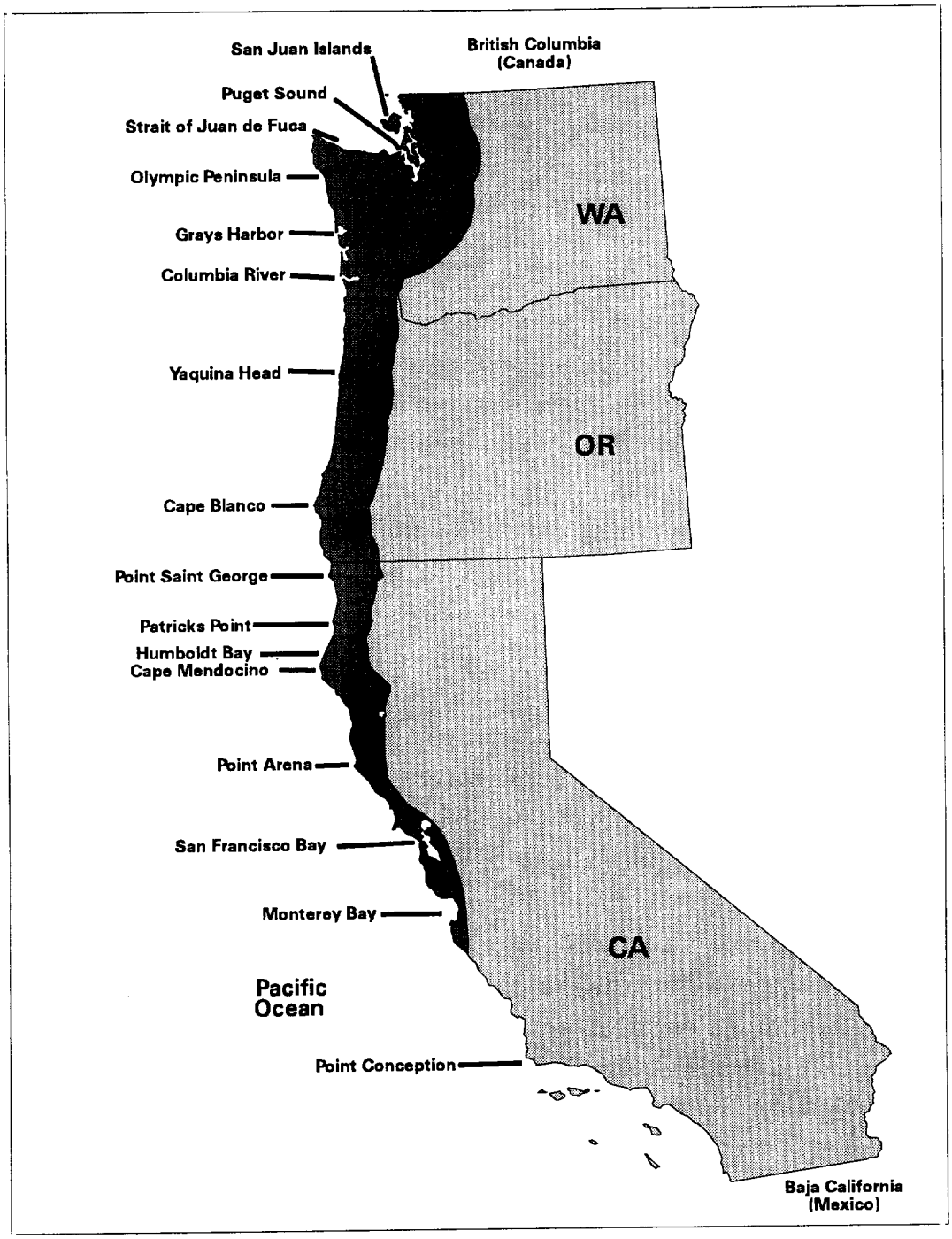

Figure 1. Estimated historical breeding/nesting range of the marbled murrelet in Washington, Oregon, and California (shown by darkly shaded area).

Within their current range, marbled murrelets are found on land and at sea in portions of six geographic zones, especially during the breeding season, but to some extent throughout the winter as well. These geographic zones (Puget Sound; Western Washington Coast Range; Oregon Coast Range; Siskiyou Coast Range; Mendocino; and Santa Cruz Mountains) are generally in the vicinity of large tracts of older forests in proximity to the coast. Areas that were historically used by marbled murrelets, but no longer support these birds, are where (or near where) coastal older forests no longer remain. The weight of evidence indicates that the major factors in marbled murrelet decline from historical levels in the early 1800's (or earlier) are (1) loss of nesting habitat, both through direct loss and changes in forest age distribution, and (2) poor reproductive success in the habitat that does remain, a phenomenon that appears due in large part to increased vulnerability of nests to predators in highly fragmented landscapes.

A substantial step in the recovery planning process for the marbled murrelet took place with the development of the Northwest Forest Plan (Forest Plan) (U.S. Department of Agriculture and U.S. Department of the Interior 1994a) and the signing of the "Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents within the range of the Northern Spotted Owl" (U.S. Department of Agriculture and U.S. Department of the Interior 1994b). The Forest Plan constitutes the backbone of this recovery plan. The recovery strategy outlined in the following pages therefore builds upon the Forest Plan in areas that were not considered or could not be considered (e.g., non-Federal lands) during development of the Forest Plan.

This recovery plan and an interagency Marbled Murrelet Conservation Assessment sponsored by the Forest Service (Ralph *et al.* 1995) were written simultaneously. This recovery plan, the Forest Plan, and the Conservation Assessment have been aided significantly by earlier efforts by the Pacific Seabird

Group, National Audubon Society, and other researchers to collate available biological and historical data on the species and conservation problems (Sealy and Carter 1984, Marshall 1988, Carter and Morrison 1992, Nelson and Sealy 1995).

The recovery plan summarizes the current biological information for the marbled murrelet, contributes new insights, and updates some information gathered since the Conservation Assessment was completed in 1993-1994. More detailed information has been summarized in other documents (Marshall 1988, Carter and Morrison 1992, Nelson and Sealy 1995, Ralph *et al.* 1995). The recovery plan differs from the Conservation Assessment in that the recovery plan's explicit goal is to develop management alternatives and strategies for recovering the marbled murrelet.

B. Conceptual Framework for Development of the Recovery Plan

A number of key considerations formed the conceptual framework of the approach to recovery planning for the marbled murrelet. This framework emerged from consideration of the biological profile of the marbled murrelet presented in detail on the following pages, which is summarized below.

The marbled murrelet was federally listed as a threatened species mainly due to the substantial loss of older forest nesting habitat. The low elevation, older forests close to the coast, which marbled murrelets require for nesting, have been heavily harvested throughout the bird's range and are severely degraded due to fragmentation. At the time of listing, old-growth forests throughout western Oregon and Washington had been reduced by about 82 percent from prelogging levels (Booth 1991). Estimates for the amount of reduction of northern California's coastal old-growth redwood forests range from approximately 85 to 96 percent (Green 1985, Fox 1988, Larsen 1991). In addition, past and current forest management practices also have resulted in a forest age distribution skewed

toward younger even-aged stands at a landscape scale (Hansen *et al.* 1991, McComb *et al.* 1993). Generally, older forests with large, old trees appear to be needed to develop the proper broad, horizontal branching structure in the forest canopy for the placement and visitation of nests.

Fragmentation of the remaining older forests may have resulted in increased populations of nest predators, and increased visibility and vulnerability of flying or nesting adults to potential predators. This change in turn has probably led to increased rates of predation on nests and possibly on adults. Rates of predation on marbled murrelet nests appear to be high, based on field observations, compared to most other seabirds and are due most often to predators whose populations have apparently increased as a result of forest fragmentation and related human activities. Because of these factors, large blocks of contiguous older forest are likely to be better nesting habitat and minimize threats to adult survival than small, fragmented blocks.

As part of the recovery planning process, a demographic model was developed to help better understand marbled murrelet population dynamics (Appendix B, Beissinger 1995a). Demographic projections show that marbled murrelet populations in Washington, Oregon and California (Pacific Northwest) are apparently declining at a rapid rate (at least 4 to 7 percent per year at most locations from 1990-1995). The model used juvenile:adult ratios and other measures of nesting success (Appendix B). Because the marbled murrelet only lays one egg and probably nests at most once a year, it has a very low annual reproductive potential. Current estimates of fecundity range from 0.02 to 0.19 female young produced per adult female per year in the Pacific Northwest (Appendix B). In other words, current estimates of nesting success and recruitment in most years are well below levels that are required to sustain current populations in the Pacific Northwest. Furthermore, the naturally low reproductive

potential of the marbled murrelet ensures that populations will recover slowly from declines or disasters (growing about 3 percent per year - Figure 2), even if the reproductive potential was fully realized over several years. The most likely causes of poor reproduction appear to be due to the effects of deforestation, as discussed above. Deforestation has occurred on a large scale and in many areas may require a century or more of forest regrowth to reverse the trend (U.S. Department of Agriculture *et al.* 1993).

The population growth rate of the marbled murrelet is sensitive to changes in adult survivorship (Appendix B, Beissinger 1995a). Factors that increase adult mortality rates, such as net fishing and oil spills, are likely to have important effects on marbled murrelet population dynamics (Carter and Kuletz 1995, Carter *et al.* 1995a). Yet, to date, these factors have only impacted populations in small portions of the marbled murrelet's range in the Pacific Northwest and occur irregularly from year-to-year.

Most importantly, the acute effects of gill nets or oil spills on adult mortality may be reversed in a much shorter time compared to the chronic effects of deforestation on fecundity. This can be seen when comparing the rate of marbled murrelet population recovery from factors that affect adult mortality to the factors that affect fecundity (Figure 2). Population declines caused by increased mortality due to net fisheries or oil spills would likely have large but acute effects that would not persist for long once the source of mortality was removed. Populations would require 23 years to double or to be restored to the original size. In comparison, the effects of deforestation are chronic and can persist for 100-200 years until forests have regrown to achieve structure that permits marbled murrelet nesting. If forests were protected from cutting and were able to mature to old-growth characteristics, the number of nesting marbled murrelets and their nesting success should increase slowly to levels typical of other alcids. Populations

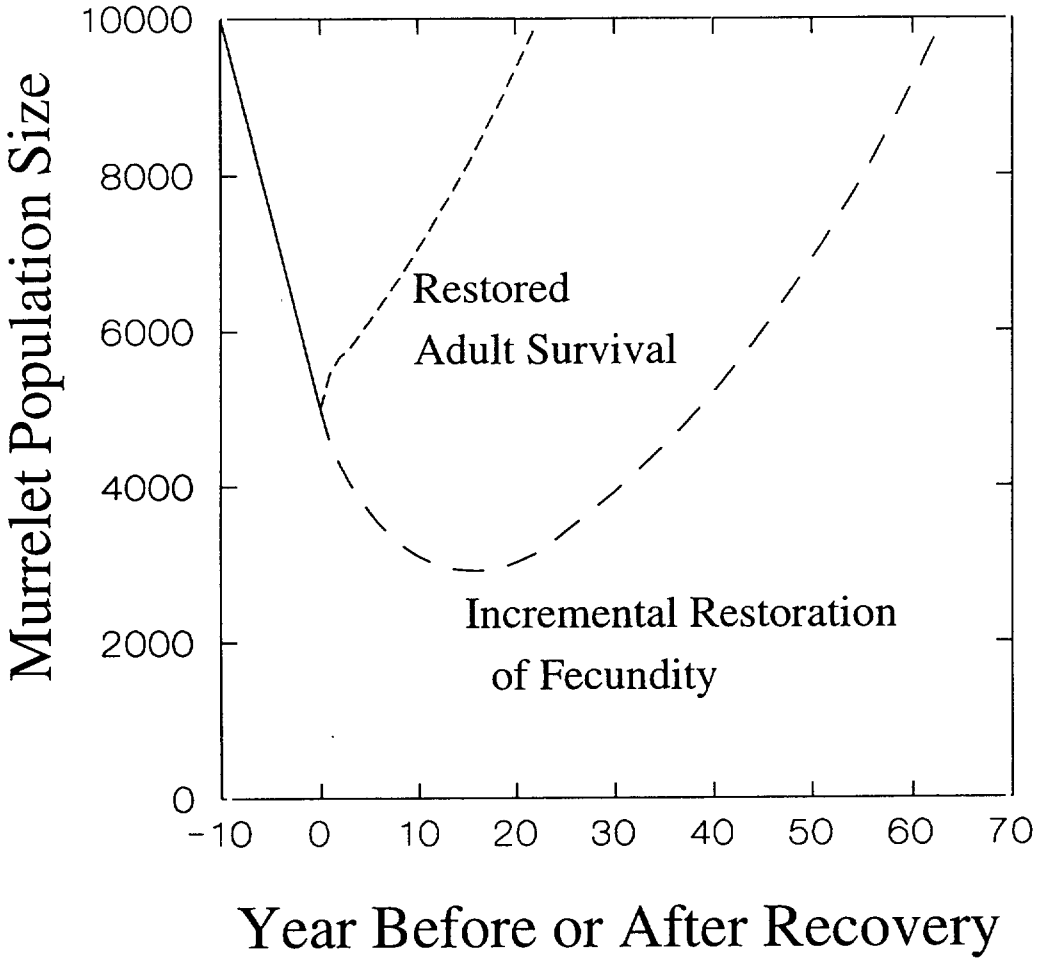

Figure 2. Comparison of the rate of recovery of a marbled murrelet population by restoring adult survival or fecundity based on the population model in Appendix B. In this hypothetical example, a marbled murrelet population of 10,000 individuals has declined by about 6 percent per year for over a decade (-10 to 0 years) and has been reduced to half. Such a decline appears to be typical of many marbled murrelet populations in the Pacific Northwest (Appendix B) and would be expected to occur if fecundity was low (0.05) and survivorship was high (0.9). If marbled murrelets achieved reproductive success similar to other alcids (fecundity = 0.3) and had good adult survivorship (0.9), then populations would be able to achieve slow growth at about 3 percent per year. The recovery of marbled murrelet populations under this slow growth potential is examined for two scenarios: (1) Restored Adult Survival - This scenario assumes that populations will grow at the above rate once the cause of mortality was eliminated; and (2) Incremental Restoration of Fecundity - This scenario examines the effects of forest regeneration by allowing marbled murrelet fecundity to increase by 0.01 for each year that forest regrowth occurs from 0.05 until fecundity reaches 0.3, where it stabilizes due to density dependence and other factors such as normal levels of nest failure.

would require 64 years to double or be restored to the original size and would decline for the first 17 years until forests had regrown sufficiently to allow fecundity to exceed 0.21.

As a result of harvest of older forests, the breeding range of the marbled murrelet has been reduced and fragmented. Within their current range, they are found on land and at-sea in portions of six geographic zones, especially during the breeding season but to some extent throughout the winter as well. These geographic zones (Puget Sound; Western Washington Coast Range; Oregon Coast Range; Siskiyou Coast Range; Mendocino; and Santa Cruz Mountains) are generally in the vicinity of large tracts of older forests in proximity to the coast (see Figure 8 and **II. RECOVERY** for a complete description of these zones). Areas that were historically used by marbled murrelets, but no longer support them, are where (or near where) coastal older forests no longer remain. Historical nesting areas occur both within and at the periphery of the historical nesting range indicated in Figure 1.

Despite the over-arching importance of increasing fecundity, there are circumstances when adult mortality can outweigh fecundity in terms of decline and recovery of specific populations. For instance, a large catastrophic oil spill (similar to the 1989 *Exxon Valdez* oil spill in Alaska) could extirpate or nearly extirpate a local population. Thus, while increasing fecundity receives most attention, reducing adult mortality also is a key feature of this recovery plan.

Nearshore waters within 2.0 kilometers (1.2 miles) of the coast are important to marbled murrelet populations. Most birds are observed at-sea in nearshore waters, which are important foraging grounds. Because of their extensive use of nearshore waters, marbled murrelets are susceptible to the impacts of oil spills and have been given one of the highest oil spill vulnerability index values among seabirds (King and Sanger 1979).

Marbled murrelets feed on a variety of fish and marine invertebrates. It is not clear whether El Niño-Southern Oscillation (El Niño) events affect marbled murrelet reproductive success or survival, as these events may do with other seabirds (Graybill and Hodder 1985; Ainley *et al.* 1988; Ainley and Boekelheide 1990; Wilson 1991; Ainley *et al.* 1994, 1995). El Niño (and other warm water) events can reduce ocean productivity (prey for marbled murrelets) in areas that normally feature upwelling (Pearcy *et al.* 1985, Schoener and Fluharty 1985, Gomez-Gutierrez *et al.* 1995), thereby possibly influencing both survival and reproductive success due to reduced prey abundance or availability. It is unclear at this time how much influence recent El Niño events have had on the generally low reproduction seen with marbled murrelets throughout the three-state area since 1992. However, drastic effects, as observed with other closely related species (e.g., common murres [*Uria aalge*]) seem unlikely because (1) prey resources in nearshore and inland waters used by marbled murrelets appear to be less affected than prey resources in more offshore waters used by seabirds that do experience problems from El Niño events; (2) marbled murrelets exhibit diet breadth (Burkett 1995), which should minimize the effects of temporary shortages of fish prey; and (3) some marbled murrelets successfully fledged some young during recent El Niño events even though some closely related species abandoned their nests at certain colonies during the egg stage (e.g., common murres). Natural variation in nesting success is typical for many seabirds and there is no evidence that it has led to endangerment in other species (Ainley and Boekelheide 1990). The marbled murrelets' life history strategy (i.e., relatively long life span, delayed maturity and low annual reproductive potential) allows individuals to reproduce successfully over their lifetimes, despite periodic adverse conditions during its lifetime. However, cumulative impacts (including nesting habitat loss, oil spills, net mortalities, etc.), in addition to repeated El Niño events, over a short time period, could contribute to serious population declines or extirpations.

Finally, in considering the biological profile of the marbled murrelet summarized above, we have concluded that the next 50 years will be the most critical period for marbled murrelet conservation efforts. Marbled murrelet populations in the Pacific Northwest are likely to continue to decline, certainly as a result of low reproduction due primarily to loss of nesting habitat, but also in concert with factors like net mortality, oil spills and, probably, predation that have increased adult mortality. Although some currently mature forest will become suitable nesting habitat during the next 50 years, most younger forest habitat will not become available for nesting marbled murrelets until after the year 2040 (U.S. Department of Agriculture *et al.* 1993). Until that time, immediate conservation efforts that minimize and mitigate the loss of actual and potential nest sites, as well as increase adult survivorship, will be necessary. Populations of marbled murrelets are still relatively large compared to many other threatened or endangered species, so there is no need at this time to begin any kind of captive propagation program for this species (Snyder *et al.* 1996). Government efforts and funds should be directed to *in situ* conservation actions and field research. However, preliminary investigation of captive care techniques and health parameters could be studied opportunistically, especially in regard to oiled bird rehabilitation.

The framework presented above is built on the best biological information currently available. The weight of evidence indicates that the major factors in marbled murrelet decline from historical levels in the early 1800's (or earlier) are (1) loss of nesting habitat and (2) poor reproductive success in the habitat that does remain, a phenomenon that appears due in large part to increased vulnerability of nests to predators in highly fragmented landscapes. There is little evidence to support alternative interpretations of factors limiting population growth, such as a long-term change in prey populations affecting marbled murrelet population size and reproductive success, or possible El Niño effects on

marbled murrelet prey resources. However, short-term impacts from El Niño (and other warm water) events may affect both marbled murrelet prey and reproductive success. It should be recognized that there is much more to be learned about the ecology of marbled murrelets. Implementation of the studies such as those listed in task 4 under "II. RECOVERY D. Narrative Outline for Recovery Actions" will help clarify the factors limiting population growth in marbled murrelets.

C. Taxonomy and Species Description

The marbled murrelet is a small Pacific seabird in the family Alcidae. This family is characterized by wing-propelled diving birds (i.e., use their wings to swim underwater) and is divided into several groups on the basis of structure and ecology, including the murres, dovekies, razorbills, puffins, guillemots, murrelets, auklets, and the extinct great auk. The six species of murrelets are grouped into two genera. The genus *Synthliboramphus* includes four species: Japanese murrelet (*Synthliboramphus wumizusume*), ancient murrelet (*Synthliboramphus antiquus*), Craveri's murrelet (*Synthliboramphus craveri*), and Xantus' murrelet (*Synthliboramphus hypoleucus*). The genus *Brachyramphus* currently includes two species, the Kittlitz's murrelet (*Brachyramphus brevirostris*) and the marbled murrelet (*Brachyramphus marmoratus*).

The marbled murrelet was first described in 1789 by Gmelin as *Colymbus marmoratus*, but in 1837 Brandt placed it under the genus *Brachyramphus* (American Ornithologists' Union 1983). Two subspecies of the marbled murrelet were recognized: North American murrelet *(Brachyramphus marmoratus marmoratus*) and Asiatic murrelet (*Brachyramphus marmoratus perdix*). However, recent information suggests that the Asiatic murrelet is a distinct species (Friesen *et al.* 1994, 1996). The American Ornithologists' Union, in its "Forty-first Supplement to the *Check-list of North American Birds*," has now

officially recognized the long-billed murrelet (*Brachyramphus perdix*) and the marbled murrelet (*B. marmoratus*) as distinct species (American Ornithologists' Union 1997). Long-billed, or Asiatic murrelets, have been recorded as accidentals at various locations in North America (Sealy *et al.* 1982, 1991).

Male and female marbled murrelets have identical plumages, but breeding and wintering plumages are distinct. Breeding adults have sooty-brown upperparts with dark bars. Underparts are light, mottled brown. Winter adults have brownish-gray upperparts except for a white band below the nape that extends up from white underparts and white scapulars (Figures 3 and 4). The plumage of fledged young is similar to that of adults in the winter, but can be distinguished for some time after fledging from winter adults if observed carefully (Carter and Stein 1995).

D. Historical and Current Distribution and Population Size

The breeding range of the marbled murrelet extends from Bristol Bay, Alaska, south to the Aleutian Archipelago, northeast to Cook Inlet, Kodiak Island, Kenai Peninsula and Prince William Sound, south coastally throughout the Alexander Archipelago of Alaska, and through British Columbia, Washington, Oregon, to northern Monterey Bay in central California. Birds winter throughout this breeding range and also occur in small numbers off southern California.

Most marbled murrelets nest in trees throughout the forested portion of the range, from Kodiak Island and the Kenai Peninsula to central California. In the Alaskan nonforested portion of the range, which includes Bristol Bay, Aleutian Islands, Alaska Peninsula, Cook Inlet, and portions of Kodiak Island and Prince William Sound, marbled murrelets can also nest on the ground (Day *et al.* 1983) or in rock cavities (Johnston and Carter 1985).

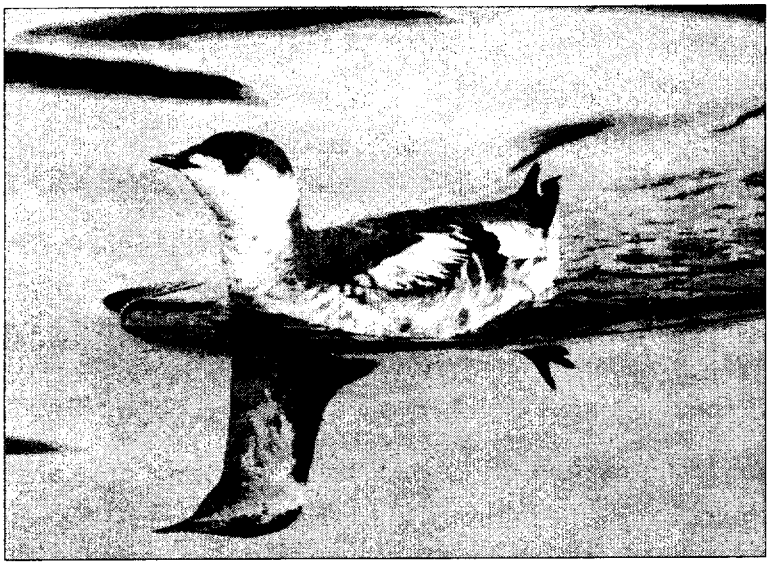

Figure 3. Marbled Murrelet in winter plumage (photo by Gus van Vliet).

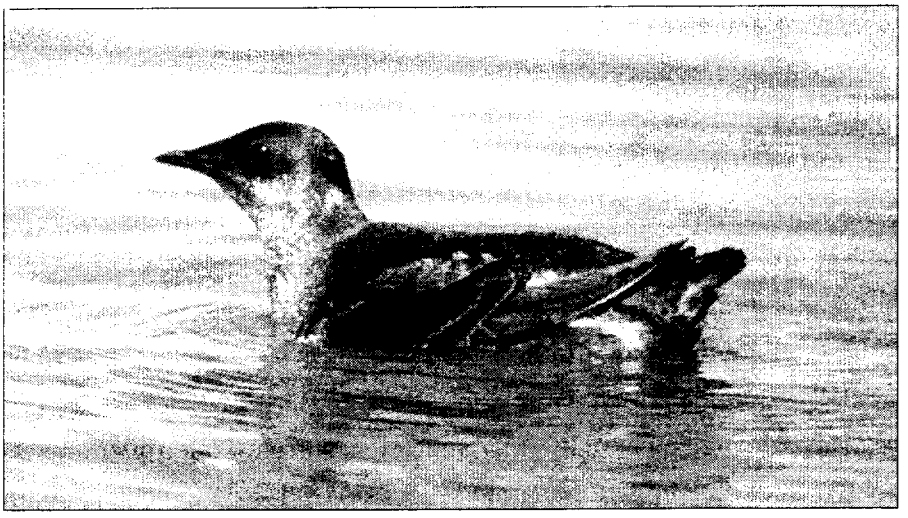

Figure 4. Marbled Murrelet in breeding plumage (photo by Gus van Vliet).

Within the range of the federally listed populations, marbled murrelets are found on land and at sea in portions of six geographic zones, especially during the breeding season, but to some extent throughout the winter as well. These geographic zones (Puget Sound, Western Washington Coast Range, Oregon Coast Range, Siskiyou Coast Range, Mendocino, and Santa Cruz Mountains) are generally in the vicinity of large tracts of older forests near the coast. Areas historically used by marbled murrelets, but no longer supporting these birds, are where older coastal forest no longer remain. Currently, breeding populations are not distributed continuously throughout the forested portions of the Washington, Oregon, and California.

Although limited information exists on the historic distribution and numbers of marbled murrelets, available information has been summarized for most areas within the species' range (Larsen 1991, Carter and Erickson 1992, Leschner and Cummins 1992, Mendenhall 1992, Nelson *et al.* 1992, Rodway *et al.* 1992, Speich *et al.* 1992, Piatt and Ford 1993; also see papers in Ralph *et al.* 1995). Much of the information is anecdotal and qualitative in nature. However, most summaries give documentation or indication of a decline or decrease in the range, distribution, and/or numbers of marbled murrelets compared to historical information (Ralph 1994).

California

Historic records indicate that marbled murrelets were "plentiful" during the winter in some years along the coast from Monterey County north to the Oregon border and irregular between Monterey and Santa Barbara (Grinnell and Miller 1944). The three separate areas where marbled murrelets currently are found in California correspond to the three largest remaining blocks of old-growth coastal conifer forests (Carter and Erickson 1992). These populations are largely separated by

areas of second-growth forest not used by marbled murrelets. A large break in the main breeding distribution is located at the southern portion of the range in California, where approximately 480 kilometers (300 miles) separate the southernmost breeding population in San Mateo and Santa Cruz counties (central California) from the next largest populations to the north in Humboldt and Del Norte counties (northern California). Most of this largely unpopulated section, especially in Mendocino County, probably contained significant numbers of marbled murrelets prior to extensive logging (Carter and Erickson 1988, Paton and Ralph 1988). Very small numbers of marbled murrelets probably still nest there. In addition, marbled murrelets may have nested in other areas of central California south of northwestern Santa Cruz County (see Figure 1) where they apparently no longer nest today.

Based on extrapolation from currently known population numbers in relation to remaining available nesting habitat, it was estimated that at least 60,000 marbled murrelets may have been found historically along the coast of California (Larsen 1991). The population size of marbled murrelets has been estimated for California over the past 20 years. Sowls *et al.* (1980) estimated the breeding population to be about 2,000 breeding birds. Carter and Erickson (1992) suggested that between 1,650 and 2,000 breeding birds might constitute the state's breeding population. Carter *et al.* (1992) derived a population estimate of 1,821 breeding birds. Ralph and Miller (1995) estimated a total state population of approximately 6,000 birds, including breeding and nonbreeding birds, from more intensive at-sea surveys specifically designed to estimate population size for marbled murrelets. Differences between estimates does not indicate that marbled murrelet numbers have increased over time between the censuses, because different methods and assumptions were used in estimating population numbers.

Oregon

Historic records show that marbled murrelets were regular summer residents, particularly in Lincoln, Tillamook, and Lane counties (Gabrielson and Jewett 1940, Nelson *et al.* 1992). Marbled murrelets in Yaquina Bay on the central Oregon coast were reported as common (Woodcock 1902, Gabrielson and Jewett 1940). The species is no longer found in significant numbers during the nesting season near the mouth of the Columbia River or in Clatsop County, where extensive harvesting of older forests has occurred.

Estimates of the recent population size in Oregon have come from a number of sources. Varoujean and Williams (1987) estimated the breeding population in Oregon to be about 5,100 individuals. Nelson *et al.* (1992) believed fewer than 1,000 breeding pairs (2,000 breeding birds) existed, with the majority of birds occurring off the central Oregon coast. Results from the most recent systematic vessel-based surveys of marbled murrelets by Strong *et al.* (1993,1995) along the Oregon coast provided a preliminary estimate of between 15,000 and 20,000 birds. Varoujean and Williams (1995) using aerial surveys estimated an abundance of 6,400 to 6,800 birds for Oregon. Estimates were higher for the recent intensive surveys (Strong *et al.* 1995) partly due to improved systematic survey methods utilized over a period of several years. As in California, however, extrapolation from counts also may have led to overestimation. Varoujean and Williams's (1995) conclusion that marbled murrelet populations in Oregon have remained relatively stable over the past 10 years is currently unsubstantiated.

Washington

In the past, marbled murrelets in Puget Sound were considered "common" (Rathbun 1915, Miller *et al.* 1935), "abundant" (Edson 1908, Rhoades 1893), or

"numerous" (Miller *et al.* 1935), as summarized in Speich *et al.* (1992). Individuals who "lived, collected, and observed" in the Puget Sound area during portions of the first half of this century felt that marbled murrelets were previously more abundant.

Currently, marbled murrelets are considered only locally common during some times of the year. Puget Sound and the northern part of the outer coast are heavily used during the breeding season. The southern portion of the outer coast potentially plays an important role as a wintering area (Varoujean *et al.* 1994), possibly for both Oregon and Washington breeding birds. In addition, there also appears to be seasonal movements of marbled murrelets into Puget Sound from British Columbia in the winter (Rodway *et al.* 1992, Speich *et al.* 1992).

The most recent estimate of marbled murrelet numbers in Washington (Speich *et al.* 1992, Speich and Wahl 1995) indicates a breeding population of approximately 5,000 birds. Varoujean *et al.* (1994) conducted aerial surveys and came up with a mean estimate of 1,800 marbled murrelets for the Washington outer coast. Thompson (1996) also found marbled murrelets to be more numerous along Washington's northern outer coast and less abundant along the southern coast. He reported that his preliminary analysis shows that this distribution is correlated with the (1) proximity of old-growth forest, (2) distribution of rocky shoreline/substrate versus sandy shoreline/substrate, and (3) abundance of kelp. The outer coast of Washington has yet to be adequately surveyed to estimate population size.

Problems with Determining Population Size

The variability in population estimates underscores the need for further development of consistent survey methods for the entire range, without which

comparable population estimates cannot be obtained. Sowls *et al.* (1980) collected data opportunistically and developed a limited amount of information on which to base a population estimate. Carter *et al.* (1992) attempted to replicate Sowls' survey effort by using single, along-shore transects placed a few hundred meters from shore to document observations between 75 and 250 meters (246 and 820 feet) on both sides of the boat. Both 1979–1980 and 1989 surveys were roughly adjusted to account for areas not surveyed. These surveys provided good information on the state-wide distribution of the species, but probably underestimated population numbers. Ralph and Miller (1995) improved estimation of population size by (1) quantifying the distance at which birds were detected and calculating the effective detection distance for all observations; (2) conducting along shore transects at several distances from shore to better assess distribution away from shore; and (3) repeating standardized surveys over a number of years as opposed to a single survey season. However, their survey results were extrapolated from small areas to estimate numbers over much larger areas. This process, with inherent weaknesses, may have led to overestimation of marbled murrelet numbers, given the non-uniform distribution of marbled murrelets at sea. In addition, future population monitoring may not have sufficient funding to sustain the high effort required with this technique. If so, less intensive efforts may again be necessary in the future with their associated lower accuracy.

E. Life History/Ecology

Marbled murrelets have a unique life history strategy that differs from most seabirds and provides special challenges in managing the species. Although marbled murrelets feed primarily on fish and invertebrates in nearshore marine waters, they fly inland to nest on large limbs of mature conifers. The marbled murrelet is the only alcid known to nest in trees.

Marbled murrelets appear to be solitary in their nesting and feeding habits, but interact in groups over the forest and at sea (Sealy and Carter 1984, Carter and Sealy 1990, Nelson and Hamer 1995a). Simultaneous detections of more than one bird are frequently made at inland sites, with pairs of birds being the most frequently observed group size (Hamer and Cummins 1990, O'Donnell *et al.* 1995). Similarly, marbled murrelets occur primarily in singles and pairs at sea (Carter and Sealy 1990). Larger group sizes are also frequently seen.

Behavior indicative of marbled murrelet forest use and nesting, an indicator of habitat occupancy (Ralph *et al.* 1994), has been documented to occur beyond 80 kilometers (50 miles) inland, though most nesting habitat likely occurs within 80 kilometers (50 miles) of the marine environment throughout the breeding range. In the Pacific Northwest, the most distant known occupied site is in Washington and is located 84 kilometers (52 miles) from marine waters. Occupancy is defined in general terms as detection of behaviors associated with murrelet nesting and forest use (Ralph *et al.* 1994).

Marbled murrelets can be heard at certain inland sites during most months of the year (Carter and Erickson 1988, Naslund 1993). Detections are highest during the spring and summer, when activity levels are greater and attendance at inland sites is more consistent and longer in duration. In spring, marbled murrelet detectability at inland sites increases to moderate intensity and reaches a peak level of activity in midsummer (Hamer and Cummins 1991, Paton and Ralph 1988, Nelson 1989). After this peak, the number of detections decreases markedly, presumably because birds are undergoing a flightless molt at sea (Carter and Stein 1995). It is not well-understood why marbled murrelets visit inland sites during the nonbreeding season. Partly based on similar behavior in other alcid species, researchers hypothesize that marbled murrelets could be visiting nesting areas in the winter to attend previous nest sites, prospect for future

nesting sites, maintain or form pair bonds, and possibly for other unknown reasons (Carter and Sealy 1986, Naslund 1993).

Marbled murrelets exhibiting nesting behaviors are often grouped in an area. Sociality of marbled murrelets at inland nest sites is not fully understood. No indication of colonial nesting has been observed; most nests occur singularly or, at most, in the vicinity of a few other nests. However, observations of marbled murrelets in and around inland forest sites indicate that small groups of marbled murrelets often approach or depart forest stands together and also interact in flight above the stands (Divoky and Horton 1995, Nelson and Peck 1995).

Solitary nests may be grouped to varying extent within suitable habitat. Two active nests discovered in Washington in 1990 were located 46 meters (150 feet) apart (Hamer and Cummins 1990). In Oregon, two active nests were discovered in 1994 only 33 meters (100 feet) apart (S.K. Nelson, pers. comm., 1994). However, it is also likely that birds nest over wide areas of a forest stand and may be highly clumped only in particular portions of a forest stand. Furthermore, like other alcids, marbled murrelets exhibit nest site fidelity (i.e. return to the same nest site each year), certainly at the level of the stand and even for specific trees. Therefore, forest sites that are occupied by marbled murrelets may attract other marbled murrelets to those stands or adjacent, unoccupied forest stands, a behavior that may be important for recovering the species.

Most or all mature adult marbled murrelets are believed to nest in a given year when food supplies and nesting habitat are adequate. During intense El Niño events (see below under "F. Reasons for Decline and Current Threats, Severe Niño Events") food availability or accessability may be limited.

Nesting

Marbled murrelets lay only one egg on the limb of a large conifer tree and probably nest only once a year (Desanto and Nelson 1995). Nesting occurs over an extended period from late March to late September (Carter and Erickson 1992, Carter and Sealy 1987a, Hamer and Nelson 1995a, Rodway *et al.* 1992). Nests are not built; the egg is placed in a small depression or cup made in moss or other debris on the limb. (See "Habitat/Ecosystem Description, Nest characteristics" below.)

Incubation lasts about 30 days and fledging takes another 28 days (Hirsch *et al.* 1981, Nelson and Hamer 1995a, Simons 1980). Both sexes incubate the egg in alternating 24-hour shifts (Nelson and Hamer 1995a; Nelson and Peck 1995; Simons 1980; Singer *et al.* 1991, 1995).

The chick is fed up to eight times daily (averaging four times a day), and is usually fed only one fish at a time (Hamer and Cummins 1991; Singer *et al.* 1992; Nelson and Hamer 1995a). Flights by adults are made from ocean feeding areas to inland nest sites at all times of the day, but most often at dusk and dawn (Hamer and Cummins 1991, Nelson and Hamer 1995a).

The young are semiprecocial, but remain in the nest less time than young of most other alcids. Before leaving the nest, the young pluck the overlying layer of down off to reveal the underlying juvenal plumage (Nelson and Hamer 1995a).

Fledglings appear to fly directly from the nest to the sea, but are sometimes found on the ground, indicating that they may have been unable to sustain flight to reach the marine environment (Carter and Sealy 1987a, Hamer and Cummins 1991, Nelson and Hamer 1995a).

Marbled murrelets probably do not reach sexual maturity until at least their second year, and most birds probably do not lay eggs until they are 3 years of age or older. Based upon the longevity of other alcids (Hudson 1985), marbled murrelets are estimated to live an average of 10 years (Beissinger 1995a, Appendix B).

Diet and Food Resources

Marbled murrelets feed on a variety of small fish and invertebrates (see summaries in Sealy 1975, Carter 1984, Vermeer *et al.* 1987, Burkett 1995); however, very little information is available on food habits of marbled murrelets in Washington, Oregon or California, and systematic stomach content analyses have never been conducted in the tri-state area. Most of the information available is from the Gulf of Alaska and British Columbia. The available information on marbled murrelet food habits, including some prey ecology information, has been compiled by Burkett (1995).

Most prey have been identified on an anecdotal basis, in the bills of adults at sea or when delivered to the chick at the nest. Due to this method of obtaining prey data and the low sample sizes of identified prey in the Pacific Northwest, little is known of the extent that different prey species are used, or whether other prey also are used. In the Pacific Northwest, the main fish prey identified in recent years are Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea harengus*), northern anchovy (*Engraulis mordax*), and smelts (Osmeridae). In the early 1900s, Pacific sardines (*Sardinops sagax*) also were documented as prey in California.

Adults, subadults, and hatching-year birds feed primarily on larval and juvenile fish, whereas nestlings are most commonly fed larger second-year fish. Sand

lance, a small marine fish, is the most common food of the marbled murrelet across its range (Table 1) and appears to be the most important prey species in the chick's diet. Pacific herring and northern anchovy, followed by osmerids (smelt) and seaperch (*Cymatogaster aggregata*), are the next most common prey items. Sardines and rockfish (Scorpaenidae) may be important dietary components, particularly at the southern end of the marbled murrelet's distribution. Marbled murrelets also have been observed foraging occasionally on inland lakes inhabited by salmonid species in British Columbia and Washington (Carter and Sealy 1986).

In the Pacific Northwest, almost nothing is known of prey species eaten by adults, which are known to differ by species and/or size from that fed to chicks (Sealy 1975, Carter 1984, Carter and Sealy 1990, Burkett 1995). Adults feed on marine invertebrates and smaller-size classes of fish than are fed to chicks. In at-sea areas more than 1–2 kilometers (0.6–1.2 miles) from shore (areas rarely used by marbled murrelets), other prey species, such as juvenile rockfish (Scorpaenidae), may be important (Ainley *et al.* 1995).

Euphausiids (luminescent shrimp-like crustaceans forming an important part of marine plankton, or krill, also important to fishes and whales) do not comprise a dominant component during the breeding season. However, this prey source is important to marbled murrelets in the winter and spring in some locales (Sealy 1975, Krasnow and Sanger 1982, Vermeer 1992). Mysids and gammarid amphipods, also shrimp-like crustaceans, are another component of the marbled murrelet diet, especially in winter (Munro and Clemens 1931; Sanger 1983, 1987) (Table 1).

The fish portion of the diet is most important in the summer, and coincides primarily with the nestling and fledgling periods (Sealy 1975, Carter 1984, Carter

Table 1--Marbled Murrelet Prey Items from Systematic Studies and Anecdotal Observations, Alaska to California (from Burkett 1995).

		Grinnell (1897) and (1910)	Simons (1980)	Sanger (1983)	Munro and Clemens (1931)	Sealy (1975)	Sealy (1975)	Carter (1984)	Carter (1984)	Carter (1984)	Carter (1984)	Mahon et al. (1992)	Mahon et al. (1992)	Guiguet (1956)	Guiguet 1956; Guiguet [1950] *in* Carter (1984)	Vermeer (1992)	Jones and Dechesne (1994)	Brooks (1928); Carter and Sealy (1986)	G. Hunt, pers. comm.	Cody (1973)	Cody *in* Carter (1984)	Strong et al. (1993)	K. Nelson, pers. comm.	Beck (1910)	P.R. Kelly (pers. comm.) *in* Carter and Erickson (1988)	Ralph et al. (1990)	Naslund (1993)
	Location[1]	AL	AL	AL	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	AL-OR	WA	WA	WA	OR	OR	CA	CA	CA	CA
	Sample Size[2]	---	1	129	4	75	6	71	11	---	5	---	---	---	---	25	---	5	---	---	---	6	---	≈19	10	1	3
	Season of Collection/Observation[3]	BR	BR	A	NB	BR	BR	BR	BR	BR	NB	BR	BR	BR	BR	NB	BR	BR	BR	BR	BR	BR	BR	NB	NB	BR	BR
	Age Class of Murrelets[4]	U	N	U	A	A	J	A	J	N	U	U	N	U	N	U	N	A	U	N	N	N	N	U	U	N	N
Invertebrates	**Prey Species[5]**																										
	Unid. Nereidae (Polychaeta)			I																							
	Littorina sitkana (Gastropoda)			I																							
	Unid. Gastropoda			I																							
	Mytilus edulis (Bivalvia)			I																							
	Loligo opalescens (Cephalopoda)					I					X																
	Unid. Cephalopoda			I																							
	Unid. Mollusca	A																									
	Acanthomysis sp. (Mysidae)			O																							
	Neomysis rayii (Mysidae)			I																							
	Neomysis sp. (Mysidae)			I																							
	Unid. mysid			I	A																						
	Atylus tridens (Amphipoda)						I																				
	Unid. Gammarid (Amphipoda)			I																							

Table 1 (cont.)

		Grinnell (1897) and (1910)	Simons (1980)	Sanger (1983)	Munro and Clemens (1931)	Sealy (1975)	Sealy (1975)	Carter (1984)	Carter (1984)	Carter (1984)	Carter (1984)	Mahon et al. (1992)	Mahon et al. (1992)	Guiguet (1956)	Guiguet 1956; Guiguet [1950] *in* Carter (1984)	Vermeer (1992)	Jones and Dechesne (1994)	Brooks (1928); Carter and Sealy (1986)	G. Hunt, pers. comm.	Cody (1973)	Cody *in* Carter (1984)	Strong et al. (1993)	K. Nelson, pers. comm.	Beck (1910)	P.R. Kelly (pers. comm.) *in* Carter and Erickson (1988)	Ralph et al. (1990)	Naslund (1993)
Invertebrates	*Thysanoessa inermis* (Euphausiid)			O																							
	T. raschii (Euphausiid)			I																							
	T. spinifera (Euphausiid)			I		X	I									O											
	Thysanoessa sp. (Euphausiid)			I																							
	Euphausia pacifica (Euphausiid)					O										O											
	Unid. Euphausiid			I	A									A		I											
	Pandalus borealis (Decapod)			I																							
	Unid. Decapod			I		I																					
	Unid. Chaetognatha			I																							
Fish	*Clupea harengus* (Clupeidae)							X	X	A	O		A		A	X			P				P				
	Sardinops sagax (Clupeidae)																							A			
	Unid. Clupeidae																										P
	Engraulis mordax (Engraulididae)							I		A										A	A				A	A	P
	Mallotus villosus (Osmeridae)		P	X																							
	Thaleichthys pacificus (Osmeridae)	P																									
	Unid. Osmeridae			O		I																A	A				A
	Onchorhynchus sp./*Salmo* sp. (Salmonidae)																	A									
	Strongylura exilis (Belonidae)																							P			

Table 1 (cont.)

		Grinnell (1897) and (1910)	Simons (1980)	Sanger (1983)	Munro and Clemens (1931)	Sealy (1975)	Sealy (1975)	Carter (1984)	Carter (1984)	Carter (1984)	Carter (1984)	Mahon et al. (1992)	Mahon et al. (1992)	Guiguet (1956)	Guiguet 1956; Guiguet [1950] *in* Carter (1984)	Vermeer (1992)	Jones and Dechesne (1994)	Brooks (1928); Carter and Sealy (1986)	G. Hunt, pers. comm.	Cody (1973)	Cody *in* Carter (1984)	Strong et al. (1993)	K. Nelson, pers. comm.	Beck (1910)	P.R. Kelly (pers. comm.) *in* Carter and Erickson (1988)	Ralph et al. (1990)	Nashlund (1993)
Fish	*Theragra chalcogramma* (Gadidae)			I																							
	Unid. Gadidae (Codfishes)			I																							
	Trichodon trichodon (Trichodontidae)			I																							
	Scorpaenidae (Rockfishes)					I		I	I		O																
	Cymatogaster aggregata (Embiotocidae)				P	O	O						A														
	Stichaeidae (Pricklebacks)					I																					
	Ammodytes hexapterus (Ammodytidae)			X		X	X	O	O	A	I	A	A	A	A		A			A		A	A		A		
	Unid. Fish	A		O	A[L]																			A			

1 AL = Alaska, BC = British Columbia, WA = Washington, OR = Oregon, CA = California

2 — = Unknown or not recorded

3 BR = Breeding, NB = Non-Breeding, A = All seasons

4 A = Adult/Subadult, J = Juvenal, N = Nestling, U = Unknown

5 X = Major, O = Minor, I = Incidental, P = Possible, A = Anecdotal observation

L Larval fish

and Sealy 1990). Energy values of prey items also help explain why marbled murrelets select certain prey species for themselves and their nestlings. Herring have high food energy and total lipid (fat) values compared to the other fish that marbled murrelets consume. Large lipid reserves at fledging presumably enhance post-fledging survival (Roby 1991). No data are available about the winter diet of marbled murrelets in the Pacific Northwest, although winter diet is known in areas of Alaska and British Columbia.

In summary, the diet of the marbled murrelet is poorly known in the Pacific Northwest. Regardless, diet breadth (i.e., use of many fish and invertebrate species in the same areas) is evident in the Pacific Northwest and farther north, and marbled murrelets are considered to be opportunistic feeders on available prey within certain size classes.

Foraging Strategies

Marbled murrelets use their wings for swimming underwater and are capable of diving to great depths within nearshore waters. The deepest record of a marbled murrelet was one captured at 27 meters (89 feet) in a gill net off central California (Carter and Erickson 1992), although birds probably can forage deeper based on known diving depths of other alcids (Piatt and Nettleship 1985).

For the most part, marbled murrelets tend to forage in relatively shallow waters with total depths ranging as deep as several hundred meters. Most birds forage in shallower waters (less than 50–100 meters [164–328 feet] deep) and usually appear to feed both near the surface and at midwater depths, based on their known capture depths in gill nets (most less than 10 meters [33 feet]), short dive times (averages between 28-69 seconds), and involvement in mixed-species feeding flocks foraging on schools of fish near the surface in some areas (Mahon *et al.*

1992, Carter *et al.* 1995a, Strachan *et al.* 1995). At times, they also may forage along the ocean bottom, especially when diving very near shore (Carter, pers. obs.).

Throughout its range, the marbled murrelet consumes a very diverse group of prey resources, especially when one considers the few studies that have been done to date. This suggests great flexibility in prey choice and a high capability for using alternative prey, indicative of opportunistic foragers (Carter 1984). Such foraging flexibility may permit the wide distribution of marbled murrelets along coasts with suitable nesting habitats throughout their breeding range.

This flexibility also may serve to reduce impacts due to inter-annual variability in prey resources due to several different factors. Thus, intermittent El Niño or other warm water events would not be expected to cause large marbled murrelet population fluctuations or great reductions in reproduction (especially over the long term), even though marbled murrelets may undergo local shifts in the locations of foraging areas. Given the variability in frequency and intensity of El Niño events, marbled murrelet production could be lower than "normal" in some years, as has been demonstrated for many other seabirds. But, like other seabirds, marbled murrelet populations have persisted through several frequent El Niño episodes over the last century and earlier. It may be able to partially compensate for these events by changing its foraging behavior and prey selection to some degree to use available resources (Sealy 1975, Krasnow and Sanger 1982, Carter 1984, Sanger 1987, Croll 1990).

Since marbled murrelets are opportunistic foragers, many types of prey may be used, depending mainly on availability (Carter 1984, Burkett 1995). Many different types of prey are available to marbled murrelets in different nearshore areas and at different times of year. However, for chick diet, adult marbled murrelets are restricted to selecting single large fish (often second-year fish,

ranging from 60–120 millimeters in length and about 2–25 grams in weight) to deliver to chicks (Carter 1984; Carter and Sealy 1987b, 1990; Burkett 1995). This restriction forces chick-feeding adults to exercise more specific foraging strategies to locate these large fish, focusing on species that are less abundant and distributed differently than adult prey (Carter and Sealy 1990). The distribution and abundance of chick prey may greatly influence overall foraging behavior during this period of the year.

Even if adult marbled murrelets can easily choose alternate prey species for their own diet, having abundant forage fish available during the nestling period may significantly reduce the energy demand on the adults by requiring less foraging time and fewer trips inland for feeding nestlings (Cody 1973, Sealy 1975, Carter 1984, Carter and Sealy 1990). The distance between nesting areas and foraging areas is probably one critical determinant of reproductive success in years of low prey abundance. Increased foraging time of adults, long flights inland, and more numerous trips inland with small prey items could potentially reduce both adult and chick survival (Burkett 1995).

F. Habitat/Ecosystem Description

Nearshore Marine Environment

Marbled murrelets feed in nearshore marine waters, mainly within 1–2 kilometers (0.6–1.2 miles) from shore. These nearshore waters include estuaries, bays, island groups, and more open coastal waters. These waters and their associated marbled murrelet prey resources (small fish and invertebrates) are influenced to a significant degree by their interface with adjacent mainland characteristics (e.g., river mouths and plumes, tidal currents, shoreline and intertidal areas, coastal points and topographical features, and human developments), as well as subsurface features (e.g., bottom sediments, banks, water depth, etc.).

Many prey species are concentrated in specific nearshore waters where freshwater or estuary spawning areas, larval and juvenile fish rearing areas, nearshore physical processes, and bottom substrates, sediments, and vegetation concentrate organisms from lower trophic levels to serve as food for marbled murrelet prey species. For instance, local fronts between estuarine and shelf waters are known areas of concentration for marbled murrelet prey and foraging marbled murrelets in British Columbia (Carter 1984, Carter and Sealy 1990).

To a lesser degree, nearshore waters and prey resources also are influenced by their connection to shelf and offshore waters (Hunt 1995). In particular, large-scale oceanic currents and upwelling along the continental shelf can interact with local topography to create or contribute to both large- and small-scale eddies and fronts at certain times of year, which can affect nearshore waters (e.g., Briggs *et al.* 1987). However, coastal topography (e.g., points, islands) can reduce the impacts of wind-induced mixing, wind-driven currents, and storm events in nearshore waters compared to the same conditions in nearby exposed shelf and offshore waters.

Unfortunately, the marine food webs in nearshore, shelf, and offshore marine environments are complex and knowledge of how they operate and are connected is limited. In particular, spawning areas are often located in more protected waters, especially closed bays. Certainly, different life stages of several potential prey species can occur in either nearshore or shelf waters. Thus, prey resources in these respective areas are somewhat distinct but are also interconnected. Winter processes affecting prey resources are even less well known than spring and summer processes.

Terrestrial Environment

Because of their small body size, cryptic plumage, crepuscular activity, fast flight speed, solitary nesting behavior, and secretive behavior near nests located in densely forested habitat, the nests of the marbled murrelet have been extremely difficult to locate (Hamer and Nelson 1995b). The first tree nest in North America was not located until 1974 (Binford *et al.* 1975), even though ornithologists had been searching for the nest site of the marbled murrelet in North America for many decades. At the same time, it became known that a tree nest of the Asiatic marbled murrelet had been discovered in 1961 (Kuzyakin 1963). Although a significant amount of nesting habitat information has been collected over the past 6 years, the efficiency of locating new nests is still low (Hamer and Nelson 1995b).

Even with the difficulties of locating nests, concern about conservation problems of the species led to intensive search efforts by biologists across the Pacific Northwest, British Columbia, and Alaska and to the discovery of 136 tree nests from 1974 to the end of the 1996 field season. Of these tree nests, 133 (98 percent) were located since 1990 (S.K. Nelson, pers. comm., 1996). The 136 nests included 20 in Alaska, 6 in Washington, 51 in British Columbia, 45 in Oregon, and 14 in California (Binford *et al.* 1975; Quinlan and Hughes 1990; Hamer and Cummins 1991; Singer *et al.* 1991,1992; Nelson *et al.* 1994; Kuletz *et al.* 1995a; Burger 1995; Nelson and Hamer 1995b; Hamer and Nelson 1995b; Naslund *et al.* 1995; S.K. Nelson, pers. comm., 1997). Although this is still a relatively small sample size compared to most seabirds studied, the sample does allow a characterization of the tree nests and nesting stands used by the marbled murrelet over a large geographical area. A more in-depth summary and discussion of information on nest stands, nest trees, and nests presented under "F. Habitat/Ecosystem Description" can be found in Hamer and Nelson (1995b).

Landscape characteristics. Throughout the forested portion of the species' range, marbled murrelets use forest stands with old-growth forest characteristics, generally within 80 kilometers (50 miles) of the coast for nesting. The furthest known nesting site from the marine environment in Washington, as defined by the discovery of an egg, eggshell, or downy chick, was 63 kilometers (39 miles). However, the furthest documented occupied site in Washington was located 84 kilometers (52 miles) from marine waters. The furthest inland nests in Oregon and California were 40 kilometers (25 miles) and 28.9 kilometers (18 miles) from the ocean, respectively (Table 2). However, birds have been detected up to 100 kilometers (60 miles) inland in British Columbia.

Hamer and Nelson (1995b) examined a sample of 47 nests in the Pacific Northwest and British Columbia, and measured a number of parameters (Tables 2 and 3); information on nest trees (Table 3) has been updated to include nest trees located through 1996. Slope, elevation, and aspect (cardinal direction the stand faces) of nest stands vary considerably (Table 2). The average elevation of nest trees was 332 meters (1,089 feet). Aspect was extremely variable, with no clear pattern or trend for stand placement with respect to aspect. With respect to slope, eighty percent of nests in the Pacific Northwest were located on the lower one-third or middle one-third of the slope.

General landscape condition may influence the degree to which marbled murrelets nest in an area. In Washington, marbled murrelet detections increased when old-growth/mature forests comprised more than 30 percent of the landscape (Hamer and Cummins 1990). Hamer and Cummins (1990) found that detections of marbled murrelets decreased in Washington when the percentage of clear-cut/meadow in the landscape increased above 25 percent. Additionally, Raphael *et al.* (1995) found that the percentage of old-growth forest and large sawtimber was significantly greater within 0.8 kilometer (0.5 mile) of sites

Table 2. The mean, standard deviation, range, and sample size for the forest characteristics of Marbled Murrelet tree nests located in the Pacific Northwest. The Pacific Northwest data include nests located in California, Oregon, Washington, and British Columbia. For some characteristics, either no data were available for that state or province, or the sample size was too small to calculate the mean and range. Sample sizes for each variable are shown in parenthesis (Table from Hamer and Nelson 1995b).

Characteristics	California n=10	Oregon n=20	Washington n=6	British Columbia n=9	Pacific Northwest n=45
Aspect (percent)	210±122 45-352 (7)	147±63 48-253 (19)	180±121 39-331 (5)	-- --	166±92 35-39 (33)
Elevation (meters)	286±125 45-46 (10)	379±152 61-646 (10)	348±176 15-610 (6)	321±310 14-1097 (9)	332±206 14-1097 (35)
Slope (percent)	18±14 0-41 (7)	41±27 10-87 (10)	21±13 0-39 (6)	3±4 0-11 (7)	23±23 0-87 (30)
Slope Position	1±0 1-1 (7)	2.1±0.9 1-3 (10)	1.3±0.5 1-2 (6)	1.3±0.7 1-3 (7)	1.5±0.8 1-3 (30)
Stand Size (hectares)[1]	352±432 100-1100 (4)	80±49 3-149 (9)	354±401 5-990 (5)	-- --	206±351 3-1100 (16)
Pct. composition low elevation trees[2]	100±0 100-100 (10)	100±0 100-100 (10)	90±9 78-100 (5)	64±29 20-100 (6)	91±19 20-100 (31)
Total tree density (number/ha)	235±178 92-504 (5)	120±72 48-282 (10)	136±28 84-162 (5)	297±136 148-530 (5)	182±132 48-530 (25)

Characteristics	California n=10	Oregon n=20	Washington n=6	British Columbia n=9	Pacific Northwest n=45
Canopy height (m)	88±0 88-88 (5)	59±8 48-75 (9)	54±5 44-59 (5)	-- --	64±16 38-88 (20)
Canopy layers (number)	-- --	2.2±0.4 2-3 (10)	3.4±0.5 3-4 (4)	-- --	2.5±0.7 2-4 (20)
Canopy closure (percent)	39±6 25-48 (7)	43±27 12-99 (8)	69±18 36-88 (5)	-- --	49±23 12-99 (21)
Distance to Coast (km)	13.1±8.3 4.9-28.9 (10)	25.8±9.7 1.6-40.0 (10)	15.9±13 4.1-34.2 (6)	11.5±3.7 3.2-17.3 (9)	16.8±10.6 1.6-40 (35)
Distance to stream (m)	108±67 30-215 (7)	280±312 8-1000 (10)	70±69 14-200 (5)	100±165 5-500 (7)	159±224 5-1000 (29)
Distance to nearest opening (m)	-- --	67±70 15-300 (20)	65±33 18-120 (5)	-- --	92±131 15-700 (30)
Stand age (years)	-- --	209±48 180-350 (10)	879±606 450-1736 (3)	-- --	522±570 180-1824 (16)

1/ Slope position codes: (1) lower 1/3, (2) middle 1/3, (3) upper 1/3.
2/ Measures of the percent of western hemlock, Douglas-fir, western red cedar, Sitka spruce, and coastal redwood in a stand.

Table 3. The mean, standard deviation, range, and sample size for platform and tree characteristics of Marbled Murrelet tree nests located in the Pacific Northwest through 1996. The Pacific Northwest data include nests located in California, Oregon, Washington, and British Columbia. For some characteristics, either no data were available for that state or province, or the sample size was too small to calculate the mean and range. Calculations were rounded to the nearest cm for all measurements except nest substrate depth. Sample sizes for each variable are shown in parenthesis. (Table compiled by S. Kim Nelson)

Characteristics	California [1] N = 14	Oregon [2] N = 45	Washington [3] N = 6	British Columbia [4] N = 51	Pacific Northwest N = 116
Tree Species					
Douglas-fir	4	32	3	2	41
Alaska yellow cedar	0	0	0	37	37
Western hemlock	1	11	3	5	20
Sitka spruce	0	1	0	6	7
Mountain hemlock	0	0	0	1	1
Coast redwood	9	0	0	0	9
Western red cedar	0	1	0	0	1
Tree diameter (cm)	308.7 ± 41.7 139.0-533.0 (14)	164.7 ± 7.8 76.0-279.0 (45)	149.5 ± 18.5 88.5-220.0 (6)	119.4 ± 8.2 60.0-370 .0 (51)	161.4 ± 8.7 60.0-533 .0 (116)
Tree height (m)	73.1 ± 2.8 48.8-86.5 (14)	61.5 ± 2.0 36.0-85.1 (45)	57.4 ± 3.7 45.1-65.0 (5)	33.2 ± 2.0 16.5-79.4 (51)	50.2 ± 1.9 16.5-86.5 (115)
Tree diameter at nest height (m)	103.2 ± 19.7 70.0-199.0 (6)	67.6 ± 4.0 29.3-122.0 (39)	78.4 ± 10.8 40.5-110.0 (6)	58.1 ± 4.7 25.5-209.0 (45)	66.1 ± 3.2 25.5-209.0 (96)

Characteristics	California [1] N = 14	Oregon [2] N = 45	Washington [3] N = 6	British Columbia [4] N = 51	Pacific Northwest N = 116
Branch height (m)	46.9 ± 3.1 31.7-67.5 (14)	41.9 ± 2.2 13.6-74.8 (44)	33.9 ± 5.5 20.1-52.9 (6)	22.7 ± 1.0 12.5-42.0 (51)	33.6 ± 1.4 12.5-74.8 (115)
Branch diameter at trunk (cm)	44.0 ± 4.6 21.0-61.0 (8)	24.6 ± 1.6 11.6-56.0 (42)	38.3 ± 5.7 13.5-50.5 (6)	29.0 ± 1.7 8.0-62.0 (50)	28.9 ± 1.2 8.0-62.0 (106)
Branch diameter at nest (cm)	24.5 ± 3.1 16.0-37.0 (6)	33.7 ± 3.9 10.0-63.0 (12)	29.4 ± 7.6 10.7-46.0 (4)	17.5 ± 2.5 15.0-20.0 (2)	29.4 ± 2.6 10.0-63.0 (24)
Branch diameter proximal to nest (cm)	xxxx	25.0 ± 1.8 10.0-50.0 (31)	xxxx	29.0 ± 1.5 15.0-62.0 (47)	27.7 ± 1.2 10.0-62.0 (79)
Branch length (m)	4.2 ± 1.1 0.9-15.0 (13)	4.9 ± 0.4 1.0-12.2 (42)	4.1 ± 1.2 1.1-7.5 (5)	3.9 ± 0.3 0.6-9.7 (51)	4.3 ± 0.2 0.6-15.0 (111)
Branch crown position (%)	64.3 ± 3.3 50.0-91.0 (14)	67.8 ± 2.6 26.0-98.0 (44)	63.4 ± 7.7 41.0-82.0 (5)	71.0 ± 1.8 40.0-95.0 (51)	68.6 ± 1.4 26.0-98.0 (114)
Branch orientation (°)	30-360 (14)	20-360 (43)	110-342 (5)	0-360 (49)	0-360 (111)
Distance nest from trunk (cm)	23.1 ± 10.5 0-122.0 (14)	100.2 ± 19.7 0-762.0 (44)	22.0 ± 12.1 0-57.0 (5)	46.5 ± 11.1 0-340.0 (50)	63.4 ± 9.6 0-762.0 (113)

Characteristics	California [1] N = 14	Oregon [2] N = 45	Washington [3] N = 6	British Columbia [4] N = 51	Pacific Northwest N = 116
Nest platform length (cm)	24.3 ± 3.7 9.5-41.9 (10)	55.4 ± 7.2 7.5-250.0 (44)	30.7 ± 7.0 10.0-57.0 (6)	52.3 ± 4.8 8.0-128.0 (44)	49.7 ± 3.8 7.5-250.0 (104)
Nest platform width (cm)	19.7 ± 4.0 6.5-50.8 (10)	26.8 ± 1.7 7.0-51.0 (44)	25.0 ± 4.7 10.0-39.0 (6)	19.1 ± 1.2 7.0-41.0 (44)	22.8 ± 1.0 6.5-51.0 (104)
Nest cup length (cm)	11.0 ± 1.2 8.3-16.5 (6)	11.0 ± 0.6 5.0-26.0 (43)	12.4 ± 2.3 5.9-20.0 (6)	9.9 ± 0.4 6.0-20.0 (49)	10.6 ± 0.4 5.0-26.0 (104)
Nest cup width (cm)	9.3 ± 1.1 6.5-14.0 (6)	10.0 ± 0.5 3.3-18.4 (43)	11.7 ± 2.5 3.1-20.0 (6)	8.7 ± 0.3 4.0-14.5 (49)	9.4 ± 0.3 3.1-20.0 (104)
Nest cup depth (cm)	3.5 ± 0.8 2.0-8.0 (7)	3.5 ± 0.3 0.5-7.1 (38)	2.6 ± 0.3 1.8-3.6 (6)	3.9 ± 0.2 1.0-6.0 (46)	3.6 ± 0.2 0.5-8.0 (97)
# Landing pads	0.6 ± 0.2 0-1 (8)	1.2 ± 0.1 0-3 (43)	2.0 ± 0.6 1-3 (3)	0.6 ± 0.1 0-3 (51)	0.9 ± 0.1 0-3 (105)
Percent moss on platform	42.2 ± 14.7 0-100 (12)	89.5 ± 2.7 50-100 (31)	58.0 ± 19.8 5-100 (5)	88.9 ± 3.8 2-100 (37)	80.7 ± 3.5 0-100 (85)

Characteristics	California [1] N = 14	Oregon [2] N = 45	Washington [3] N = 6	British Columbia [4] N = 51	Pacific Northwest N = 116
Moss depth on platform (cm)	1.2 ± 0.7 0-8.1 (12)	4.7 ± 0.4 0-12.0 (43)	1.4 ± 0.7 0-3.5 (5)	4.9 ± 0.3 1.0-10.0 (48)	4.2 ± 0.2 0-12.0 (108)
Duff and litter depth on platform/ nest cup (cm)	4.2 ± 1.7 0-20.0 (11)	3.0 ± 0.6 0-12.0 (30)	2.5 ± 0.4 1.6-3.8 (5)	4.9 ± 1.0 0.8-10.0 (8)	3.5 ± 0.5 0-20.0 (54)
Cover above nest (%)	87.1 ± 7.9 5.0-100 (13)	78.1 ± 3.3 5.0-100 (41)	89.2 ± 4.4 70.0-100 (6)	77.7 ± 2.2 30.0-100 (47)	79.6 ± 1.9 5.0-100 (107)
Distance to cover above nest (cm)	210.7 ± 64.7 1.3-444.4 (10)	71.8 ± 12.6 2.5-300.0 (40)	104.8 ± 64.1 19.0-360.0 (5)	96.0 ± 11.9 10.0-350.0 (45)	98.2 ± 10.7 1.3-444.4 (100)

[1] Data from Binford et al. 1975; Kerns and Miller 1995; Singer et al. 1991, 1995, unpubl. data; PALCO unpubl. data.
[2] Data from Hamer and Nelson 1995b, S. K. Nelson unpubl. data.
[3] Data from Hamer and Nelson 1995b, T. Hamer unpubl. data.
[4] Data from Jordan and Hughes 1995, Manley and Kelson 1995, A. Burger unpubl. data, I. Manley unpubl. data.

(203-hectare [501-acre] circles) that were occupied by marbled murrelets than at sites where they were not detected. Raphael *et al.* (1995) suggested tentative guidelines based on this analysis that sites with 35 percent old-growth and large sawtimber in the landscape are more likely to be occupied. In California, Miller and Ralph (1995) found that the density of old-growth cover and the presence of coastal redwood were the strongest predictors of marbled murrelet presence.

Forest characteristics. From Prince William Sound, Alaska, and south, nesting occurs in trees in older forests (Binford *et al.* 1975; Sealy and Carter 1984; Carter and Sealy 1987a; Quinlan and Hughes 1990; Hamer and Cummins 1990, 1991; Singer *et al.* 1991, 1992; Carter and Morrison 1992; Burger 1995; Grenier and Nelson 1995; Hamer 1995; Hamer and Nelson 1995b; Kuletz *et al.* 1995a). Evidence that tree nesting occurs almost exclusively in older forests includes (1) all tree nests have been located in old-growth or mature trees greater than 76 centimeters (30 inches) diameter at breast height in California, Oregon, Washington, British Columbia, and Alaska; (2) stranded downy young and fledglings have been found on the ground in or near old-growth or mature forests; (3) marbled murrelet concentrations are found offshore from old-growth and mature forests during the nesting season; and (4) numerous visual and auditory detections of marbled murrelets flying have been made in or adjacent to old-growth and mature forests (Marshall 1988).

The average age of forest stands for a sample of 16 nests in the Pacific Northwest and British Columbia was calculated as 522 years (Table 2). For the 61 tree nests found in North America with available information, all have been found in old-growth or mature forests (Hamer and Nelson 1995b).

Nest stands are typically composed of low elevation conifers, which include Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), Sitka

spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and coastal redwood (*Sequoia simpervirens*) (Table 2). The average nest stand size was 206 hectares (509 acres), with stands ranging in size from as small as 3 hectares (7 acres) to as large as 1,100 hectares (2,718 acres) (Hamer and Nelson 1995b). This includes forests, generally characterized by large trees (80 centimeters [32 inches] or greater diameter at breast height), a multistoried stand, and a moderate to high canopy closure. Nest stands in Oregon and Washington are characterized by medium to large diameter trees with an average size of 47.7 centimeters (19 inches) diameter at breast height. In certain parts of the range (Oregon Coast Range), marbled murrelets are also known to use mature forests with an old-growth component of large trees (Grenier and Nelson 1995).

The average density of all trees is 324 per hectare (131 per acre); the average density of larger trees (greater than 46 centimeters [18 inches] diameter at breast height) is 93.8 per hectare (38 per acre). There are multiple canopy layers (2–3) and snags are present (Nelson *et al.* 1994). For nest stands in the Pacific Northwest, the average canopy closure was 49 percent, but the average canopy closures for stands in Oregon and California were much lower than for Washington (Hamer and Nelson 1995b).

Miller and Ralph (1995) compared marbled murrelet survey detection rates among four stand size classes in California. Recording a relatively consistent trend, they observed that a higher percentage of large stands (33.3 percent) had occupied detections when compared to smaller stands (19.8 percent), while a greater percentage of the smallest stands (63.9 percent) had no presence or occupancy detections when compared to the largest stands (52.4 percent) (Miller and Ralph 1995). However, these results were not statistically significant, and the authors did not conclude that marbled murrelets preferentially selected or used larger stands. The authors suggested the effects of stand size on marbled murrelet

presence and use may be masked by other factors such as stand history and proximity of a stand to other old-growth stands. Schieck *et al.* (1995) found that marbled murrelet presence and abundance was positively correlated with old-growth stand size in British Columbia, but their data were not statistically significant. Rodway *et al.* (1993) recommended caution when interpreting marbled murrelet detection data, such as that used by Miller and Ralph (1995) and Schieck *et al.* (1995), because numbers of detections at different sites may be affected by variation caused by weather, visibility, and temporal shifts in activity.

Nest tree characteristics. All nests in Washington, Oregon, and California were located in old-growth or mature trees that were greater than 76 centimeters (30 inches) diameter at breast height. Trees must have large branches or deformities for nest platforms, including debris platforms created by mistletoe infestations. Some younger-aged stands (65–150 year-old stands) on the Tillamook State Forest in Oregon appear to contain nesting platforms created by dwarf mistletoe and canopy moss, occurring only in discrete patches in these younger-aged stands. Eggshell fragments and at least six old nests have been located in this type of stand (S.K. Nelson, pers. comm., 1996).

The most common tree species used for nests in the Pacific Northwest and British Columbia was Douglas-fir, followed by Alaska yellow cedar (*Chamaecyparis nootkatensis*), coastal redwood, western hemlock, Sitka spruce, western red cedar and mountain hemlock (*Pseuga mertensiana*) (Table 3). Douglas-fir and western hemlock were the only nest tree species used by marbled murrelets in all three states and British Columbia (Hamer and Nelson 1995b, S.K. Nelson, pers. comm., 1996). California nest sites have been located in stands containing old-growth redwood and Douglas-fir, while nest sites in Oregon and Washington have been located in stands dominated by Douglas-fir, western hemlock, and Sitka spruce.

The average nest tree diameter was 161 centimeters (63 inches) for those measured in the Pacific Northwest and British Columbia. The smallest diameter nest tree was located in British Columbia, with a diameter at breast height of 60 centimeters (24 inches) (Table 3).

The condition of nest trees varied, with 77 percent considered alive/healthy and 23 percent as declining. No nests were reported in snags (Hamer and Nelson 1995b, S.K. Nelson, pers. comm., 1997).

The diameter of nest branches, measured at the tree trunk, averaged 29 centimeters (11 inches) and ranged from 10 to 63 centimeters (4 to 25 inches). There appeared to be little variability among states with respect to this parameter (Table 3). Nest branch length averaged 4.3 meters (14 feet) and ranged from 0.6 meters to 15 meters (2 to 49 feet) long.

Nest characteristics. Most nests have been located on large or deformed branches with moss covering. However, a few nests have been located on smaller branches, and some nests were situated on duff platforms composed of conifer needles or sticks rather than moss. Nests were typically located in the top third of the dominant tree canopy layer and usually had dense overhead protection. Such locations allow easy access to the exterior of the forest and provide shelter from potential predators.

Nest platforms were created primarily by large branches. Limb structure (i.e., where a secondary limb branched off of a primary limb), also created platforms. Cases of dwarf mistletoe-infected limbs, large secondary limbs, natural depressions on a large limb, and old stick nests also were recorded as forming platforms (Hamer and Nelson 1995b).

Nests are not built, and the eggs are laid in a small depression or cup made in moss or other debris on a limb. Nest cups were located an average of 63 centimeters (25 inches) from the tree trunk, and 80 percent were located within 1 meter of the tree trunk. For 113 nests found in North America, moss formed 49 percent of the substrate, moss mixed with lichen or litter formed 36 percent of the nests, and litter 15 percent, in addition to the underlying bark of the nest branch itself. The average moss depth at the nest cup was 4.2 centimeters (1.6 inches). In almost all cases, canopy closure directly above the nest was high, averaging 80 percent. Eighty-one percent of all nests in the Pacific Northwest and British Columbia had greater than or equal to 75 percent overhead cover (Hamer and Nelson 1995b, S.K. Nelson, pers. comm., 1997).

G. Reasons for Decline and Current Threats

The marbled murrelet population may decline until the population eventually reaches an equilibrium with the amount and quality of nesting habitat available, or is extirpated in the three-state area. The weight of evidence indicates that the major factors in marbled murrelet decline from historical levels in the early 1800's (or earlier) are (1) loss of nesting habitat and (2) poor reproductive success in the habitat that does remain.

Loss of Nesting Habitat

The principal factor considered to affect the marbled murrelet throughout the southern portion of its range (from British Columbia south to California) is the loss of nesting habitat (older forests) (U.S. Fish and Wildlife Service 1992a), mainly from commercial timber harvest and forest management practices. Additional losses have occurred from natural disturbances such as windthrow, both natural and human-caused fire, and development.

The geographical area of suitable marbled murrelet habitat was greatly reduced in Washington, Oregon, and California during the 1800s and 1900s. Most suitable nesting habitat (old-growth and mature forests) on private lands within the range of the Washington, Oregon, and California population has been eliminated by timber harvest (Green 1985, Norse 1988, Thomas *et al.* 1990). Remaining tracts of potentially suitable habitat on private lands throughout the range are subject to continuing timber harvest operations. In most areas, second-growth forests have been or are planned to be harvested before they will attain the characteristics of older forests. Thus, this habitat loss is largely permanent, without considerable change in management actions over the next century.

At the time of the first comprehensive survey of forests in western Oregon and Washington was conducted in the mid-1930's (Andrews and Cowlitz 1940), old-growth Douglas-fir, Sitka spruce, and western hemlock covered 459,700 hectares (1,136,000 acres) in the Oregon Coast Range, and 1,314,700 hectares (3,248,500 acres) on the Olympic Peninsula and the Puget Sound region of Washington (generally within 100 kilometers (60 miles) of Puget Sound). Harvest of older forest has not been evenly distributed over western Oregon, Washington and northwestern California. The earliest logging was concentrated at lower elevations and the Coast Ranges (Thomas *et al.* 1990), generally equating with the range of the marbled murrelet and in regions generally considered to be the highest quality marbled murrelet habitat.

Washington. Old-growth harvest continued at a high rate after the 1930's survey, especially on private lands, but increasingly on public lands as well. Two billion board feet, two-thirds of which was old-growth (Wall 1972), were harvested from private lands in western Washington in 1958; by 1970, annual harvest from private lands had nearly doubled to 3.8 billion board feet, 80 percent of which was old-growth. Harvest from public lands in western Washington accelerated from

about 0.5 billion board feet in 1949 to 2 billion board feet in 1970. Most or all of this harvest was probably old-growth, although specific data are not available. The establishment of Olympic National Park was fundamental to preserving additional old-growth forest on the Olympic Peninsula that has otherwise been heavily harvested.

Oregon. Historic old-growth was less extensive than in western Washington due to large wildfires, many human-caused, which burned in the Oregon Coast Range in the mid-1800s and early 1900s. Teensma *et al.* (1991) estimated that 200-year and older stands composed from 40 percent to 50 percent of Coast Range forests between 1850 and 1920 and declined to 20 percent in 1940 following large fires in the Tillamook area.

Prior to logging, 800,000 to 1,200,000 hectares (2 to 3 million acres) of suitable marbled murrelet habitat existed in the Oregon Coast Range. This may be compared to the current estimate of 200,000 hectares (500,000 acres) of medium/large conifer identified on Federal lands in the Coast Range by the Forest Ecosystem Management Assessment Team (FEMAT) (U.S. Department of Agriculture *et al.* 1993). Except for an uncertain amount of habitat on the Tillamook and Elliott State Forests and some other State lands, along with a limited amount on private lands, virtually all remaining potential habitat in the Coast Range is on Federal lands.

California. A large proportion of forests within the nesting radius of the coast are privately owned and have been intensively managed. Logging began in central California in the early 1800's and expanded throughout northern California in the 1850's and 1860's. By the early 1900's, certain areas had been largely logged of old-growth forests, especially on the Monterey Peninsula, northern Monterey Bay, Berkeley Hills and parts of southern Marin County. This habitat loss began the

isolation of the central California marbled murrelet population from the populations in northern California. Logging proceeded in the forests of Sonoma and Mendocino counties throughout the 20th century, such that almost all old-growth forest had been lost in this region by the mid to late 1900's.

In northern and remaining parts of central California, several parks were set aside, starting with Big Basin State Park in 1902. Most parks were designated between 1920 and 1950 and about 4–5 percent of old-growth redwood forest had been preserved in parks by 1978 when less than 15 percent of the original 770,000 hectares (1.9 million acres) of old-growth redwood remained (Green 1985). Most other remaining old-growth forest (more than 80 percent) was on private lands and in parks in Humboldt and Del Norte counties.

Other impacts to nesting habitat. Reduction of older forests is attributable largely to timber harvesting and land conversion practices, although forest fires and windthrow have caused considerable losses as well. Some old-growth areas subjected to forest fires and windthrow still provide habitat suitable for marbled murrelets. Mature forests that naturally regenerated from such perturbations retain scattered old-growth and mature trees, a diversity of structure and can be used for nesting. This is particularly true in coastal Oregon, where there has been extensive fire history. However, with one exception, no occupied sites have been located in young stands, clear-cuts or young/mature mixed forests in Oregon that lack remnant old-growth or mature trees (S.K. Nelson, pers. comm.).

It is not known if these mature/old-growth stands now support as many marbled murrelets as the historic old-growth areas, or whether reproductive success of birds using these stands is now lower, as indicated by low productivity at sea. Some activity has been recorded in residual old-growth stands in California, but these stands were immediately adjacent to large old-growth stands. Nesting has

been documented in residual stands in California but it is likely that this habitat is not used as extensively as old-growth forests by marbled murrelets. Mature second-growth forest stands do not appear to support breeding when they are isolated from older forest or residual (fragmented) older forest stands (Larsen 1991). While marbled murrelets occasionally may nest in unusual habitats, there is an overwhelming body of evidence that nesting in Washington, Oregon, and California does not occur to any significant degree other than in older forests and adjacent or nearby residual stands.

Poor Reproductive Success and Predation

Alcids typically choose nesting areas that are relatively free from predation. Hamer and Nelson (1995b) suggest that predation on marbled murrelet nests is relatively high compared to typical conditions experienced by other alcids and temperate forest-nesting birds (Desanto and Nelson 1995). The few noted exceptions include alcid colonies with introduced or high numbers of predators (Murray *et al.* 1983) and some species of sub-canopy and canopy-nesting neotropical migrants (Martin 1992). Predation at alcid colonies by introduced mammalian predators often leads to colony extirpation (Bailey 1993) or reduction of the size of the nesting colony to areas inaccessible to the predators. Compared to most other alcids, marbled murrelets are believed to be highly vulnerable to nest predation due to the use of the forest environment during the nesting season.

Great changes have occurred in the forested landscape of the Pacific Northwest over the past century, including loss of late-successional forests, habitat fragmentation, and increased amounts of edge (Harris 1984, Morrison 1988, Hansen *et al.* 1991). Some species of avian predators appear to be able to adjust to these habitat changes (Marzluff and Balda 1992), while other birds like the marbled murrelet, appear to be less able to adjust to the modification of the native

forest landscape. Because predation can be a major factor affecting certain nesting success in birds (Ricklefs 1969), the combination of habitat modification and adaptations of predators to these modifications may be having a tremendous impact on the overall fitness of marbled murrelets and other forest wildlife.

Habitat Fragmentation and Edge Effect. The potential relationship between forest fragmentation, edge, and adverse effects on forest nesting birds has received increased attention during the last few decades. Among all Pacific Northwest birds, the marbled murrelet is considered to be one of the most sensitive to forest fragmentation (Hansen and Urban 1992).

Edge habitats have been well-demonstrated to differ from core habitats in several ecological systems. In a comprehensive review, Paton (1994) concluded that "strong evidence exists that avian nest success declines near edges." Ratti and Reese (1988) did not find the edge relationship documented by Rudnicky and Hunter (1993), Vander Haegen and DeGraaf (in press), and others (see Paton 1994). However, Ratti and Reese (1988) did observe lower rates of predation near "feathered edges" compared to "abrupt" edges (e.g., clearcut or field edges), and suggested that the vegetative complexity of the feathered edge may better simulate natural edge conditions than do abrupt edges. These authors also concluded that their observations were consistent with Gates and Gysel's (1978) hypothesis that birds are poorly adapted to predator pressure near abrupt artificial edge zones. Edge effects have been implicated in increased forest bird nest predation rates for other species of birds (Chasko and Gates 1982, Yahner and Scott 1988). Wilcove (1985) speculated that relatively small increases in nest predation combined with other impacts of habitat fragmentation, such as loss of habitat heterogeneity and dispersal corridors between forest patches, could cause local extinctions of forest bird species.

Small patches of habitat have a greater proportion of edge than do large patches of the same shape (Schieck *et al.* 1995). However, Paton (1994) noted that many of these studies involved lands where forests and agricultural or urban areas interface, or they involved experiments with ground nests that are not readily applicable to canopy nesters such as marbled murrelets. Paton (1994) therefore stressed the need for studies specific to forests fragmented by timber harvest in the Pacific Northwest and elsewhere.

The relationship between forest fragmentation, predation, and marbled murrelet nesting success has not been specifically demonstrated through an intensive study. However, it has been hypothesized that logging activities increase the susceptibility of marbled murrelet nests to predation, because of increased edge and fragmentation created by clear-cut harvest and selective harvest of stands. Nelson and Hamer (1995b) found that successful marbled murrelets tended to nest in larger stands than did unsuccessful marbled murrelets, but these results were not statistically significant. Vander Haegen and DeGraaf (in press) found that nests in shrubs less than 75 meters (246 feet) from an edge were three times as likely to be depredated as nests greater than 75 meters (246 feet) from an edge. Likewise, Rudnicky and Hunter (1993) found that shrub nests on the forest edge were depredated almost twice as much as shrub nests located in the forest interior. They also observed that shrub nests were taken primarily by avian predators such as crows and jays, which is consistent with the predators believed to be impacting marbled murrelets. Ground nests were taken by large mammals such as raccoons and skunks. Nelson and Hamer (1995b), in the only direct measure of marbled murrelet reproductive success, found that successful marbled murrelet nests were significantly further from edge than unsuccessful nests, and cover directly around the nest was significantly greater at successful nests (Nelson and Hamer 1995b).

Studies of artificial and natural nests conducted in Pacific Northwest forests also indicate that predation of forest bird nests may be affected by habitat fragmentation, forest management, and land development (Hansen *et al.* 1991; Vega 1993; Bryant 1994; C. Chambers, pers. comm., 1994; Nelson and Hamer 1995b; Marzluff *et al.* 1996). Marzluff *et al.* (1996) are conducting the only experimental predation study that uses simulated marbled murrelet nests, and they have documented predation of artificial marbled murrelet nests by birds and arboreal mammals. Preliminary results indicate that proximity to human activity and landscape contiguity may interact to determine rate of predation. Interior forest nests in contiguous stands far from human activity appear to experience the least predation (Marzluff *et al.* 1996).

Although ongoing research should shed more light on the specific factors that affect marbled murrelet nest predation and stand size preferences, the best available information strongly suggests that marbled murrelet reproductive success may be adversely affected by forest fragmentation associated with certain land management practices. Based on this information, the maintenance and development of suitable habitat in relatively large contiguous blocks as described in this plan is expected to contribute to the recovery of the marbled murrelet. These blocks of habitat should contain the structural features and spatial heterogeneity naturally found at the landscape level, the stand level, and the individual tree level in Pacific Northwest forest ecosystems (Hansen *et al.* 1991, Hansen and Urban 1992, Ripple 1994, Bunnell 1995, Raphael *et al.* 1995, Schieck *et al.* 1995).

Adaptations to predation. Marbled murrelets have little defense against predators at their nests other than the ability of adults and nestlings to remain hidden on the nest, and the ability of adults to access and depart from the nest without being detected by visual predators. They have evolved a variety of

morphological and behavioral characteristics indicative of selection pressures from predation (Carter and Stein 1995, Nelson and Hamer 1995a, Ralph *et al.* 1995a). A few of these characteristics include cryptic coloration of plumage and eggshells, adults flying to and from nests by indirect routes and concentrating their activities during crepuscular periods when light levels are low, low motionless posture of incubating adults, chicks retention of their cryptic down plumage until just prior to fledging, young fledging just after dusk, and selection of nest sites with high vertical and horizontal cover (Nelson and Hamer 1995a). The solitary nesting habitat of the marbled murrelet and selection of new nest sites from year to year may also be adaptations to reduce predation.

Nest predation. The potential combined effects of increased nest vulnerability and increased predator populations could be having a great impact on nest success. From 1974 through 1993, of those marbled murrelet nests in Washington, Oregon, and California where success/failure was documented, approximately 64 percent of the nests failed. Of those nests, 57 percent failed due to predation (Table 4). Corvids (ravens, crows, and jays) are suspected to have caused the majority of known nest failures.

Potential nest predators include the common raven (*Corvus corax*), Steller's jay (*Cyanocitta stelleri*), American crow (*Corvus brachyrhynchos*), gray jay (*Perisoreus canadensis*), great horned owl (*Bubo virginianus*), sharp-shinned hawk, Cooper's hawk (*Accipiter cooperii*), northern goshawk, common raccoon (*Procyon lotor*), American marten (*Martes americana*), Townsend chipmunk (*Eutamias townsendii*), northern flying squirrel (*Glaucomys sabrinus*), Douglas squirrel (*Tamiasciurus douglasii*), and fisher (*Martes pennanti*) (Marzluff *et al.* 1996). Ravens, Steller's jays, and possibly great horned owls are known predators of eggs or chicks (Nelson and Hamer 1995b).

Table 4. Marbled Murrelet tree nests by state or province, site, year, and outcome (from Nelson and Hamer 1995b).

State or Province Nest site/year found	Nest Outcome Successful	Failed	Unknown	Reason for Failure[1]	Predator[2]
Washington					
Lake 22/1991[a]	2	-	-	---	---
Jimmycomelately/1991[a]	-	-	1	---	---
Heart of Hills/1991[a]	-	1	-	Chick fell out	---
Olympic/1991[a]	-	-	1	---	---
Nemah/1993[b]	1	-	-	---	---
Oregon					
Five Rivers/1990[c]	-	1	-	Chick fell out	---
Valley of Giants/1990[c]	-	1	-	Predation of chick	?Great Horned Owl
Five Rivers/1991[c]	1	-	-	---	---
Valley of Giants/1991[c]	-	1	-	Predation of egg	?Common Raven
Cape Creek/1991[c]	-	1	-	Predation of egg	?Common Raven
Siuslaw #1/1991[c]	1	-	-	---	---
Siuslaw #2/1991[c]	-	1	-	Predation of chick	?Steller's Jay
Boulder Varnike/1992[c]	-	1	-	?Predation of chick	?
Valley of Giants/1992[c]	-	1	-	Predation of egg	?Common Raven
Copper Iron/1992[c]	1	-	-	---	---
Valley of Giants/1993[d]	-	-	8	---	---
Green Mountain/1993[d]	-	-	2	---	---
Five Rivers/1993[d]	-	-	1	---	---
Five Mile Flume/1993[d]	-	-	1	---	---

State or Province Nest site/year found	Nest Outcome Successful	Failed	Unknown	Reason for Failure[1]	Predator[2]
California					
"J" Camp/1974[e]	-	1	-	Chick fell out	---
Waddell Creek/1989[f]	-	1	-	Predation of chick	Steller's Jay
Opal Creek/1989[f]	-	1	-	Predation of egg	Common Raven
Father/1991/1992[g]	2	-	-	---	---
Palco/1992[h]	-	1	2	Chick died	---
Prairie Cr. SP/1993[a]	-	1	-	Unknown	---
Jedediah Smith SP/93[a]	-	1	-	Unknown	---
British Columbia					
Walbran/1990/1991[i]	-	-	2	---	---
Carmanah/1992[j]	-	-	1	---	---
Walbran/1992[j]	-	-	2	---	---
Clayoquot/1993[k]	-	-	2	---	---
Carmanah/1993[k]	-	-	1	---	---
Caren/1993[l]	1	-	-	---	---

1/ ?Predation = predation known or suspected based on available evidence.
2/ ?Predator = suspected predator; species seen in vicinity of nest.
a/ Hamer, unpublished data
b/ Ritchie, pers. comm
c/ Nelson, unpublished data; Nelson and Peck 1995
d/ Nelson, unpublished data
e/ Binford et al. 1975
f/ Singer et al. 1991
g/ Singer et al. 1995
h/ Kerns, pers. comm.
i/ Manley and Kelson 1995
j/ Jordan and Hughes 1995
k/ Hughes, pers. comm.
l/ P. Jones, pers. comm.

Increased human activities in forests, such as picnic grounds, can attract corvids and thus increase the chances of predation (Singer *et al.* 1991, Marzluff and Balda 1992). More importantly, these activities can increase survival of corvids and result in potentially higher populations of corvids. Such activities may also result in direct habitat modification (Binford *et al.* 1975).

Possible explanations for high predation rates include (1) the high predation rates are normal, although it is unlikely that a stable population could have been maintained under the predation rates presently being observed (Appendix B, Beissinger 1995a); (2) populations of marbled murrelet predators, such as corvids and great horned owls, are increasing in the western United States, largely in response to habitat changes and food sources provided by humans (Robbins *et al.* 1986; Rosenberg and Raphael 1986; Johnson 1993; Marzluff *et al.* 1994, 1996; National Biological Service 1996); (3) creation of excessive forest edge habitat may increase the vulnerability of marbled murrelet nests to predation and ultimately lead to higher rates of predation; and (4) the relatively high predation rate observed for marbled murrelets may be affected by sampling bias. Nests near forest edges may be more easily located by observers, and more susceptible to predation because observers may attract predators. Nelson and Hamer (1995b) believed that researchers had minimal impacts on predation in most cases because the nests were monitored from a distance, were monitored relatively infrequently, and precautions were implemented to minimize predator attraction.

Low productivity. Recent at-sea survey work also indicates that current populations of marbled murrelets are experiencing extremely low productivity and estimated recruitment (Appendix B). Low productivity likely reflects poor breeding success at nests, although to a lesser extent it could also reflect the development of a larger than normal nonbreeding adult segment of the population. In other words, a portion of the marbled murrelet population currently observed

on the ocean may be nonbreeding or unsuccessfully breeding adults that do not contribute to the species' reproduction because reproduction is delayed until at least their second year. Most probably do not lay eggs until they are 3 years old or older.

Low productivity has important biological implications because it leads to low recruitment that eventually results in population declines. Thus, reduced productivity and recruitment are strong indicators of the poor condition of this species, and provide additional concern beyond observed or expected population declines for the long-term viability of populations.

Adult mortality. Adult predation has been documented to occur in marine and terrestrial environments. Marbled murrelet adults have been observed to be preyed upon by peregrine falcons (*Falco peregrinus*) and remains of marbled murrelets have been observed in peregrine eyries (Campbell *et al.* 1978). Adults have also been observed to be killed by sharp-shinned hawks (*Accipiter striatus*) (Marks and Naslund 1994) and northern goshawks (*Accipiter gentilis*) (N. Naslund, pers. comm.). Peregrine falcons and common ravens have been observed to chase marbled murrelets just above and within the forest canopy (Nelson and Hamer 1995).

In addition, adult mortality in the terrestrial environment has been documented to occur from interactions with vehicles (Sprot 1928; Balmer 1935; S.K. Nelson, pers. comm., 1996) and power lines (Young 1931; S.K. Nelson, pers. comm., 1996). Although adult mortality is difficult to document in the terrestrial environment because of the secretive nature of the species, if this mortality is high, it could have a significant affect on population viability.

Net Mortality

Mortality of seabirds in nearshore net fisheries can have serious impacts to local seabird populations, especially for alcids (Carter and Sealy 1984, Piatt *et al.* 1984, Atkins and Heneman 1987, Jones and DeGange 1988, Takekawa *et al.* 1990, DeGange *et al.* 1993). There have been estimates of hundreds to thousands of marbled murrelets killed annually in gill nets in British Columbia and Alaska (Carter and Sealy 1984; Sealy and Carter 1984; Wynne at al. 1991, 1992; Mendenhall 1992; DeGange *et al.* 1993; Carter *et al.* 1995a).

Large nearshore net fisheries have occurred in four main areas in the Pacific Northwest: (1) Puget Sound, (2) Columbia River area, (3) central California, and (4) southern California (Figure 5). The Columbia River net fisheries actually occur in the river and away from where marbled murrelets have been observed in recent years. A more in-depth summary and discussion of net fisheries and marbled murrelets is found in Carter *et al.* (1995a) and is summarized for Washington, Oregon, and California below.

Washington. Large gill-net and purse seine fisheries have existed in Puget Sound and the Columbia River area since at least the 1940s, but fishing effort in many of these fisheries has been reduced in recent years because of declines in salmon stocks. Although the actual number of known mortalities of marbled murrelets from net fisheries is relatively low and data are available from some fisheries, it is not yet possible to accurately determine the extent of mortality of net fishing on marbled murrelets in Washington with the available data (Carter *et al.* 1995a).

Puget Sound marbled murrelet populations have shown the highest juvenile:adult ratios (or levels of productivity) in the Pacific Northwest, so any impacts from net fisheries, even at modest levels, can have important effects on this marbled

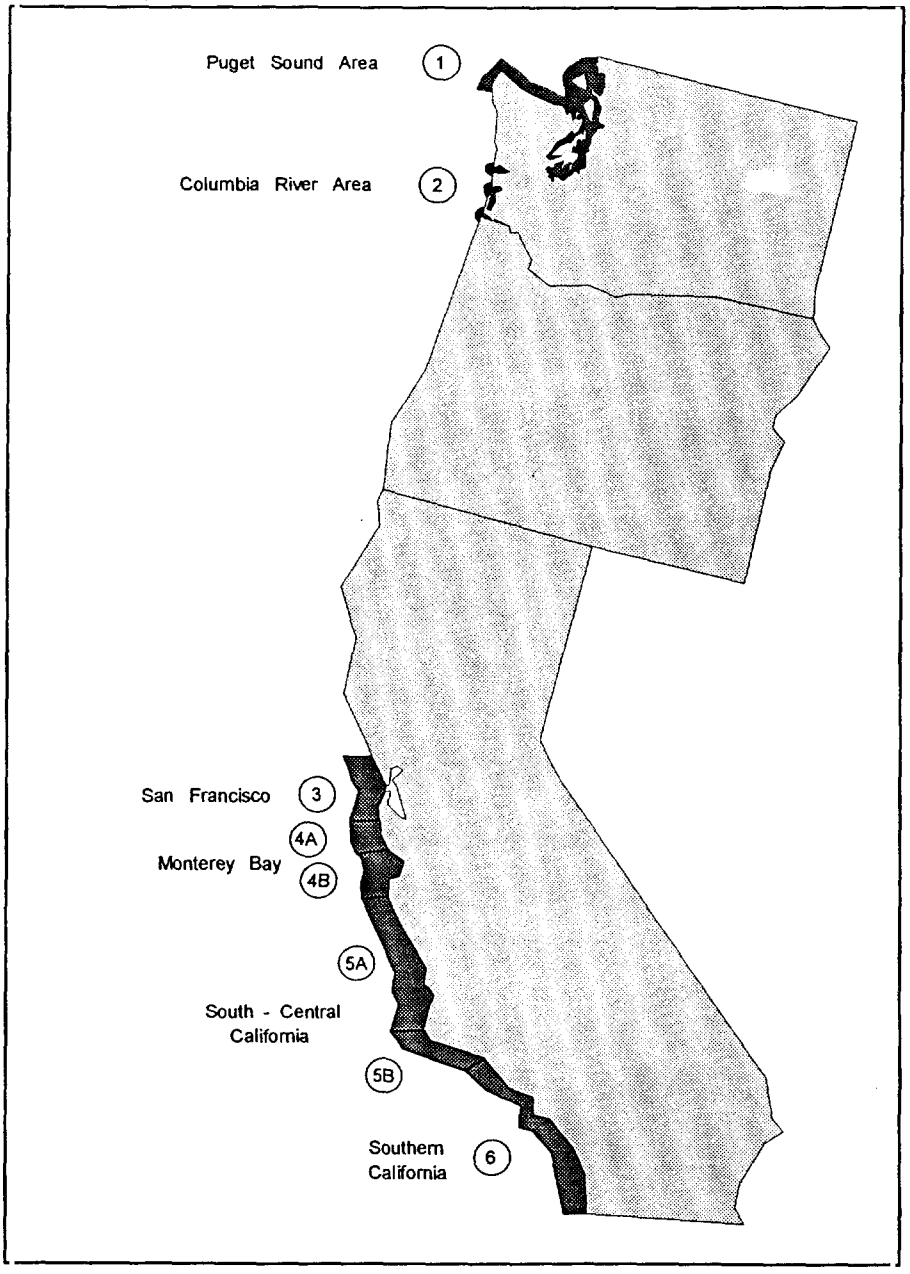

Figure 5. Locations of gill-net fisheries along the coasts of California, Oregon and Washington. Numbers refer to fishing areas referred to in Carter *et al.* (1995a). In central and southern California, numbers 3,4, 5, and 6 refer to murrelet population. The effects of mortality appear to be additive and result in greater rates of population decline than simply the number of birds removed from California Department of Fish and Game fishing districts D10, D17, D18, and D19/20, respectively. (Figure taken from Carter *et al.* 1995a).

the population (Beissinger 1995b). It is also likely that birds killed in the late-breeding and nonbreeding seasons include some wintering birds from British Columbia (Rodway *et al.* 1992, Speich *et al.* 1992).

Speich and Wahl (1989) reported that marbled murrelets, along with other seabirds, were killed as bycatch in certain fisheries in Washington, based on reports by local fishermen (S.M. Speich, pers. comm.; T.R. Wahl, pers. comm.). The best estimate of marbled murrelet entanglement was derived from the 1994 observer program in the north Puget Sound sockeye salmon fishery. Based on one observed entanglement, an estimate of 15 marbled murrelets entangled/season (range (2–59) was derived (Pierce *et al.* 1996). However, the distribution of fishing effort in 1994 in this fishery may have reduced murrelet/fisheries conflicts (J. Grettenberger, pers. comm.). An estimate of 12 marbled murrelets entangled in 1993 was also made for the Makah Tribe set gill-net fishery, based on an observer program (U.S. Fish and Wildlife Service 1994b). No marbled murrelet entanglements were reported from the 1994 chum fisheries observer program (Erstad *et al.* 1996). It is likely that net mortality has had and still may have substantial impacts on Washington marbled murrelet populations, especially in Puget Sound.

In 1995, specific measures, such as closure of areas of known marbled murrelet concentrations, were implemented to reduce marbled murrelet mortality. Surveys to evaluate murrelet/fisheries overlap (Courtney *et al.* 1996), and testing of modified gill nets and pingers (Melvin and Conquest 1996) that may help reduce mortality are also being pursued. Several gillnet/seabird regulations were recently adopted by the Fish and Wildlife Commission, including removing sections of floats along corklines for purse seines, using modified gear in 1998 in Areas 7/7A, closing gillnet fishing for most of the night and during morning change of light, and the go-ahead to study seabird hooking and mortality in the sport fishery (J. Grettenberger, pers. comm. 1997).

Oregon. Gill-net fishing has been prohibited in estuaries, bays and along the outer coast of Oregon since 1942 (Nelson *et al.* 1992). No net-caused mortalities of marbled murrelets are known in Oregon.

California. Nearshore gill and trammel net fisheries have existed in central and southern California since the early 1900's but increased dramatically in size during the 1970's and 1980's (Takekawa *et al.* 1990, Carter *et al.* 1995a). Gill-net fishing in northern California, north of Point Reyes, Marin County, is prohibited.

In central California, between 1979 and 1987, thousands of seabirds (especially common murres) were killed in gill-net fisheries and included marbled murrelets. Carter and Erickson (1988, 1992; also see Sealy and Carter 1984) summarized the known evidence of mortality of marbled murrelets from these fisheries that was estimated to have killed hundreds of marbled murrelets. This mortality has probably had a serious impact in the past on the very small central California population. Although a few birds may still be killed there despite current regulations, there has been no direct evidence of mortality since 1986. No marbled murrelets have been reported killed in southern California net fisheries.

Oil Spill and Other Marine Pollution

Mortality and reduced breeding success of seabirds due to various forms of marine pollution are well-known. Large oil spills have killed millions of seabirds around the world in this century, as was recently well-publicized during the 1989 *Exxon Valdez* spill in Alaska (Piatt and Lensink 1989, Piatt *et al.* 1990, Ford *et al.* 1996). Most marbled murrelets are observed at-sea in nearshore waters within 2.0 kilometers (1.2 miles) of the coast, which are important foraging grounds. Because of their extensive use of nearshore waters, marbled murrelets are susceptible to the impacts of oil spills and have been given one of the highest oil spill vulnerability index values among seabirds (King and Sanger 1979).

Oil spill mortality. Oil pollution has been highlighted as a significant threat or conservation problem for marbled murrelets in southern Alaska, southern British Columbia, Washington and California (King and Sanger 1979; Wahl *et al.* 1981, Sealy and Carter 1984, Carter and Erickson 1988, 1992, Marshall 1988, Carter and Kuletz 1995). Large oil spills result periodically from oil tanker mishaps (groundings, collisions, explosions, accidental spillages), similar mishaps by other large ocean-going vessels, offshore oil wells (well blow-outs, accidental spillages), unloading and loading cargo from onshore and offshore facilities, and onshore facility spills that enter the ocean. Small oil spills occur frequently and are chronic in many areas due to tank cleaning at sea, bilge pumping, seeps, etc. All types of boats and marine transportation vessels may be involved.

Between the late 1800s and 1968, medium and large oil spills occurred frequently, but were rarely documented with respect to seabird mortality in California, Oregon, and Washington. Few reports of marbled murrelet or other seabird mortality for this period are available (Carter and Kuletz 1995; Manuwal *et al.*, in prep.). Since 1968, several large and medium oil spills have occurred (Figures 6a & 6b) for which seabird mortality was often estimated. Actual numbers of oiled marbled murrelets that have been recovered are few.

The thousands of marbled murrelets killed during the *Exxon Valdez* spill (Piatt and Lensink 1989, Piatt *et al.* 1990, Ford *et al.* 1996) have increased concerns about the impacts of oil pollution on the species since 1989. The 1991 *Tenyo Maru* spill off of the Olympic Peninsula, Washington, represents the largest recovery of oiled marbled murrelets after a spill, except for the *Exxon Valdez* spill. Approximately 45 marbled murrelet carcasses were recovered on the beaches, and it was estimated that 200–400 birds had probably been killed (Carter and Kuletz 1995). This mortality represents a significant proportion of the local breeding population. A minimum of 11 marbled murrelets were estimated to have been killed by the *Apex Houston* oil spill in central California. This mortality was

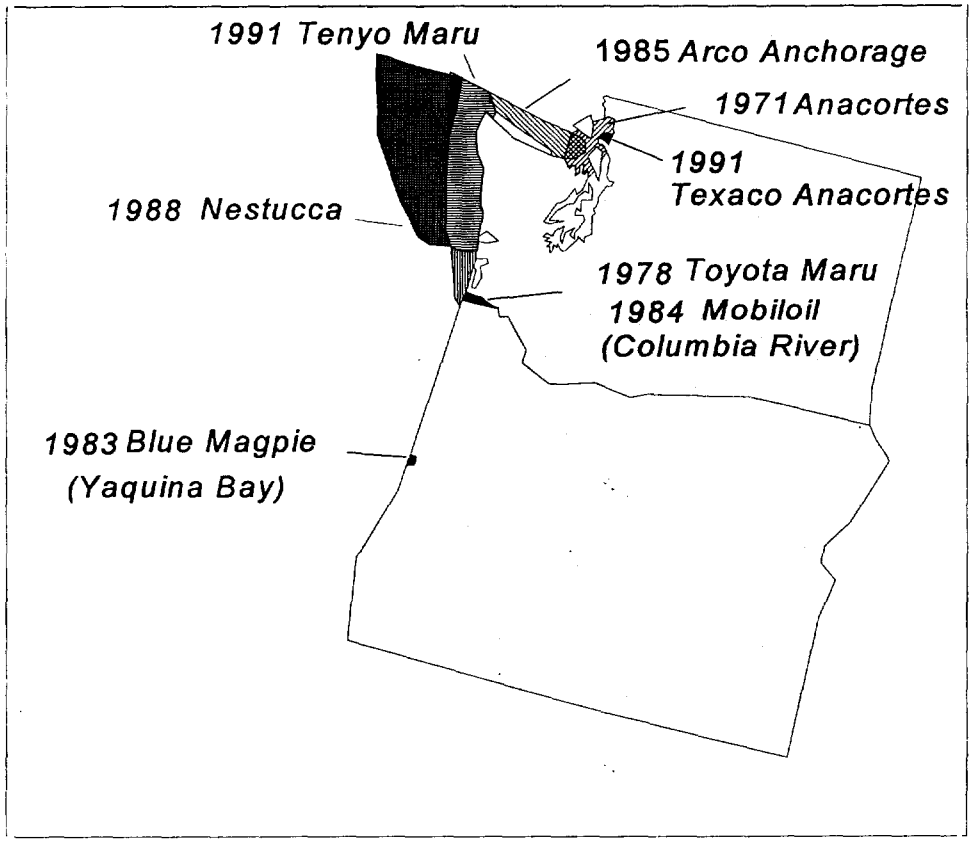

Figure 6a. West coast oil spills (1969–1992) in Oregon and Washington. The approximate locations of large and medium oil spills where seabird mortality was assessed are indicated (Carter and Kuletz 1995).

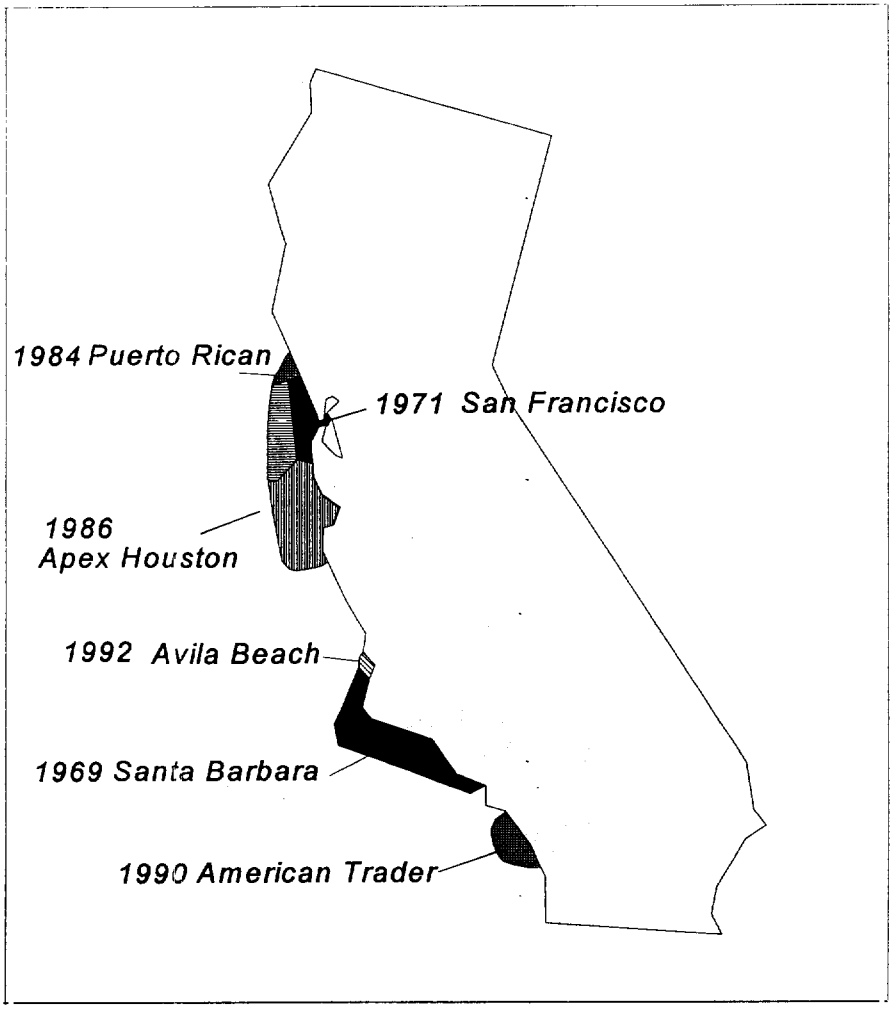

Figure 6b. West coast oil spills (1969–1992) in California. The approximate locations of large and medium oil spills where seabird mortality was assessed are indicated (from Carter and Kuletz 1995).

considered to be significant to the small breeding population in this area (Carter and Kuletz 1995).

In addition to large and medium oil spills, chronic oil pollution (e.g., small oil spills, bilge dumping, seeps, etc.) has occurred in coastal areas throughout this century. There are sporadic reports of oiled marbled murrelets separate from known large and medium spills, especially in California (Carter and Erickson 1992).

Other marine pollution. The other main sources of marine pollution in California, Oregon and Washington that may affect seabirds are chlorinated hydrocarbon contaminants and chemical dumping, including effluent from onshore sources and direct dumping of chemicals at sea (Fry 1995). For example, DDE pollution in the Southern California Bight was responsible for poor reproductive success and population decline in brown pelicans and double-crested cormorants for decades (Gress *et al.* 1973, Anderson *et al.* 1975). High levels of mercury have been recorded in fish and fish-eating birds in British Columbia (Fimreite *et al.* 1971); however, there have been no recorded mercury problems with marbled murrelets. Eight marbled murrelets recovered from gill-net fisheries in Puget Sound were analyzed for contaminants, and all looked to be within normal ranges for seabirds from clean environments (J. Grettenberger, pers comm., 1997). The effects of other marine pollution on marbled murrelets have not been fully investigated.

Threats to Pacific Northwest marbled murrelet populations. The threat of various types of marine pollution to marbled murrelet populations varies among different areas of California, Oregon and Washington, based on the locations of coastal oil facilities, tanker and other shipping routes, industrial development and other urban or coastal developments. Marbled murrelet populations near coastal locations with onshore oil facilities, offshore oil facilities, tanker ports, and large

industrial developments are most threatened with marine pollution. Medium or small oil spills from tankers and other traffic that pass by coastal areas far out to sea are likely to have less impact on marbled murrelets.

Four important marbled murrelet populations face the greatest threats (Carter and Kuletz 1995) (Figure 7):

(1) *Puget Sound* contains one of the more concentrated marbled murrelet populations in the three-state region. This population is threatened with a high probability of large oil spills and significant chronic oil and other marine pollution. Puget Sound contains onshore oil facilities, tanker ports receiving large numbers of tanker and barge trips annually, large industrial developments, tanker and other shipping routes, bypass traffic into southern British Columbia, and other coastal and urban developments. It has experienced several oil spills and other pollution events that have impacted seabirds.

(2) *Central California* contains a small disjunct population of marbled murrelets at the southern edge of their breeding range. This population is threatened with a high probability of large oil spills, and significant chronic oil and other marine pollution. San Francisco Bay occurs just north of this area and is a major location for onshore oil facilities, industrial development, and other coastal and urban developments. In particular, San Francisco Bay receives one of the largest number of tanker trips per year of any oil port along the west coast (Figure 7). Much of this tanker and barge traffic passes close by coasts where marbled murrelets are concentrated at sea, especially during the breeding season. In addition, small numbers of marbled murrelets killed in oil spills in southern California may belong to the central California breeding population. In the future, offshore oil development also may occur off central

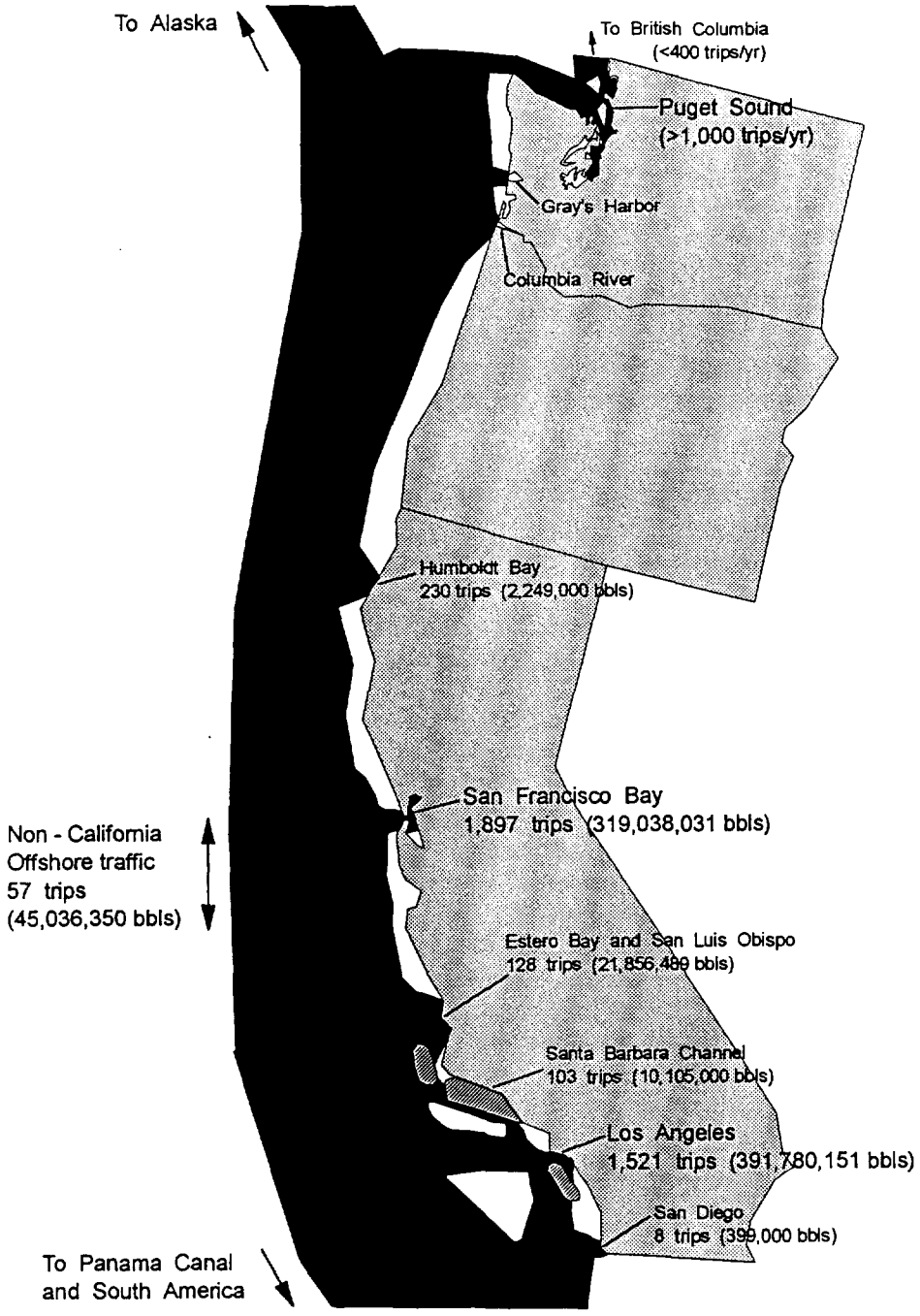

Figure 7. Tanker and barge movements to major ports along the west coast for crude oil and petroleum. Major tanker lanes are indicated in black. Areas with offshore oil facilities in southern California are indicated by cross-hatching. California data represent movements and volume transported in 1992 (DNA Associates 1993). Data for Washington and British Columbia represent average traffic (Dickens Associates Ltd. 1990).

California. Oil deposits exist on the outer continental shelf in this area but a moratorium on leasing is currently in effect.

(3) *Columbia River and Grays Harbor Area* in southwestern Washington contains a small population of marbled murrelets. Less tanker and barge traffic passes into these locations than into Puget Sound or San Francisco Bay, but this area receives much offshore tanker traffic related to Puget Sound and southern British Columbia (Figure 7). At the south end of this area, significant shipping traffic also penetrates inland through the Columbia River, carrying moderate amounts of oil and other pollutants.

(4) *Northern California* contains one of the largest marbled murrelet populations in the three-state region. Humboldt Bay occurs within this area and receives a moderate number of tanker trips per year (Figure 7), and has some industrial development within the Bay. Future spills of any size could have a great impact on this important population. In the future, offshore oil development may occur off northern California. Oil deposits exist on the outer continental shelf in this area but a moratorium on leasing is currently in effect.

In the last few decades, oil pollution has had considerable impacts on marbled murrelet populations in Prince William Sound (Alaska), central California, and western Washington. However, these effects have probably been felt only sporadically by local populations. When oiling mortality is considered as a cumulative effect, with other human activities that affect small declining populations of marbled murrelets, the relative effects of oil pollution become greater and recovery becomes more difficult, or perhaps impossible for certain areas (Carter and Kuletz 1995).

It is important to recognize that the impacts of oil and other marine pollution are likely to increase in the future. To date, marbled murrelet populations in the Pacific Northwest have been spared very large oil spills, such as the *Exxon Valdez* spill in Alaska. However, west coast populations currently exist under the constant threat of such a disaster that could eliminate or greatly reduce an entire population in short order. Even without a very large spill, other large, medium and small spills will occur and impact populations although their expected frequency of occurrence is difficult to predict.

Possible Changes in Prey Abundance and Distribution

Nesting habitat, previously discussed, and prey resources are the two main factors that can regulate seabird populations (Cairns 1992). Three main concerns about marbled murrelet prey resources include (1) well-publicized declines have occurred recently in the Pacific Northwest in some harvested fish populations due to over-fishing and habitat changes (e.g., salmon [*Oncorhynchus* sp.], Pacific Sardines), and certain marbled murrelet prey species are fished commercially in some areas; (2) severe El Niño events were well-documented as affecting breeding success and survival of several seabird species during the 1982–1984 and 1992–1993 El Niño events, which may have affected marbled murrelet survival and reproduction; and (3) marine biologists have recently better identified long-term (multi-decadal) cycles of warm and cold waters in the North Pacific that may have affected marbled murrelet prey populations.

In light of these changes in the marine environment in general, some biologists have hypothesized that sufficient prey may not be available to maintain marbled murrelets and other seabird populations at present or historical levels and reduced prey might cause or contribute to long-term reduced reproductive success through impacts on body condition and energetics. Possible changes in prey resources

were considered by examining available information on (1) marbled murrelet diet, (2) abundance and distribution of nearshore prey resources, and (3) effects of long-term oceanic cycles and El Niño events on marbled murrelet prey resources and habitats.

Marbled murrelet diet. Marbled murrelets feed on a variety of small fish and invertebrates. In the Pacific Northwest, the main fish prey identified in recent years are Pacific sand lance, Pacific herring, northern anchovy, and smelts (Osmeridae). Details of the marbled murrelet diet are discussed above under "Life History/Ecology, Marbled Murrelet Diet and Food Resources."

Prey abundance and distribution. Little is known about the status of known or potential prey resources on the west coast because assessments of fish populations over large areas require extensive studies over many years. Long-term and current studies by the National Marine Fisheries Service, California Department of Fish and Game, Oregon Department of Fish and Wildlife, and Washington Department of Fish and Wildlife are focused primarily on harvested species, including Pacific sand lance, Pacific herring, Pacific sardines, and smelts.

In particular, there apparently is no substantial summarized information on changes in abundance and distribution of Pacific sand lance and smelts on the west coast. Some limited information on the recent status of certain harvested or previously-harvested prey species is available and summarized below:

Pacific sardines: Total biomass has increased dramatically between 1983-1995 off the west coast. Sardines were almost absent from this area in the 1950s to 1970s although they were harvested in large numbers as far north as southern British Columbia in the early 1990s. Little or no harvest has occurred in most areas since the 1950s. However, low level commercial harvest has occurred in southern

California during recent growth in sardine populations. Spawning first occurred north of Point Conception in 1991 and was documented as far north as Half Moon Bay in central California, in 1994 (Deriso *et al.*, in press). Massive spawning was also documented even farther north off the mouth of the Columbia River, Oregon, in 1994 (Bentley *et al.* 1996).

Pacific herring: Spawning biomass and spawning stock biomass in central California (San Francisco and Tomales Bays) have oscillated or increased, but there was no consistent downward trend from 1972-1994 (California Department of Fish and Game 1995). In 1995-1996, spawn biomass reached its highest level since 1981-1982 (E.E. Burkett, pers. comm., 1996). In Puget Sound, the overall spawning biomass of Pacific Herring has remained fairly stable over the last two decades (Washington Department of Fish and Wildlife 1995). However, herring spawning in the Columbia River mouth and parts of Puget Sound probably have declined from historical levels due to habitat changes in these estuaries (Burkett 1995, Washington Department of Fish and Wildlife 1995). In certain industrialized estuaries in Puget Sound (e.g., near Seattle and Tacoma), eelgrass beds have been lost and certain herring stocks in local areas probably are extinct (D. Pantella, pers. comm., 1996).

Northern anchovy: Total biomass and spawning biomass in central California experienced a peak period from 1973 to 1976 (Jacobsen *et al.* 1995). However, total biomass and spawning biomass before this peak (1963–1972) and afterwards (1977–1995) have oscillated but, in general, have remained at lower levels. Total biomass for a few years in the early 1990s was somewhat lower than in the 1980s; however, it began increasing in 1994–1995. In Oregon, the National Marine Fisheries Service (P.J. Bentley, pers. comm., 1996) recently repeated surveys that had been conducted in the 1970s (Richardson 1981) on the shelf south of the mouth of the Columbia River. Northern anchovy were found in lower numbers

and the remaining core population had re-located in a smaller area much closer to shore within 0.6–1.2 kilometers (1–2 miles) of the mouths of Willapa Bay and Gray's Harbor in southwestern Washington. Previous work in the 1970s in Oregon had been conducted during the same peak period noted in California. Peak spawning biomass occurred in 1975–1976 (Richardson 1981). Thus, it is likely that current prey levels off Oregon are similar to pre-peak levels, as found in California. In Puget Sound, northern anchovy are frequently found in fisheries trawling, but no estimates of their biomass or information on changes in abundance are available (D. Pantella, pers. comm.). Little or no harvest of northern anchovy has occurred on the west coast since the mid-1980s.

Pacific sand lance and smelts: Recent efforts by the Washington Department of Fish and Wildlife have been focused on identifying spawning beaches throughout Puget Sound. In 1989, fisheries biologists first discovered that Pacific sand lance spawn on upper beach areas also used by Surf smelt (*Hypomesus pretiosus*) (D. Pantella, pers. comm., 1996). Since then, spawning areas have been found throughout Puget Sound and Washington inner waters although many beaches have not yet been surveyed. During exploratory surveys, Pacific sand lance and Surf smelt have been found to be very abundant although variation may occur on a short-term basis. Overall spawning biomass estimates are not yet available and adult biomass cannot be determined accurately using standard trawl sampling techniques. Surf smelt appear to prefer closed bays for spawning areas as do Pacific herring, while Pacific sand lance will use more open coastlines. These species are now considered to be much more abundant than was known previously, with biomass probably reaching the same order of magnitude as Pacific herring (Washington Department of Fish and Wildlife 1995). Other smelts may also form prey for marbled murrelets in Puget Sound. For example, anadromous stocks of longfin smelt (*Spirinchus thaleichthys*) and eulachon (candlefish) (*Thaleichthys pacificus*) occur in the Nooksack River in northern

Washington and in the Fraser River in southern British Columbia, respectively (Hart 1973, Washington Department of Fish and Wildlife 1995). However, these prey species are not as widespread in Washington inner estuarine waters as the Surf smelt and Pacific sand lance. To date, little harvest of these species have occurred in Washington. There is apparently no information on the status of these species in California and Oregon.

Regardless of what could appear as trends in certain areas, spawning biomass for harvested species in sampled areas at sea often is not a good indicator of available prey for seabirds over wide areas at sea or in nearshore waters used by marbled murrelets. Many factors can dramatically affect survival of eggs and larvae and the distribution of juvenile, subadult and adult fish before they become potential prey for seabirds (McGurk and Warburton 1992, Butler *et al.* 1993). In particular, none of the available studies have directly examined the status of prey resources in nearshore areas where marbled murrelets feed. Most spawning areas are disjunct from marbled murrelet feeding areas.

With the exception of the Pacific sardine and the northern anchovy in offshore and shelf waters, there are no clear indications that marbled murrelet prey resources have changed (i.e. increased or decreased) over broad areas of nearshore waters in central California, and inner Washington waters and current levels are not known to be different from historical ranges (A.D. MacCall, pers. comm.; D. Pantella, pers. comm.). Local changes may have occurred, especially due to man's activities, that may have reduced overall abundance of certain prey species in localized areas (e.g., Pacific herring in parts of Puget Sound). However, such reductions have not been documented to affect overall prey abundance and availability for marbled murrelets in nearshore feeding areas where the birds are opportunistic foragers, foraging over large areas and switching between prey species as necessary.

The conclusion reached was that, at present, insufficient information exists to substantiate the claim that overall prey abundance and distribution has changed to a degree that could hinder the maintenance of current marbled murrelet populations or prevent their recovery to higher levels. In fact, marbled murrelet population size is so far below projected historical levels (based on estimated historic and current nesting habitat) (e.g., Larsen 1991) that prey resources would have to be much lower than their former levels for a change in prey density to be evident or operate to reduce prey availability to marbled murrelets. No evidence is available for such drastic changes in overall prey abundance and availability in nearshore waters where marbled murrelets feed in the Pacific Northwest. However, certain prey species may have changed in offshore and shelf waters or in certain local nearshore areas, which may have affected marbled murrelets to some, probably small, unknown degree.

Overfishing of prey resources. Without evidence of declines in prey resources in nearshore feeding areas, without extensive fisheries on prey resources, and without a known narrow focus by marbled murrelets on key prey species, it is difficult to imagine that overfishing may currently affect marbled murrelet prey resources in the Pacific Northwest. However, overfishing has contributed to changes in seabird reproduction and survival in other parts of the world (e.g., Peru, North Sea, eastern Canada), especially when fisheries focus on removing key prey species or providing waste or "offal" for scavenging species (see several summary papers in Nettleship *et al.* 1984, Furness *et al.* 1988).

Possible prey changes for certain seabirds may have reduced populations at the South Farallon Islands as a result of past overfishing of Pacific sardines in California (Ainley and Lewis 1974). However, there is little information on the extent that seabirds formerly fed on Pacific sardines and many other factors probably contributed to or caused observed population sizes.

Recently, Ainley *et al.* (1994, 1996) implicated overfishing impacts on winter prey resources to explain poor recovery of certain species of seabirds at the South Farallon Islands and in Washington that had declined in numbers due to gill-net and oil-spill mortality and the effects of El Niño (Ainley and Boekelheide 1990, Takekawa *et al.* 1990, Wilson 1991). On the other hand, winter diet of most seabirds is poorly known, catch statistics do not reflect prey abundance or availability, other factors can explain poor recovery, and recent increases in populations have indicated that limited recovery is now occurring for certain species (e.g., common murres) at the South Farallon Islands in central California (Manuwal *et al.*, in prep.; Sydeman *et al.*, in prep.).

One example of the well-documented potential effects on seabirds from overfishing is known on the west coast. Nesting brown pelicans (*Pelecanus occidentalis*) fed almost exclusively on northern anchovy in a localized area near nesting colonies in the inner Southern California Bight in the 1960s and 1970s (Anderson and Gress 1984, MacCall 1984). Both fishery catch and pelican breeding success were tied to the abundance of northern anchovies prior to the late 1970s. Fish abundance subsequently dropped to lower levels and the fishery became much reduced. Much concern was expressed about the possible effects of the fishery on the depressed population of brown pelicans, which were in the early stages of recovery from near extinction due to DDT pollution. However, since the late 1970s, the pelican population has increased dramatically (Carter *et al.* 1995b, Gress 1995).

Fish scale deposition studies summarized in Burkett (1995) provide evidence that abundance of coastal pelagic fish species varied considerably before the inception of modern fisheries. Commercial fishing has, however, probably exacerbated the natural variability in recent decades because reduced stock size and loss of old fish, which is an inescapable result of fishing, increase the speed and magnitude of

population decreases during periods of poor reproduction (Anonymous 1993). Natural variability linked with impacts from fishing activity make it difficult for managers to predict fish abundance and yields. Many factors, including socioeconomic ones, must be used when modeling fish populations, ecosystems, and fishery impacts (Wilson *et al.* 1991).

Ocean cycles. Decline of certain alcids in parts of the west coast over the last few decades [e.g., common murre, Cassin's auklet (*Ptychoramphus aleuticus*), and tufted puffin (*Fratercula cirrhata*)] can be accounted for through mortality at sea (from fishing nets or oil pollution) or impacts at nesting areas, rather than prey changes (Carter *et al.* 1995b). However, breeding success of several seabird species at the South Farallon Islands (located in shelf waters) has been shown to be tied to the availability of key prey species, especially short-belly rockfish (*Sebastes jordani*) and northern anchovy (Ainley and Boekelheide 1990; Ainley *et al.* 1993). Long-term declines in these prey species due to oceanic cycles could result in lower breeding success at this colony (Ainley *et al.* 1994; W.J. Sydeman, pers. comm.). However, several species, including common murres, have been increasing slightly in recent years and birds may now be selecting other prey resources (Manuwal *et al.*, in prep.; Sydeman *et al.*, in prep.; Ainley *et al.* 1996).

Long-term cycles of warm and cold water years over several decades are known in offshore and shelf waters in the North Pacific Ocean (Beamish 1995). These cycles may have contributed to alternating periods of abundance and scarcity for northern anchovy and Pacific sardines, a recurring pattern known to occur over several centuries (Baumgartner *et al.* 1992, Holmgren-Urba and Baumgartner 1993, Butler *et al.* 1993).

Such cycles have not been shown to affect marbled murrelet prey in nearshore waters, where many other factors contribute to sustaining prey populations over

time. In particular, nearshore features appear to be more important to many marbled murrelet prey species than broad-scale water temperature changes in offshore and shelf waters, especially in the inner waters of Washington and British Columbia (Carter 1984; Burkett 1995; D. Pantella, pers. comm.). However, a decline in the abundance of northern anchovy in offshore and shelf waters may lead to a decline in northern anchovy in nearshore waters. Whether or not marbled murrelets feed on northern anchovy in a specific feeding area will be dependent on many factors and it is likely that if anchovy are less abundant then marbled murrelets will use other prey species.

While water temperature changes may affect plankton and lower trophic levels of parts of the murrelet's marine food web, it also is difficult to determine the timing and degree to which upper trophic levels may be affected with the poor current state of knowledge. In any case, marbled murrelet and other seabird populations on the west coast have managed to survive through many past changes in such multi-decade cycles by reproducing adequately to maintain their populations over large geographic areas. In fact, populations of certain seabird species that feed on a variety of similar prey species are increasing on the west coast over the past several decades despite a major shift in ocean cycles in the late 1970s, especially double-crested cormorants (*Phalacrocorax auritus*) and rhinoceros auklets (*Cerorhinca monocerata*) (Carter *et al.* 1992, 1995b,c; McChesney *et al.* 1995). In summary, it has been determined there is insufficient information to conclude that significant declines or increases of marbled murrelet prey resources in nearshore waters occur in response to long-term ocean cycles.

Regardless of insufficient data to demonstrate possible prey changes for marbled murrelets, distinct long-term changes in prey resources may have occurred in localized areas, which may have led to changes in the local at-sea distribution of marbled murrelets over time. While marbled murrelets are restricted to foraging primarily in nearshore waters, they are known to shift nearshore feeding areas

between years off the Oregon coast (Strong 1995) although consistent at-sea aggregations are known between years in parts of California and British Columbia (Sealy and Carter 1984, Carter and Sealy 1990, Burger 1995, Kelson *et al.* 1995, Ralph and Miller 1995, Strong and Becker 1997). In any case, marbled murrelets appear capable of small-scale changes in foraging areas, perhaps within coastal regions as long as about 20–80 kilometers (12–50 miles), based on daily foraging distances from nest sites and between at-sea feeding areas known from radio telemetry studies (Carter and Sealy 1990, Jodice and Collopy 1995, Kuletz *et al.* 1995b).

Severe El Niño events. Annual variation in fish and marine invertebrate populations occur, especially during severe El Niño events. El Niño events on the west coast typically result in high water temperatures and other changes to marine waters, related to oceanographic and meteorological changes elsewhere in the Pacific Ocean. El Niño conditions can occur every few years, but severe El Niños occur infrequently. They have occurred most recently in 1957-1959, 1982-1984, and 1992-1993 (Ainley and Boekelheide 1990, Hayward 1993, Hayward *et al.* 1994). It is not clear whether severe El Niño events affect marbled murrelet reproductive success or survival as they may do with some other seabirds (Graybill and Hodder 1985; Ainley *et al.* 1988; Ainley and Boekelheide 1990; Wilson 1991; Ainley *et al.* 1994, 1995).

Severe El Niños and other warm water events can reduce primary productivity and populations in higher trophic levels (invertebrates and fish) in offshore and shelf waters that normally feature upwelling (Pearcy *et al.* 1985, Schoener and Fluharty 1985, Gomez-Gutierrez *et al.* 1995), thereby influencing abundance and availability of certain potential prey (fish or invertebrates). Changes in prey in these areas also could affect the abundance and availability of prey in nearshore waters for marbled murrelets. However, only northern anchovy, Pacific sardines

and rockfish are known to be affected by severe El Niño events (e.g., Fiedler 1984, Vantresca *et al.* 1995; see Burkett 1995).

Certainly, offshore and shelf waters opposite most of the nearshore range of the marbled murrelet in the Pacific Northwest (except Juan de Fuca Strait and Puget Sound) are affected by upwelling processes within the California Current. However, other factors also affect prey resources in nearshore waters (see above) and probably have greater influence on prey recruitment, abundance, and availability.

Prey resources in inland waters (i.e., Juan de Fuca Strait and Puget Sound) also appear to be either less affected or not affected by El Niño events, compared to prey resources in offshore waters where certain seabirds experienced problems from severe El Niño events. For instance, seabird populations in inner water areas, especially rhinoceros auklets at Protection Island that feed extensively on Pacific sand lance, were not known to be affected to a large degree during the 1992-1993 or 1983-1984 El Niño events (Wilson and Manuwal 1986; U.W. Wilson, pers. comm.).

It is unclear at this time how much influence the severe 1992-1993 El Niño event may have had on the generally low production of marbled murrelets observed throughout the Pacific Northwest since 1992. While reduced breeding success occurred for 1–2 years in relation to this El Niño event for common murres and some other alcids, breeding success and breeding population size returned to previous levels afterwards, at least in 1994–1995 (Manuwal *et al.*, in prep.; Sydeman *et al.*, in prep.). Furthermore, marbled murrelets exhibit diet breadth and, as opportunistic feeders, should minimize the effects of temporary shortages of fish prey by feeding on a wider variety of prey, perhaps over wider areas (Burkett 1995).

At least some marbled murrelets were able to successfully reproduce during the severe 1992-1993 El Niño event. Several juveniles were discovered at inland localities in central and northern California (E.E. Burkett, pers. comm.), although juvenile:adult ratios at sea were slightly depressed in Oregon and northern California (Appendix B). Similarly, inland activity levels may have been slightly lower in some areas in Oregon since 1992–1993 (S.K. Nelson, pers. comm.). In 1995, marbled murrelet nesting and inland activity levels in central California appeared to be depressed during a less severe El Niño event and then increased in 1996 (E.E. Burkett, pers. comm.).

Other alcids (e.g., common murres) either did not breed, abandoned their nests during the egg stage or had poor breeding success in 1992 or 1993 in central and northern California and Oregon (Carter *et al.* 1996; Manuwal *et al.*, in prep.; Sydeman *et al.*, in prep.; W.J. Sydeman, pers. comm.). However, many of these species forage over shelf waters. In any case, years of higher or lower nesting success are typical for many seabirds in the California Current and there is no evidence that it has led to endangerment in other species (Ainley and Boekelheide 1990).

The marbled murrelet's relatively long life span and low annual reproductive effort allow them to survive and reproduce successfully despite periodic adverse prey conditions during its lifetime. This life history strategy serves to maintain populations despite major environmental fluctuations such as during occasional severe El Niño events. Severe El Niños may have short-term impacts on marbled murrelets, although such impacts have not been well-documented. It is unlikely that severe El Niño events have had long-term impacts on marbled murrelet populations that might interfere with the maintenance of current populations or prevent recovery to higher levels. However, cumulative impacts (including nesting habitat loss, oil spills, net mortalities, etc.), in addition to repeated El Niño

events, over a short time period, could contribute to serious population declines or extirpations.

H. Current Regulatory Mechanisms and Management of Marbled Murrelet Habitat

State Regulations and Habitat Management

California. In March 1992, the marbled murrelet was listed as an endangered species in the State of California pursuant to the California Endangered Species Act (CESA). Section 2052 of the California Endangered Species Act states, "The Legislature further finds and declares that it is the policy of the State to conserve, protect, restore, and enhance any endangered species or any threatened species and its habitat and that it is the intent of the Legislature, consistent with conserving the species, to acquire lands for habitat for these species". The definition of "conserve" is as follows (Section 2061), "Conserve, conserving, and conservation mean to use, and the use of, all methods and procedures that are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary". Fundamentally the provisions of the California Endangered Species Act include those of the Federal recovery planning process under the Endangered Species Act (Burkett, *in litt.*, 1994).

Provisions within the California Endangered Species Act require consultation between the State lead agency, project applicants and the State's trustee agency for wildlife, the California Department of Fish and Game. Consultation with non-State lead agency project applicants also occurs under the California Environmental Quality Act (CEQA). This act was enacted in 1973 as a system of checks and balances for land-use development and management decisions in California.

The marbled murrelet is classified as a Sensitive Species by the State Board of Forestry. The California Department of Forestry and Fire Protection is the lead agency responsible for regulating timber harvest on private and State forest lands. Forest Practice rules, enacted in 1991, require surveys for marbled murrelets and consultation with California Department of Fish and Game. California Department of Fish and Game has recommended that annual training is desirable for marbled murrelet surveyors who must successfully pass an evaluation procedure prior to conducting forest surveys. California Department of Fish and Game personnel review Timber Harvest Plans (THPs) prepared by timber companies for private and State forest lands, conduct pre-harvest inspections to evaluate whether or not proposed harvest sites contain marbled murrelet habitat, and review timber company assessments of marbled murrelet use of each Timber Harvest Plan. In addition, California Department of Fish and Game personnel review survey station layout and survey results prior to submission of Timber Harvest Plans. Mitigation measures (seasonal restrictions, buffers, monitoring, conservation easements) incorporated into timber Harvest Plans may avoid the take of marbled murrelets and offset potential indirect impacts.

If California Department of Fish and Game concludes in a biological opinion that take or jeopardy to the marbled murrelet may occur as a result of a project, the project can not be approved unless accompanied by authorization under Section 2080.1 or 2081 of the California Endangered Species Act. Agreements between California Department of Fish and Game and project applicants pursuant to Section 2081 mirror similar agreements during the Habitat Conservation Planning process under the Federal Endangered Species Act. At this time, there are no management agreements for the marbled murrelet under section 2081, and there are no approved Habitat Conservation Plans for marbled murrelets in California.

Currently, some State park units are drafting General Plans that will consider marbled murrelet conservation needs. Some units are preparing management plans for routine park activities that may affect marbled murrelets. These plans will be reviewed by California Department of Fish and Game under the California Environmental Quality Act review process. California Department of Fish and Game personnel also review and comment on Federal environmental documents for projects that may affect marbled murrelets.

There are also provisions in the California Endangered Species Act (Sections 2080.1 and 2095) for joint consultation between project applicants, the California Department of Fish and Game and the U.S. Fish and Wildlife Service on projects that may affect jointly-listed species such as the marbled murrelet. Joint consultation should become standard operating procedure under a recent Memorandum of Understanding between the California Department of Fish and Game and the U.S. Fish and Wildlife Service.

The California Endangered Species Act does not contain a mandatory equivalent of critical habitat as per the Federal Endangered Species Act, but it does contain an "essential habitat" section (2074.6). In practice, essential habitat has been viewed the same as critical habitat, although at times the State may be more restrictive. However, in order to provide predictability and consistency to land managers, it is important that the State and the U.S. Fish and Wildlife Service work closely to identify essential habitat and promote marbled murrelet recovery in California.

Oregon. On May 18, 1994, the Fish and Wildlife Commission was petitioned to list the species as endangered in Oregon under the Oregon Endangered Species Act (M. Nugent, pers. comm.). The Oregon Fish and Wildlife Commission reviewed the petition in July 1994, and found the information substantive. On

May 24, 1995, the Fish and Wildlife Commission listed the marbled murrelet as threatened in Oregon. Currently, there are no formal State regulations protecting marbled murrelets. Under the Oregon Forest Practices Act, known nest trees cannot be harvested, but regulations are not in place to specifically address marbled murrelets. The amended Oregon Endangered Species Act (Oregon Laws Chapter 590) was enacted in July 1995. This act requires State agencies to follow "guidelines" to protect individual members of a listed species. The "guidelines" are required to be adopted by the Oregon Fish and Wildlife Commission by administrative rule. Rules have not yet been developed; in the interim, agencies are required to comply with Federal law.

The Oregon Department of Forestry (ODF), in cooperation with the Oregon Department of Fish and Wildlife and consulting firms, has funded and completed intensive marbled murrelet surveys in and around timber sale areas on State lands since 1992. These surveys have resulted in the identification of many forest sites where marbled murrelets exhibit occupied behavior on State forest lands. The Oregon Department of Forestry, in consultation with Oregon Department of Fish and Wildlife and the U.S. Fish and Wildlife Service, has developed a marbled murrelet Management Plan for State forest lands. The objectives are to (1) avoid take of the species and (2) provide flexibility in future forest management planning and Habitat Conservation Plan (HCP) development. The Oregon Department of Forestry also developed a Habitat Conservation Plan for the Elliott State Forest, which addresses marbled murrelets and spotted owls in conjunction with the Forest's long range plan (Oregon Department of Forestry 1995). The Oregon Department of Forestry is also in the process of developing a Habitat Conservation Plan for all of their northwest Oregon State forest lands, which will include management of marbled murrelets.

Washington. The marbled murrelet was State-listed as threatened in the fall of 1993. Under its State Forest Practices Act, the Washington Department of Natural Resources is the lead State agency responsible for regulating the harvest of commercial timber from private and State Department of Natural Resources managed timberlands in Washington. The Washington Department of Fish and Wildlife provides management recommendations to Washington Department of Natural Resources on proposed harvests within known marbled murrelet areas. A Science Advisory Group (SAG) to the Forest Practices Board was established to review specific recommendations made by the Washington Department of Fish and Wildlife and to answer questions regarding marbled murrelet protection. A report was prepared that addresses suitable habitat definitions, stand size, and protection of known occupied sites. This report was presented to the Board and provided recommendations and options for marbled murrelet protection on non-Federal forest lands in Washington (Cummins *et al.* 1993). The Forest Practices Board recently adopted a permanent rule (which goes into effect August 22, 1997) for protecting marbled murrelets on non-Federal lands in Washington. The rule includes provisions that establish marbled murrelet detection areas where surveys are required, shared survey responsibilities, revision of platform criteria and definitions, survey protocols, disturbance avoidance criteria, and small landowner exemptions. Where the rule applies, occupied marbled murrelet sites should be protected. The Washington Department of Natural Resources also has just completed a Habitat Conservation Plan for all western Washington State lands that addresses marbled murrelets, along with other species.

Federal Regulations and Habitat Management

Approximately 89 percent of the estimated marbled murrelet habitat on Bureau of Land Management and U.S. Forest Service lands is contained within areas designated for protection (U.S. Department of Agriculture and U.S. Department of the Interior 1994a).

U.S. Forest Service. The National Forest Management Act of 1976 (NFMA) and its implementing regulations require the U.S. Forest Service to manage National Forests to provide sufficient habitat to maintain viable populations of native vertebrate species, such as the marbled murrelet. These regulations define a viable population as "ha[ving] the estimated numbers and distribution of reproductive individuals to insure its continued existence is well-distributed" (36 CFR 219.19). U.S. Department of Agriculture Regulation 1900-4 directs the Forest Service to (1) manage habitats for all existing native and desired non-native plants, fish, and wildlife in order to maintain at least viable populations of such species; (2) conduct activities and programs to assist in the identification and recovery of threatened and endangered plant and animal species; and (3) avoid actions that may cause a species to become threatened or endangered.

The marbled murrelet is listed as a "threatened" species on the Regional Forester's Sensitive Species List for both Regions 5 (California) and 6 (Washington and Oregon) of the U.S. Forest Service. U.S. Forest Service Manual direction (FSM 2672.4), derived from the Endangered Species Act of 1973, as amended, states that all projects, programs, and activities require review and documentation of possible effects/impacts on proposed, threatened, or endangered species. A biological evaluation or assessment must be prepared to document this analysis. Any action that "may affect" a listed species must be submitted for consultation with the U.S. Fish and Wildlife Service (S. Madsen, *in litt.*, 1994).

New National Forest Management Act regulations have been proposed and it is unclear how these new regulations, if adopted, will change Forest Service management of marbled murrelets. However, they have not been finalized so the current National Forest Management Act regulations still apply.

Bureau of Land Management. The Bureau of Land Management (BLM) administers the use of a variety of natural resources on over 1,011,000 hectares (2.5 million acres) in western Oregon. These western Oregon lands involve an extensive checkerboard and fragmented land ownership pattern and include nearly 850,000 hectares (2.1 million acres) known formally as the Revested Oregon and California Railroad lands (O&C lands); almost 162,000 hectares (400,000 acres) of largely scattered public domain lands; and about 30,000 hectares (75,000 acres) of reconveyed Coos Bay Wagon Road lands (CBWR lands). Forested lands in western Oregon total some 2,250,000 acres or 88 percent of the Bureau of Land Management lands (W. Logan, *in litt.*, 1993).

The Bureau of Land Management's principal authority and direction to manage the Revested Oregon and California Railroad lands is found in the Revested Oregon and California Railroad Act of August 28, 1937 (50 stat. 874; 43 U.S.C. 1181a., et seq.). Under this Act, Revested Oregon and California Railroad lands classified as timberlands are to be managed under sustained yield principles to provide a permanent source of timber supply, watershed protection, streamflow regulation and recreation facilities. Most of the remaining Bureau of Land Management-administered land is intermingled public domain. It was brought under sustained yield management principles by the Bureau of Land Management's 1969 application to withdraw these lands from entry under all public land law, except for certain disposal acts. Withdrawal was completed by public land Order 5490 (40 FR 7450 (1975). In addition, many activities of the Bureau of Land Management are governed by the Federal Land Policy and Management Act of 1976 (FLPMA)(90 stat. 2743. 43 U.S.C. 1701). This law established policy for Bureau of Land Management administration of public land under its jurisdiction by mandating that "the public lands be managed in a manner that will protect the quality of scientific...ecological, environmental...values [that] will preserve and protect certain public lands in their natural condition; and...will provide food and

habitat for fish and wildlife...." Section 102(a) (11) of FLPMA requires the prompt development of regulations and plans to protect areas of critical environmental concern. These are defined as "...areas within the public lands where special management attention is required...to protect and prevent irreparable damage to important...fish and wildlife resources or other natural systems or processes."

Bureau of Land Management permitting and management actions also are designed to protect federally listed or proposed threatened and endangered species. Proposed projects that might affect such species are reviewed with the U.S. Fish and Wildlife Service through consultation under the Endangered Species Act. Consistent with policy identified in Bureau of Land Management's nationwide Fish and Wildlife 2000 plan, habitats would be managed to maintain populations of Federal candidate species at a level that would avoid endangering the species. Bureau of Land Management actions would be designed to similarly protect State-listed and Bureau of Land Management sensitive species. Permitted and management actions would not be expected to lead to Federal listing of any species.

Bureau of Land Management and U.S. Forest Service (Habitat Management). In October 1989, as part of an interagency agreement between the U.S. Department of Agriculture (U.S. Forest Service) and the U.S. Department of the Interior (Bureau of Land Management, U.S. Fish and Wildlife Service, and National Park Service), an interagency scientific committee was formed to develop a scientifically-credible conservation strategy for the northern spotted owl (*Strix occidentalis caurina*). Although marbled murrelets were not yet listed in 1989, and the strategy was specific to spotted owls, reserve systems were an integral part of the plan and those reserves near the coast undoubtedly contained some nesting habitat for marbled murrelets.

The conservation strategy was built around 5 general concepts of reserve design (Thomas *et al.* 1990):

(1) Species that are well-distributed across their range are less prone to extinction than species confined to small portions of their range,

(2) Large blocks of habitat, containing multiple pairs of the species in question, are superior to small blocks of habitat with only one to a few pairs,

(3) Blocks of habitat that are close together are better than blocks far apart,

(4) Habitat that occurs in less fragmented (i.e., contiguous) blocks is better than habitat that is more fragmented, and

(5) Habitats between blocks function better to allow a species to move (disperse) through them the more nearly they resemble suitable habitat for the species.

Most of the subsequent conservation strategies, including those developed in this plan for the marbled murrelet, have incorporated all or many of the above listed concepts.

On April 13, 1994, The Secretary of Agriculture and the Secretary of Interior signed a Record of Decision (ROD) adopting Alternative 9 of the President's Forest Plan (U.S. Department of Agriculture and U.S. Department of the Interior 1994b). This is an ecosystem approach to management of Late-Successional Forests and their associated species within the range of the northern spotted owl. Marbled murrelets and their nesting habitat on Federal lands are specifically considered in this plan. The strategy that was developed was based on a Late-Successional Reserve (LSR) System first identified by Johnson *et al.* (1991) and

principles outlined in Thomas *et al.* (1990), and provides additional protection through surveys and protection of occupied marbled murrelet sites outside of the mapped Late-Successional Reserves. In developing the strategy for marbled murrelet nesting habitat on Federal lands, the key components were (1) stabilization or improvement of nesting habitat through protection of all occupied sites (both current and future), (2) development of future habitat in large blocks (creating more interior habitat and thereby possibly decreasing avian predation), and (3) improvement of distribution of habitat, thereby improving distribution of marbled murrelet populations (U.S. Department of Agriculture *et al.* 1993). The plan designed a network of Late-Successional Reserves, in part, around older forests containing suitable marbled murrelet nesting habitat and areas known to be currently occupied by marbled murrelets. Though much of the forest habitat contained within the Late-Successional Reserves is not currently suitable nesting habitat, it would be allowed to grow and develop characteristics that would make it suitable. Timber harvest within Late-Successional Reserves would be limited to harvest related to catastrophic disturbance (salvage) and harvest in younger stands less than 80 years of age in most Late-Successional Reserves. However, thinning is allowed in stands older than 80 years in the Northcoast Adaptive Management Area, and in the Oregon and California Klamath Provinces. Within the matrix (lands outside the reserve system), the plan provides protection of all known and future occupied marbled murrelet sites.

Surveys of marbled murrelet habitat are required prior to forest-modifying activities within the matrix on Federal lands according to an approved survey protocol. If behavior indicates occupancy, all contiguous existing and recruitment habitat (i.e., stands that are capable of becoming marbled murrelet habitat within 25 years) within a 0.5-mile radius will be protected (U.S. Department of Agriculture and U.S. Department of the Interior 1994a). There are approximately 526,000 hectares (1,300,000 acres) of potential (estimated) marbled murrelet

nesting habitat protected as part of the mapped Late-Successional Reserve network. Additional habitat is protected through other designations such as adaptive management areas, congressional reserves, administratively withdrawn areas, and riparian reserves.

Bureau of Indian Affairs. Indian reservation lands are set aside for the exclusive use and benefit of Indian peoples pursuant to treaties, statutes, and executive orders. Reservation lands are held in trust by the U. S., with the Secretary of the Interior having the principal responsibility for fulfilling the trust responsibilities of the U.S. Each reservation is governed by a sovereign tribal government. Tribal governments have many sovereign, treaty-reserved powers, including the right to regulate the users of the land and resources within their reservation boundaries. This right includes the use and management of fish and wildlife resources and habitat. In addition, Indian tribes retain treaty-secured hunting, fishing, and gathering rights on lands outside of reservations (U.S. Fish and Wildlife Service 1992b).

The management strategy of the Bureau of Indian Affairs (BIA) for the marbled murrelet recognizes the unique legal relationship of the U.S. with Indian tribal governments. It focuses on working with Indian tribal governments on a government to government basis to develop management strategies for reservation lands and trust resources that avoid taking of marbled murrelets where feasible, while facilitating the trust responsibility of the U.S. to foster tribal self-determination. The Bureau of Indian Affairs's approach recognizes that marbled murrelet management relating to reservation lands and Indian trust resources must balance the needs of the species and the environmental, economic, and other objectives of the Indian tribes within the range of the marbled murrelet (D. Renwald, *in litt.*, 1993).

The Bureau of Indian Affairs and all Federal agencies of the U.S. must fulfill the Federal trust responsibility to Indian tribes by (1) protecting, conserving, and enhancing Indian fish, wildlife, and other resources in a manner consistent with the highest fiduciary standards; (2) administering Federal fish and wildlife conservation laws in manner consistent with the highest fiduciary standards; (3) administering Federal fish and wildlife conservation laws in a manner consistent with the United States' trust responsibility to Indian tribes; and (4) administering Federal fish and wildlife conservation laws in a manner consistent with Indian treaty rights, in the absence of a clear statement of congressional intent to abrogate or modify Indian treaty rights.

Federal agencies should identify Indian trust resources and reserved rights that may be affected by proposed agency plans or actions. Government to government consultation, with recognized tribal governments (i.e., with reserved rights or jurisdiction over the trust property that may be affected) should be initiated at the earliest possible time. Conflicts that may arise should be resolved collaboratively with affected tribes, consistent with the Federal government's trust responsibility. Mandatory imposition of marbled murrelet management measures upon Indian tribes and their trust resources that restricts the exercising of Indian treaty rights should not be proposed unless a determination is made that such management measures are (1) reasonable and necessary for the preservation of the marbled murrelet; (2) the conservation purpose of the restriction cannot be achieved solely by regulation of non-Indian activities; (3) the restriction is the least restrictive alternative available to achieve the required conservation purpose; (4) the restriction does not discriminate against Indian activities either as stated or as applied; and (5) voluntary tribal conservation measures are not adequate to achieve the necessary conservation purpose. These measures are stated in a Presidential Memorandum to Heads of Executive Departments, dated April 29, 1994 under Secretarial Order No. 3175.

Within the broad framework discussed above, Bureau of Indian Affairs has established a number of specific actions required to comply with section 7 (c) of the Endangered Species Act and its responsibilities as a consultant to the Marbled Murrelet Recovery Team. The Bureau of Indian Affairs's main goals for marbled murrelet protection and management are to

(1) work with tribal governments to accurately assess marbled murrelet population and habitat conditions for Indian reservations within the range of the marbled murrelet;

(2) facilitate information exchange between tribal governments, the Bureau of Indian Affairs, and the U.S. Fish and Wildlife Service, as well as provide assistance to tribal governments on survey protocols and training for surveyors;

(3) develop standards for incidental take and reasonable and prudent measures to minimize take in collaboration with affected tribal governments and the U.S. Fish and Wildlife Service;

(4) assist tribes in resolving conflicts between marbled murrelet management needs and management needs of other species;

(5) provide the U.S. Fish and Wildlife Service with accurate and complete biological assessments;

(6) assist tribes in managing habitat consistent with tribal priorities, reserved Indian rights, and legislative mandates; and

(7) assist tribes in obtaining the most up-to-date scientific information on the marbled murrelet and its habitat requirements, so that they can develop management measures for Indian reservation lands sensitive to the species' needs and assist in the development of positive steps to aid in recovery.

Management for the marbled murrelet may present serious challenges for those tribes that rely upon economic return from the harvest of suitable forest habitat. It will be particularly difficult for tribes to embrace conservation measures for reservation lands that significantly affect the economic and social development of Indian people, especially if the measures proposed for Indian trust lands and waters are more restrictive than those applied to non-Indian-owned state and private lands, or if measures are intended to address past and anticipated future losses of habitat on non-Indian-owned lands (D. Renwald, *in litt.*, 1994).

National Park Service. On its lands, the National Park Service is mandated to "conserve the scenery and the natural and historic objects and the wildlife therein, and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." Its duty in "the protection, management, and administration of these areas ... shall not be exercised in derogation of the values and purposes for which these various areas have been established" (National Park Service Organic Act, 16 USC 1). Every national park has its own enabling legislation that specifies its purpose and objectives. In addition, each park shall have a general management plan that includes measures for the preservation of the park's resources, indications of types and general intensities of development, identification of visitor carrying capacity, and potential modifications to external boundaries (National Park Service Organic Act, 16 USC 1a-7).

A policy of the National Park Service is to manage natural resources "with a concern for fundamental ecological processes as well as for individual species and features". The National Park Service will "identify and promote the conservation of all federally-listed threatened, endangered, or candidate species within park boundaries and their critical habitats. Active management programs will be conducted as necessary to perpetuate the natural distribution and abundance of threatened or endangered species and the ecosystems on which they depend. All management actions for protection and perpetuation of special status species will be determined through the Resource Management Plan (RMP) for each park. The National Park Service will cooperate with the U.S. Fish and Wildlife Service and National Marine Fisheries Service in matters pertaining to federally-listed threatened and endangered species, including the delineation of critical habitat and recovery zones on park lands, and will participate on recovery teams" (National Park Service Management Policies 1988:4).

The National Park Service has four management zones defined in each park's general management plan: natural, cultural, development and special use. The marbled murrelet has the greatest protection in natural zones. Interference with natural processes in park natural zones is allowed only (1) when directed by the Congress, (2) in some emergencies when human life and property are at stake, or (3) to restore native ecosystem functioning that has been disrupted by past or ongoing human activities. In cultural zones, policies for natural zones are followed when they are compatible with cultural resource objectives. Park development zones are managed and maintained for intensive visitor use. In development zones adjacent to natural zones, management is aimed at maintaining as natural an environment as possible, given the use of the zone. Special use zones include transportation rights-of-way, exploration/mining, grazing, forest utilization, commercial, and reservoir uses (National Park Service Management Policies 1988:4).

National Park Service lands within 80 kilometers (50 miles) of the coastline that could potentially contain marbled murrelets include the following: Olympic and Mount Rainier National Parks and San Juan Island National Historic Park in Washington; Fort Clatsop National Memorial in Oregon; Redwood National Park, Point Reyes National Seashore, and Golden Gate National Recreation Area (including Muir Woods National Monument) in California (C. Meyer, *in litt.*, 1994).

Because timber harvesting is generally not allowed on National Park Service lands, most forest land that is suitable marbled murrelet nesting habitat is in a natural zone and is protected from unnatural alterations. However, efforts to better assess and mitigate for other potential human impacts in National Parks are needed. To protect offshore habitat, coastal parks have participated on interagency teams to identify park resources sensitive to oil spills. However, the parks have not been proactive in developing specific protective measures for marbled murrelets in the marine environment, nor do they have specific protocols for post-spill marbled murrelet monitoring.

Most of the suitable marbled murrelet habitat on National Park Service-managed land is in Olympic National Park on lower elevation areas, and in Redwood National and California State Parks. Olympic National Park has approximately 162,000 hectares (400,000 acres) of suitable spotted owl habitat. One-third to one-quarter of these acres may be suitable marbled murrelet habitat. None of the parks has developed an active management plan for the marbled murrelet. Marbled murrelets are specifically identified in RMPs for most of the national parks. However, the identified marbled murrelet inventories or research are unfunded, except for Redwood National Park, whose funding comes largely from non-National Park Service sources.

Potential threats to marbled murrelet habitat in national parks include road, trail and building construction projects, wildfire, mining, hazard tree removal, new visitor developments, human refuse management, visitor noise, and noise disturbance from heavy equipment and helicopter use. Road realignment or widening projects are not uncommon and can remove old-growth trees. New visitor facilities may increase corvid predator populations. Both Redwood National Park and Olympic National Park have had activities such as routine maintenance projects, hazard tree removal, fire management, and activities in the development zones reviewed for their potential effects on marbled murrelets. Mount Rainier National Park conducted some surveys in 1994, intensive surveys in 1995 and surveyed fewer locations in 1996. They will have some surveying for marbled murrelets done in 1997 to determine the effects of routine maintenance activities on this species.

In summary, because the National Park Service's objectives match recovery objectives for the marbled murrelet more closely than any other major land-managing agency, national park units are typically viewed as protected refuges of pristine forest for marbled murrelets. To the extent that pristine habitat is not harvested, this is true. However, to fully protect marbled murrelets, the parks need more information on where marbled murrelets are nesting on their lands and the effect of noise, visitor activity, fire regime, and smoke disturbance on nesting birds and chicks. With this information, they can develop guidelines for avoiding or mitigating adverse and cumulative effects of management activities.

National Oceanic and Atmospheric Administration (NOAA). The National Oceanic and Atmospheric Administration oversees the administration of 5 National Marine Sanctuaries (National Marine Sanctuary) on the west coast, including Point Reyes-Farallon Islands National Marine Sanctuary, Monterey Bay National Marine Sanctuary, Channel Islands National Marine Sanctuary, Cordell

Banks National Marine Sanctuary (all in California), and the Olympic Coast National Marine Sanctuary in Washington. The Point Reyes-Farallon Islands National Marine Sanctuary extends from Bodega Head (Sonoma County) to Rocky Point (Marin County), including waters 3 nautical miles beyond state waters (i.e., 3–6 nautical miles from shore) and waters within 12 nautical miles of the Farallon Islands. The Monterey Bay National Marine Sanctuary extends from Rocky Point (at the southern end of the Point Reyes Farallon Island National Marine Sanctuary) to Cambria (San Luis Obispo County), including waters inside the 500 fathom isobath (ranging from 5–15 nautical miles from shore) and extended to deeper depths to include all waters of Monterey Bay proper. San Francisco Bay is excluded as are a few small areas off harbors and near San Francisco. The Channel Islands National Marine Sanctuary extends from shore out to 3 nautical miles around the 4 northern Channel Islands and Santa Barbara Island, and is not known to be used regularly by marbled murrelets. The Cordell Banks National Marine Sanctuary extends from the northern most boundary of the Point Reyes-Farallon Islands National Marine Sanctuary to the 1,000 fathom isobath northwest of the Bank, then south along this isobath to the Point Reyes National Marine Sanctuary boundary and back to the northeast along this boundary to the beginning point. The Cordell Banks National Marine Sanctuary also is not used regularly by marbled murrelets. The Olympic Coast National Marine Sanctuary extends along the northwest Washington coast from Koitlah Point (just northeast of Cape Flattery) south to the Copalis River (north of the mouth of Grays Harbor). The seaward boundary of the Olympic Coast National Marine Sanctuary extends north of Koitlah Point to the U.S./Canada international boundary westward to where it meets the 100 fathom isobath on the continental shelf west of Cape Alava, then continues south along the 100 fathom isobath until west of the Copalis River where it heads directly to shore. La Push Harbor is excluded from the Olympic Coast National Marine Sanctuary. Overall, the Olympic Coast National Marine Sanctuary consists of about 2,500 square nautical miles of coastal and ocean waters, and the submerged lands thereunder.

National marine sanctuaries were established between 1981 and 1995 under the Marine Protection, Research, and Sanctuaries Act of 1972 (16 U.S.C. Sections 1431 et seq.). The mission of the Marine Sanctuary Program is to identify, designate and manage areas of the marine environment of special national significance due to their conservation, recreational, ecological, historical, research, educational, or esthetic qualities. The goals of the program are (1) to provide enhanced resource protection; (2) to support, promote and coordinate research; (3) to enhance public awareness and wise use; and (4) to facilitate multiple use.

The Monterey Bay National Marine Sanctuary (4,024 square nautical miles) contains the entire marine portion of the breeding range of the Santa Cruz Mountains population of marbled murrelets. The Point Reyes-Farallon Islands National Marine Sanctuary (9,448 square nautical miles) contains smaller numbers of wintering marbled murrelets, probably from the Santa Cruz Mountains population and possibly some from the Mendocino population.

Prohibited activities, whose absence may benefit marbled murrelets and other seabirds in the Monterey Bay National Marine Sanctuary, include (1) exploring, developing or producing oil, gas or minerals; (2) discharging of pollutants or other hazardous materials (with exceptions), either within the Sanctuary or outside but may drift into the Sanctuary; (3) drilling, dredging, constructing or placing structures on the seabed, or otherwise altering the sea bed (with exceptions); (4) taking any seabird (except as permitted); (5) flying motorized aircraft below 1,000 feet within four zones (including zone 1 from Point Santa Cruz to Pescadero Point, zone 2 from the Carmel River to Cambria, zone 3 within 5 miles of Moss Landing, and zone 4 over Elkhorn Slough); (6) operating motorized personal water craft (except in four designated zones and access routes near Pillar Point Harbor, Santa Cruz, Moss Landing, and Monterey Harbor); and (7) possessing

(within the sanctuary) any seabird taken either within or outside of the Sanctuary. In addition, all Department of Defense activities shall be carried out in a manner that avoids adverse impacts on Sanctuary resources (excepting pre-existing activities). Prohibited activities are similar but not identical in the Gulf of the Farallones National Marine Sanctuary. To date, the newly-formed Monterey Bay National Marine Sanctuary has not specifically considered management or research related to the marbled murrelet.

The Olympic Coast National Marine Sanctuary contains most of the marine portion of the breeding range of the Western Washington Coast Range population of marbled murrelets. Prohibited activities in the Endangered Species Act that may benefit marbled murrelets are the same as for the Monterey Bay National Marine Sanctuary, except that (1) motorized aircraft are prohibited below 2,000 feet within on nautical mile of Flattery Rocks, Quillayute Needles, or Copalis National Wildlife Refuge; and (2) the Department of Defense is prohibited from conducting bombing activities and will take prompt action to mitigate unintended harm from other allowed activities in the Olympic Coast National Marine Sanctuary. There are several exceptions for tribal and military activities.

Regulation and Protection Under the Endangered Species Act

Prohibitions under section 9. Section 9 of the Endangered Species Act , prohibits unauthorized "take" of endangered or threatened species. Federal agencies can obtain authorization for "take" through the section 7 consultation process if such take is incidental to and not the purpose of an otherwise lawful activity. Non-Federal entities may also obtain authorization for "take" through incidental take permits based on habitat conservation plans approved under section 10(a) of the Endangered Species Act.

The Endangered Species Act mandates that Federal agencies proposing an action that "may affect" the marbled murrelet "consult" with the U.S. Fish and Wildlife Service regarding the effects of the action. Section 7(a)(2) of the Endangered Species Act states that it is the Federal agency's responsibility, with the assistance of the U.S. Fish and Wildlife Service, to insure that the action is not likely to jeopardize the continued existence of the species. If an action is not likely to jeopardize the species but is anticipated to result in incidental "take" of individuals, the Federal agency may receive from the U.S. Fish and Wildlife Service a written statement that provides an exemption from the takings prohibition of section 9 of the Endangered Species Act.

General definition of "take": Section 3(19) of the Endangered Species Act defines the term "take" to include "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct". The terms "harm" and "harass" have been further defined by regulations at 50 CFR §17.3 as follows:

- *Harass* means an intentional or negligent act or omission that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns that include, but are not limited to, breeding, feeding, or sheltering.

- *Harm* means an act that actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering.

Take of marbled murrelets, within the meaning of these definitions, may result from a variety of activities.

Actions in the terrestrial environment. Marbled murrelets are likely to be taken in the terrestrial environment as a result of any activities that

(1) kill or injure birds;
(2) impair essential behaviors by adversely affecting occupied or unsurveyed suitable breeding habitat; or
(3) cause significant disturbance of breeding birds, leading to reduced reproductive success.

Habitat removal or adverse impact. Activities that adversely impact marbled murrelet habitat include the clearing or partial removal of forest for agriculture, mining, timber harvest, road or trail construction, land development, and similar uses. However, land uses strategies that retain mature/old-growth forest characteristics and minimize fragmentation of forest stands may avoid taking marbled murrelets in some cases.

The recovery plan has identified the conservation of occupied habitat as an important component in the recovery of the species. Modification of occupied habitat would generally pose a high risk of take of marbled murrelets. Likewise, modification of suitable but unsurveyed habitat also may pose a significant risk of take, but this risk will vary depending on habitat quality and location. For example, risk of take would be lower for an action occurring in marginal (but suitable) habitat near the edge of the species' inland range compared to the risk for the same action occurring in high quality habitat that might be closer to the marine environment.

Take of marbled murrelets is not likely in suitable habitat that has been surveyed to protocol with no occupancy detected (incidental take may still occur due to the potential for survey error). However, it is important to note that adverse effects to the species may still result from modification of suitable unoccupied habitat. As the population recovers, or as other occupied areas are lost to timber harvest or

natural processes (e.g., wildfire), these areas may be used by dispersing or colonizing birds.

Activities occurring outside the range of the species are not likely to take marbled murrelets. Activities occurring within the range of the species but within unsuitable habitat are also not likely to take marbled murrelets, assuming that this unsuitable habitat is not important for maintaining important conditions for adjacent occupied habitat.

The effects of habitat removal on the marbled murrelet have been described earlier in this plan. Whether or not take occurs, and in what amounts, as a result of habitat modification will depend on the type and location of the action. Impacts due to timber harvest may include a complete loss of habitat (clearcut), a degradation of habitat (some selective harvest), or harvest of unsuitable habitat adjacent to and contiguous with suitable habitat. Impacts from timber harvest can also occur in unsuitable habitat that is not contiguous with suitable habitat, but is in the vicinity (within 0.8 kilometers (0.5 miles)). Clearcutting of marbled murrelet habitat and other harvest prescriptions that produce even-aged, monotypic forest ecosystems produce habitat unsuitable for the marbled murrelet. Silvicultural prescriptions that promote multi-aged and multi-storied stands may, in some cases, retain suitability for marbled murrelets and perhaps increase the quality of habitat over time. However, the time frame within which this might occur is unknown and is probably site-specific. In most cases timber harvest and other serious modifications result in the elimination of suitable habitat unless marbled murrelet habitat needs are factored into the harvest strategy. Marbled murrelet habitat needs are discussed elsewhere in this recovery plan; retention of habitat characteristics such as stand size, canopy closure, and horizontal structure may avoid or minimize impacts on nesting marbled murrelets.

Minimizing likelihood of take related to habitat modification: The marbled murrelet is a secretive and elusive bird that poses a difficult problem to land managers and biologists. Land managers should determine which of their project areas can reasonably be expected to contain marbled murrelets prior to implementing various actions that may adversely affect the species.

The U.S. Fish and Wildlife Service and action agencies are currently relying on the Pacific Seabird Group's (PSG) marbled murrelet survey protocol (Ralph *et al.* 1994) and subsequent updates to the protocol in 1995, 1996, and 1997 (Ralph *et al.*, *in litt*, 1995b, 1996, 1997) to determine if potential habitat is likely to be occupied by nesting marbled murrelets. This protocol is not error-free, but given the paucity of information on this species and its cryptic behavior, it represents the best available method for assessing the likelihood that marbled murrelets occupy a given forest stand at this time.

The U.S. Fish and Wildlife Service recommends that land managers survey all project areas to protocol (Ralph *et al.* 1994) prior to implementing actions that may adversely affect suitable habitat. The survey protocol will continue to be refined and modified as new information is generated concerning the species. Surveys are labor-intensive and expensive, and current research efforts have enabled predictions to be made regarding the probable use of forest stands by marbled murrelets. Models that predict occupancy based on the forest characteristics have been developed in Oregon (Hamer and Meekins 1996) and Washington (Hamer and Cummins 1991). Until more research is completed, the U.S. Fish and Wildlife Service will continue to rely mainly upon survey efforts to identify the highest quality habitat (i.e., occupied sites).

Disturbance effects: Noises associated with a variety of human activities could disturb nesting marbled murrelets and may cause take (see tasks 3.1.3, 4.4.1.3, 4.4.2.1). Examples of such activities include those using loud machinery (e.g.,

chainsaws, heavy equipment, pile drivers, etc.) or explosives during timber harvest, road or trail construction, and brush clearing within one quarter-mile (one mile for explosives) of occupied or unsurveyed suitable habitat. The U.S. Fish and Wildlife Service may modify these buffer distances if

(1) site-specific conditions warrant it,
(2) if future research suggests that marbled murrelets are relatively tolerant of human activities, or
(3) if experimentation or literature review reveal that noises are attenuated to ambient levels in shorter distances.

Marbled murrelets may be relatively sensitive to disturbance due to their secretive nature and their vulnerability to predation. Although there is little detailed information concerning the murrelet's vulnerability to disturbance effects, research on a variety of other bird species suggest that such effects are possible and, in some cases, likely. These studies have shown that disturbance can affect productivity in a number of ways including nest abandonment; egg and hatchling mortality due to exposure and predation; depressed feeding rates of adults and offspring; reduced body mass or slower growth of nestlings; and avoidance of otherwise suitable habitat. Activities that generate large amounts of noise or create significant visual disruptions probably are most likely to affect marbled murrelets and may lead to take through harm and harassment. Due to the significant lack of disturbance-related information on marbled murrelets, it should be assumed that any amount of disturbance would result in negative impacts, although it is expected that these negative impacts are much less than the impacts due to the loss of occupied habitat.

Some marbled murrelets have been discovered nesting near roads, and it is likely that some individual birds habituate to human activities. The potential for this and other forms of habituation is unknown at this time and should be the subject

of future research. In the meantime, there are several ways that potential adverse effects of disturbance can be minimized, thereby reducing the risk of take.

Within one quarter-mile of suitable habitat, a seasonal restriction of some activities to avoid the nesting season may eliminate all risk of disturbance-related take. Daily-timing restrictions of activities can reduce the potential for take by avoiding what are believed to be relatively sensitive time periods for this species. Research on marbled murrelets, for example, has demonstrated that early after hatch, adult marbled murrelets tend to concentrate their nest visits during the crepuscular hours and that nestlings are left unattended for most of the diurnal period (however, adults may increase diurnal visits to the nest as the chicks develop). The daily timing restriction will minimize (but not eliminate) the potential that adult marbled murrelets will be disturbed when visiting the nest to feed offspring. The U.S. Fish and Wildlife Service and other Federal agencies have developed guidance to aid in the design of projects that minimize potential disturbance of breeding marbled murrelets.

Activities in the marine environment. Marbled murrelets are likely to be taken in the marine environment as a result of any activities that

(1) kill or injure birds;
(2) impair essential behaviors by adversely modifying foraging habitat; or
(3) cause significant disturbance of foraging or roosting birds.

Activities known to take large numbers of marbled murrelets in the marine environment include net fisheries and oil spills (see tasks 3.1.2.1 and 3.1.2.2). Both cause direct mortality and injury, and the latter may adversely affect habitat quality for long periods of time. Marbled murrelets have also been caught on fishing lures in British Columbia (Carter *et al.* 1995a; Campbell 1967; J.D. Kelson, pers. comm.). Small numbers have been reported caught on lines near

Santa Cruz, California. This form of mortality and injury requires further study to assess how important it may be. Marbled murrelets may also be taken during encounters with boats passing through important foraging areas (see task 4.4.2.1); such boats may harm and harass feeding marbled murrelets and cause them to expend energy avoiding otherwise suitable foraging sites.

Relative impacts of different types of take. As the previous discussion implies, all forms of take are not equal in terms of their effects on the species. Some take can be direct mortality, while other take may represent a failed breeding attempt that leaves adult birds relatively unharmed.

Direct mortality or injury due to net fisheries or oil spills is in some cases the easiest take to quantify— a proportion of dead birds are sometimes recovered or observed. Take due to disturbance or habitat modification, on the other hand, is exceedingly difficult to measure because the manifestation of the adverse impact (e.g., egg or chick mortality, reduced productivity) is often removed in time and space from where the impact took place. This difficulty is exacerbated with the marbled murrelet due to the secretive nature of the species and the limited information regarding its life history.

Loss of marbled murrelet nesting habitat is a major cause of the species' decline. Activities causing habitat loss are considered by the U.S. Fish and Wildlife Service to pose one of the highest risks of take based on our current understanding of the species' population trends. Habitat loss has negative effects that may last decades to centuries, depending on the extent of the habitat modification and its location on the landscape. Recruitment of juvenile marbled murrelets into the adult breeding population is believed to be occurring at extremely low rates. Therefore, maintenance of known and potential nesting habitat is a primary goal of this recovery plan (see tasks 3.1.1, 3.2.1, and 3.2.2). Take of adult birds in gill nets or from oil spills is also likely to be a serious impact to certain breeding

populations. Take from disturbance, on the other hand, is relatively less serious because breeding habitat is not modified and adult birds are usually not seriously harmed; these birds can reasonably be expected to breed again in subsequent years.

Migratory Bird Treaty Act

Marbled murrelets are also protected from "take" by the Migratory Bird Treaty Act (16 U.S.C. 703 *et seq.*), but no protection is afforded habitat under this statute.

Northern Spotted Owl Critical Habitat

On January 15, 1992, the U.S. Fish and Wildlife Service finalized designation of 2.8 million hectares (6.88 million acres) as critical habitat for the northern spotted owl in Washington, Oregon, and California (U.S. Fish and Wildlife Service 1992b). These critical habitat areas included most of the Habitat Conservation Areas (HCAs) defined in the ISC Report (Thomas *et al.* 1990; see also discussion above) and added areas around and between them. Acres in spotted owl critical habitat, in addition to HCAs and other protected land allocations, equaled approximately 78 percent of the suitable marbled murrelet habitat managed by the U.S. Forest Service on the Mount Baker-Snoqualmie, Olympic, Siuslaw, and Siskiyou National Forests (G. Gunderson, pers. comm.). Although these critical habitat areas may have provided some additional protection for the marbled murrelet, critical habitat designation for the owl did not necessarily preclude harvest of older forests or other project activities from occurring within critical habitat boundaries. Federal agencies are required to consult with the U.S. Fish and Wildlife Service on any actions they authorize, fund, or carry out that may affect spotted owl critical habitat. Habitat requirements and impacts specific to

marbled murrelets are not addressed during consultation on spotted owl critical habitat.

Marbled Murrelet Conservation Assessment Report

In November 1992, the Pacific Southwest Research Station and Region 6 of the U.S. Forest Service were given the assignment to conduct an assessment of the marbled murrelet throughout its range in North America. The goal was to consolidate the available information concerning marbled murrelet ecology and current habitat conditions, and to evaluate the likelihood of long-term persistence of marbled murrelet populations throughout their current range. All aspects of the murrelet's ecology are being addressed and involve coordination of research information and development of several chapters with the Recovery Team. Drafts were developed and reviewed, and a final publication, *Ecology and Conservation of the Marbled Murrelet*, was released in May 1995 (Ralph *et al.* 1995a).

Marbled Murrelet Critical Habitat

Final Rule. Critical habitat is defined in section 3(5)(A) of the Act as "(i) the specific areas within the geographical area occupied by the species, at the time it is listed . . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed . . . upon determination that such areas are essential for the conservation of the species." 16 U.S.C. 1532(5)(A). At the time the marbled murrelet was listed as a threatened species, critical habitat was not designated due to it not being determinable at that time.

Critical habitat was designated for the marbled murrelet on May 24, 1996 (U.S. Fish and Wildlife Service 1996). Lands designated were those areas identified as essential to the conservation of the species, with the major foundation of the designation being the Forest Plan. The U.S. Fish and Wildlife Service determined that the physical and biological habitat features (referred to as the primary constituent elements) associated with the terrestrial environment that support nesting, roosting, and other normal behaviors are essential to the conservation of the marbled murrelet and require special management considerations.

The U.S. Fish and Wildlife Service identified 32 critical habitat units (CHUs) in Washington, Oregon, and California, encompassing approximately 1,573,340 hectares (3,887,800 acres) of Federal and non-Federal lands (see Appendix A; Figures 1-3). The majority (78 percent) of the areas were located on Federal lands and were almost entirely located in Late-Successional Reserves, as established in the Forest Plan (Appendix A; Table 1). These areas accounted for 86 percent of the known occupied sites on Federal lands.

Within the Critical Habitat Units (areas essential for successful nesting), the U.S. Fish and Wildlife Service focused on two primary constituent elements: (1) individual trees with potential nesting platforms, and (2) forested areas within 0.8 kilometer (0.5 mile) of individual trees with potential nesting platforms, and a canopy height of at least one-half the site-potential tree height. This includes all such forests, regardless of contiguity. These primary constituent elements were considered essential to provide and support suitable nesting habitat for successful reproduction of the marbled murrelet.

Potential nest trees include large trees, generally more than 81 centimeters (32 inches) diameter at breast height with the presence of potential platforms or deformities such as large or forked limbs, broken tops, dwarf mistletoe infections,

witches' brooms, or other formations providing platforms of sufficient size to support adult marbled murrelets. Platforms should have cover for protection from weather and predators, which may be provided by overhanging branches, limbs above the nest area, branches from neighboring trees, or surrounding forest areas.

On a landscape basis, forests with a canopy height of a least one-half the site-potential tree height in proximity to potential nest trees are likely to contribute to the conservation of the marbled murrelet. These forests may reduce the differences in microclimates associated with forested and unforested areas, reduce potential for windthrow during storms, and provide a landscape that has a higher probability of occupancy by marbled murrelets. Nest trees may be scattered or clumped throughout the area. Potential areas may contain fewer than one potential nesting tree per acre.

Within the boundaries of designated critical habitat, only those areas that contain one or both primary constituent elements are, by definition, critical habitat. Areas without any primary constituent elements are excluded by definition.

Not all suitable nesting habitat was included in the designation. Emphasis was placed on those areas considered most essential to the species' conservation in terms of habitat, distribution, and ownership. That does not mean that lands outside of designated Critical Habitat Units are not important to the marbled murrelet. Some areas outside this designation may prove to contain elements important to the recovery of the species. However, the U.S. Fish and Wildlife Service could not designate areas that were not included in a proposed rule. The U.S. Fish and Wildlife Service will consider these areas for potential inclusion in any future revisions of marbled murrelet critical habitat. Any lands within critical habitat that are covered by a legally-operative incidental take permit for marbled murrelets, based on an approved Habitat Conservation Plan that addresses

conservation of the marbled murrelet, are excluded from critical habitat while the permit is active. In 1996, the Oregon Department of Forestry was operating under an incidental take permit for marbled murrelets on the Elliott State Forest, therefore this area was excluded from critical habitat.

No critical habitat was designated in the marine environment. Existing laws such as the Oil Pollution Act of 1990; the Clean Water Act; the Coastal Zone Management Act; the Marine protection, Research and Sanctuaries Act; and the Outer Continental Shelf Act all provide varying degrees of benefits to marbled murrelets, directly or indirectly, in the marine environment (U.S. Fish and Wildlife Service 1996). Even if an area is essential to the conservation of the species, if it does not require special management considerations or protections then it would not be designated as critical habitat.

While increasing recruitment and reducing mortality in the murrelet's terrestrial nesting habitat is a major goal of this recovery plan, the species is inextricably tied to its marine habitat throughout the year. Aside from a few individuals that may occasionally feed in freshwater lakes, virtually all of the murrelet's diet consists of marine animals. Some adult mortality probably also occurs in the marine environment from natural and human activity sources. Given the essential role marine habitat plays in the marbled murrelet's life cycle, recovery efforts will not be successful unless feeding, loafing, resting, and wintering marine habitats for the species and habitats for prey resources are secure.

Protection provided by the critical habitat designation. Critical habitat serves to focus conservation activities by identifying areas that contain essential habitat features and that may require special management consideration. Critical habitat is addressed under section 7 of the Endangered Species Act with regard to actions by Federal agencies; however the Endangered Species Act does not provide any

additional protection to lands designated as critical habitat. The proposal to list critical habitat for the marbled murrelet (U.S. Fish and Wildlife Service 1994a) clarifies the role of the critical habitat designation:

> Designating critical habitat does not create a management plan for the areas, establish numerical population goals or prescribe specific management actions (inside or outside of critical habitat), or have a direct effect on areas not designated as critical habitat. Specific management recommendations for critical habitat are addressed in recovery plans, management plans, and in section 7 consultation.

PART II. RECOVERY

"Every entity is only to be understood in terms of the way in which it is interwoven with the rest of the Universe."
- Alfred North Whitehead, Philosopher

II. RECOVERY

A. Objectives and Criteria

Recovery Objectives

The objectives of this recovery plan are (1) to stabilize and then increase population size, changing the current downward trend to an upward (improving) trend throughout the listed range, (2) to provide conditions in the future that allow for a reasonable likelihood of continued existence of viable populations, and (3) to gather the necessary information to develop specific delisting criteria. To achieve these objectives, the following steps are necessary: (1) increase the productivity of the population, as reflected by total population size, the juvenile:adult ratio, and other measures of nesting success; (2) minimize or eliminate threats to survivorship; (3) identify and conduct the research and monitoring necessary to determine specific delisting criteria; (4) encourage cooperative research; and (5) coordinate monitoring and research efforts. The key method to stop population decline and encourage future increase in population growth is to stabilize and increase habitat quality and quantity on land and at sea.

Delisting Criteria

Delisting can be considered after research and monitoring provide necessary information on present populations and life history requirements for the development of recovery criteria. These criteria should be reasonable, attainable, and adequate to maintain the species over the period of reduced habitat availability during the next 50 years and to insure viable populations over the long-term (greater than 200 years). Interim delisting criteria are provided below:

(1) Trends in estimated population size, densities and productivity have been stable or increasing in four of the six zones over a 10-year period. This period of time will encompass at least one to two El Niño events, based on recent frequency of occurrences.

(2) Management commitments (marine and terrestrial) and monitoring have been implemented that provide for adequate protection of marbled murrelets in the six Conservation Zones for at least the near future (50 years). These commitments include delineating and protecting areas of terrestrial and marine habitat essential for recovery within each Conservation Zone (task 2) and developing and implementing landscape management strategies for each of the six Conservation Zones (task 2.3). Monitoring commitments include accurate and repeatable inventory and monitoring of marbled murrelet populations and trends at-sea and monitoring the amount and condition of terrestrial habitat (task 4.1).

Providing more specific delisting criteria will be possible after

(1) Marbled murrelet population size, population trends, and demographic goals have been better determined for each of the six Conservation Zones (Figure 8 and task 1). The parameters must be adequate to ensure sustainable populations throughout its range (e.g., 100–200 years);

(2) The quantity, quality, and distribution of nesting habitat within each zone that is necessary to sustain appropriate demographic and population size goals of marbled murrelets have been better determined, and that these requirements are projected to be met in the near future (50 years). To determine the amount of habitat required to stabilize the population, information on the amount and quality of forest habitat required to support a

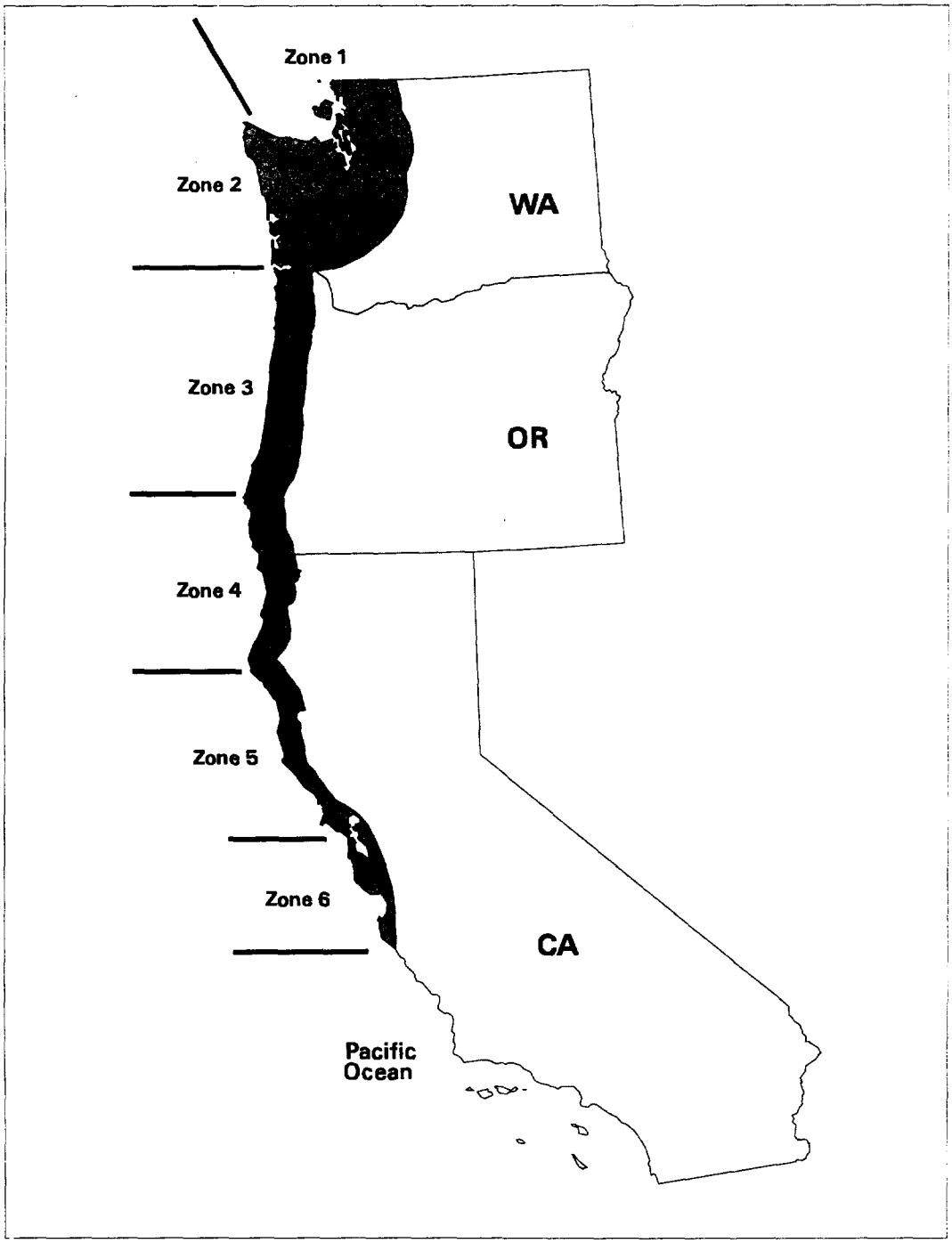

Figure 8. Map of the six Marbled Murrelet Conservation Zones (Zones). See text for descriptions.

specific number of marbled murrelets in each Conservation Zone is needed along with the current trend of population size, density and productivity;

(3) The quantity, quality, and distribution of marine habitats and prey populations that are necessary to sustain demographic and population size goals of marbled murrelets in each Conservation Zone have been better determined, and that these requirements are projected to be met in the near future (next 50 years) at a minimum.

(4) Detailed studies of the survivorship and productivity of marbled murrelets are completed.

B. Recovery Strategy for the Marbled Murrelet

Maintaining a well-dispersed population is necessary for the long-term survival and recovery of the marbled murrelet. This recovery plan divides the range of the murrelet into six Conservation Zones to enable meeting this objective. Delineation of these zones was based on current population and habitat distributions, threats, and geopolitical boundaries. The Conservation Zones (Puget Sound; Western Washington Coast Range; Oregon Coast Range; Siskiyou Coast Range; Mendocino; and Santa Cruz Mountains) are generally in the vicinity of large tracts of older forests in proximity to the coast and are described below in tasks 1.1–1.6. These Zone delineations will assist in the design of management actions and evaluation of impacts at several scales. They also are the functional equivalent of recovery units as defined by current Service policy.

The respective status of the populations in each of these Conservation Zones is highly varied, as is their potential to contribute to the murrelet's recovery. For example, the near total historical habitat loss in Zone 5 (Mendocino) may eventually lead to the extirpation of this population no matter what conservation

efforts are made. Although conservation measures in this zone could benefit the species and are strongly recommended (see task 1.5), this zone can not be relied on to contribute to the recovery of the species. Zone 6 also appears vulnerable to extirpation due to small population size, habitat conditions, a lack of Federal land ownership in the area, and isolation from other murrelet populations. Although Zone 6 is expected to contribute to recovery and is essential to the species in the short term (50–100 years), a viable population in this Zone may not be achievable in the long term due to stochastic and catastrophic events.

Populations in the other Zones are in relatively better shape and have the potential to recover the species if the recommendations in this recovery plan are implemented. To allow for the eventual long-term survival and recovery of the listed species, each of these remaining Zones must be managed to produce and maintain viable marbled murrelet populations that are well distributed throughout the respective Zones. In some areas, Federal lands provide the bulk of this contribution. In other areas, Federal lands are lacking and non-Federal lands play a necessary role in long-term survival and recovery (FEMAT 1993:IV-165; U.S. Department of Agriculure and U.S. Department of Interior 1994a:3&4-249; U.S. Fish and Wildlife Service 1994c:46; see also task 2.3).

It is necessary to produce and maintain well-distributed populations in these Zones because of the murrelet's vulnerability to environmental fluctuations and catastrophes and because of the species' slow reproductive rate, which inhibits its ability to rebound from adverse impacts. Random environmental events and catastrophes can adversely affect the viability of threatened populations (Shaffer 1996; Meffe and Carroll 1996:191), including populations with relatively widespread distributions such as the marbled murrelet (Raup 1991: 122, 182). Such fluctuations and catastrophes are discussed earlier in this document and include floods, fire, oceanic conditions, disease, oil spills, and other natural or human caused impacts.

There are many recent examples of such events, some of which are localized while others are widespread. During the winter of 1955-56, for example, catastrophic flooding destroyed important murrelet nesting habitat in old-growth redwood groves in the Eel River drainage of northern California, greatly reducing the groves in size (Johnston 1994). Bull Creek, a tributary of the Eel River located in Humboldt Redwoods State Park, lost 524 large redwood trees to these floods (Stone and Vasey 1968). Such impacts were likely significant to the murrelet because recent surveys of breeding murrelets in Humboldt Redwoods State Park found that 96% of the nesting behaviors (i.e., "occupied" survey stations; see Ralph *et al.* 1994) observed in the entire park (@24,000 acres of potential nesting habitat) were concentrated in alluvial flats of the Bull Creek area (@1000 acres of old growth redwood) (Ralph and Miller, unpubl. data). These alluvial flats, with their large old growth redwood trees and moist microclimate, provide ideal growing conditions for murrelet nest trees. But this same location on the valley floor also makes the trees vulnerable to flood events, and it was estimated that 15 major floods of this scale have occurred in this drainage during the last 1000 years (Stone and Vasey 1968).

Periodic fire and catastrophic windstorms also remove large amounts of murrelet nesting habitat. The Columbus Day windstorm in 1962 blew down an estimated 11.2 billion board feet of timber in the Oregon and Washington Coast Ranges (Lucia 1967), much of which was likely murrelet nesting habitat. Since the 1840s, the Oregon Coast Range has experienced a series of large scale, human and natural caused fires that destroyed extensive amounts of older forest throughout Conservation Zone 3 (Ripple 1994). It is likely that these fires, in conjunction with harvest of old growth timber in the same area during the same period, led to a dramatic decline in the Zone 3 murrelet population. Other examples of these types of natural and human caused catastrophes can be found throughout the three state range of the listed species.

Even though the marbled murrelet was originally widespread over the listed three state range, it is important to recognize that the resilience to extinction of widespread species can be negated if these species are subjected to a new stress over a large area (Raup 1991: 122, 182). For the marbled murrelet, this stress was the removal of an estimated 85 to 95 percent of its older forest nesting habitat due to timber harvest and human caused fire. As a consequence of such widespread habitat loss and the subsequent reduction in the range and vigor of the species, the murrelet is now more vulnerable to environmental fluctuations and catastrophes that the species otherwise would probably have been able to tolerate. These chance events, such as the floods, fire, oil spills, and windstorms described above and earlier in this plan, could now cause or facilitate the extirpation of the entire listed species or one or more of the Zone populations. This risk is further exacerbated for the murrelet because populations that have negative long-term growth rates, as does the listed population of the murrelet (see Appendix B, Ralph 1994, Ralph *et al.* 1995), have little or no capacity to overcome catastrophic population losses (Lande 1993).

The zone approach in this recovery plan addresses this risk to the long-term survival and recovery of the murrelet by employing two widely recognized and scientifically accepted goals for promoting viable populations of listed species: (1) creation or maintenance of multiple populations so that a single or series of catastrophic events cannot destroy the whole listed species; and (2) increasing the size of each population in the respective Conservation Zones to a level where the threats of genetic, demographic, and normal environmental uncertainties are diminished (Mangel and Tier 1994; NRC 1995:91, 104; Tear *et al.* 1995; Meffe and Carroll 1996:192).

In general, the larger the number of populations and the larger the size of each population, the lower the probability of extinction (Raup 1991:182, Meffe and Carroll 1996:190). This basic conservation principle of redundancy applies to the marbled murrelet. By maintaining viable populations in the Conservation Zones,

the threats represented by a fluctuating environment are alleviated and the species has a greater likelihood of achieving long-term survival and recovery. Conversely, loss of one or more of the murrelet Zone populations will result in an appreciable increase in the risk that the entire listed species may not survive and recover.

Therefore, when evaluating the potential impacts of land management actions that may affect the marbled murrelet, the Service will consider whether a significant loss of individual murrelets or habitat in one Conservation Zone -- without long term mitigation alleviating the impacts of that loss -- would adversely affect the viability of the population in that Zone as well as the long-term viability of populations in other Zones. Excessive impacts to one or more of the Zones could jeopardize the long-term survival and recovery of the murrelet by increasing the risk that catastrophic events might devastate the whole listed species (i.e., the remaining Zonal populations).

Protect Habitat

The central reason for listing the Washington, Oregon, and California population of the marbled murrelet as threatened was the loss of nesting habitat (old-growth and mature forests). To fulfill the initial objective of stabilizing population size, this recovery plan focuses on protecting adequate nesting habitat by maintaining and protecting occupied habitat and minimizing the loss of unoccupied but suitable habitat through several means, including designation of critical habitat, implementation of the Forest Plan and the development of HCPs that contribute to the conservation of the murrelet. The Forest Plan provides a substantial contribution towards protecting nesting habitat on Federal lands, especially habitat that is currently occupied by marbled murrelets, and represents the backbone of this Recovery Plan strategy. On May 24, 1996, the Service also designated critical habitat for murrelets.

In addition, recovery of the marbled murrelet will require some non-Federal lands, with several important areas occurring on private and state lands. Currently, there are several large HCPs that have been completed or are under development that address marbled murrelets, especially on key state lands. Adequately designed and implemented HCPs will be very important in the conservation of marbled murrelets on state and private lands and are likely to be the most effective and acceptable means of protecting most occupied sites on non-federal lands in the near future and potentially providing replacement habitat in the long term. Lands covered by approved HCPs would not require additional protection (e.g., designation as critical habitat). Land acquisition and land exchanges between agencies and private land owners may be another effective way to protect occupied sites and/or block up both ownerships and suitable habitat. These land exchanges would be especially important in areas with little Federal ownership such as southwestern Washington, northwestern Oregon, northern California, and central California in areas near the coast.

Furthermore, protection of marine habitats is also a critical component of a successful recovery strategy. Marbled murrelets spend most of their lives in the marine environment. While some feeding activities may take place on freshwater lakes and rivers and some adult mortality results from accidents or predation in the terrestrial environment, most of the marbled murrelet's biological and physical interactions occur at sea, usually within 2 kilometers (1.2 miles) of the shoreline. In addition, adult mortality from both natural and anthropogenic causes occurs in the marine environment. Given the essential role the marine environment plays in the daily and seasonal life of the marbled murrelet, protecting the quality of the marine environment (task 2.2) and reducing adult and juvenile mortality in the marine environment (task 3.1.2) are integral parts of this marbled murrelet recovery effort.

Decrease or Eliminate Threats

Forming the foundation of the interim recovery strategy are specific management recommendations for the protected habitat areas. These recommendations include short-term actions for stabilizing the population, and longer-term actions for increasing population growth and distribution.

The short-term actions are critical because of the length of time necessary to develop most new nesting habitat (100–200 years). They should be factored into decisions on which areas should be secured and how habitat (both terrestrial and marine) should be maintained or improved. Short-term actions include: (1) maintaining occupied habitat; (2) maintaining large blocks of suitable habitat; (3) maintaining and enhancing buffer habitat; and (4) decreasing risks of loss of nesting habitat due to fire and windthrow. Because low productivity or breeding success appears to be a substantial problem, minimizing disturbance and reducing predation at nest sites is also an important first step in the recovery process. Potential negative impacts on murrelet populations are not restricted to the terrestrial environment. Habitat quality in the marine environment must also be considered, including the reduction of pollution and the likelihood of oil spills. Mortality of adults and juveniles from net fisheries must also be reduced or eliminated.

Long-term actions include increasing the amount, quality and distribution of suitable nesting habitat. Increasing the stand size of suitable habitat to provide more interior forest conditions and increasing the number of stands of suitable nesting habitat are considered key to long-term recovery. Within secured habitat areas, this means protecting currently unsuitable habitat to allow it to become suitable, reducing fragmentation, providing replacement habitat for current suitable nesting habitat lost to disturbance events and habitat lost to both timber harvest and disturbance events in the past. In the long term, the distribution of

nesting habitat should be improved. Silvicultural techniques also might increase the speed of habitat development and the structural qualities of the habitat. These same principles apply to non-federal lands through the development of HCPs that adequately address conservation of the murrelet, through incorporation of the principles and tasks provided in this recovery plan.

Given the essetial role the marine environment plays in the daily and seasonal life of the marbled murrelet, protecting and improving the quality of the marine environment and reducing adult and juvenile mortality in the marine environment are integral parts of this marbled murrelet recovery effort.

Conduct Research and Monitoring

A better understanding of the species is essential in order to adequately refine this recovery strategy for the marbled murrelet. A key to the entire recovery effort is conducting necessary research to provide managers with adequate information to better determine specific delisting criteria and to make necessary adjustments to the recovery strategy.

Current population size and trend information needs to be refined through additional at-sea surveys, refined survey sampling design, and data analysis techniques. Information on marbled murrelet survivorship estimates and juvenile:adult ratios at-sea also needs to be collected over a number of years (e.g., 5–10 years) to further validate the current population model. Several years are required to account for possible natural variability and the periodic occurrence of El Niño (and other warm water) conditions that may lead to variation in breeding success.

Some other possible factors that may contribute to or limit population growth need to be explored in more depth, including prey resources and fluctuations in their availability, the effects of net fisheries and oil pollution, nesting habitat requirements and effects of avian predation on nest success. The role that research and monitoring play in this recovery effort can not be overemphasized.

Update and Revise Recovery Plan and Objectives

As with many species, there are considerable gaps in our understanding of marbled murrelet life history requirements. Therefore, it is anticipated that the life of this initial recovery plan will be relatively short due to the expected gain in knowledge of the species over the next 5–10 years. Based on additional research, monitoring, and implementation of the Forest Plan, it is hoped that this recovery plan can be revised in 5–10 years. New information generated by additional research will be incorporated in the next version to allow for better definition of recovery tasks, and development of more specific delisting criteria.

C. Recovery Actions

The following narrative outline identifies actions necessary to address the recovery objectives. These actions include:

- Establishing six Marbled Murrelet Conservation Zones (Zones) and develop landscape-level management strategies for each Zone.

- Identifying and protecting habitat areas within each Zone, including the marine environment, through implementation of the Forest Plan, designation as critical habitat, better use of existing laws, or other methods (e.g., HCPs), and developing management plans for these areas.

- Monitoring populations and habitat, and surveying potential breeding habitat to identify potential nesting areas (e.g., occupied sites).

- Implementing short-term actions to stabilize and increase the population that include maintaining potential suitable habitat in large contiguous blocks and buffer areas; maintaining habitat distribution and quality; decreasing risk of fire and windthrow; decreasing adult and juvenile mortality; reducing nest predation; increasing recruitment; and initiating research to determine impacts of disturbance in both marine and terrestrial environments.

- Implementing long-term actions to stop population decline and increase population growth by increasing the amount, quality and distribution of suitable nesting habitat, decreasing fragmentation, protecting "recruitment" habitat, providing replacement habitat through silvicultural techniques, and improving marine habitat quality.

- Initiating research to develop and refine survey and monitoring protocols, refine population estimates, examine limiting factors, evaluate disturbance effects, and obtain additional life history data.

- Establishing a Regional Coordination body for the marbled murrelet research efforts, including data storage and retrieval in databases and archives (see also Appendix C).

D. Narrative Outline for Recovery Actions.

1. Implement management plans for each Marbled Murrelet Conservation Zone.

1.1. Puget Sound Zone (Zone 1).

The Puget Sound Zone extends south from the U.S.-Canadian border along the east shore of Puget Sound to the southern end of Puget Sound, thence northward along the west shore of Puget Sound to Port Townsend, there turning westward along the north shore of the Olympic Peninsula to Koitlah Point, just northeast of Cape Flattery. The Zone includes all the waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the U. S.-Canada border. The Zone extends inland a distance of 80 kilometers (50 miles) from eastern Puget Sound and includes the northern and eastern sections of the Olympic Peninsula. Most of the marbled murrelet population occurring in the State of Washington is found in this Zone.

Currently, this is the main Zone in the three-state area where net fisheries may result in considerable mortality to marbled murrelets. In addition, there is a high threat of oil and other marine pollution.

Because of loss of late-successional forest habitat and its replacement with urban development in the Puget Trough, remaining suitable nesting habitat for marbled murrelets on the eastern shore of Puget Sound is a considerable distance from the marine environment (more than 32 kilometers [more than 20 miles]), lending special importance to remaining nesting habitat that is closest to Puget Sound. That is also the case for the remaining habitat in the south Puget Sound area. Although there are only a small number of marbled murrelets known to nest in this area, recovery efforts should be directed toward increasing the size and distribution of marbled murrelet populations here and not further contracting the their distribution.

There is also considerable suitable marbled murrelet nesting habitat on the eastern Olympic Peninsula that is not currently located in Late-Successional Reserves. This habitat may be important for the maintenance of marbled

murrelet populations of southern Puget Sound. The Washington Department of Natural Resources recently completed a Habitat Conservation Plan for all of its State forest lands in western Washington and marbled murrelet management was a part of that Habitat Conservation Plan.

1.2 Western Washington Coast Range Zone (Zone 2).

The Western Washington Coast Range Zone extends from Koitlah Point west to Cape Flattery, and south to the Columbia River. This Zone includes waters within 2 kilometers (1.2 miles) of the Pacific Ocean shoreline as well as waters south of the U.S.-Canada border off Cape Flattery, and extends inland to the midpoint of the Olympic Peninsula and in southwest Washington as far as 80 kilometers (50 miles) from the Pacific Ocean shoreline. Some net fisheries occur in the Zone near Cape Flattery and large oil spills are a considerable threat.

Forest lands in the northwestern portion occur on public and private lands while most forest lands in the southwestern portion are privately owned and have been harvested in the last century. There are relatively few known marbled murrelet occupied sites.

To maintain a well-distributed marbled murrelet population, recovery efforts should be directed toward increasing the size and distribution of marbled murrelet populations and not furthering the gap in distribution between the Peninsula and the small populations in southwestern Washington. Non-Federal lands in this Zone currently provide a limited amount of marbled murrelet nesting habitat and have the potential to be managed to increase the amount of suitable nesting habitat in the future. The Washington Department of Natural Resources recently completed a Habitat Conservation Plan for all of its State forest lands in western Washington and marbled murrelet management was a part of that Habitat Conservation Plan.

1.3 Oregon Coast Range Zone (Zone 3).

The Oregon Coast Range Zone extends from the Columbia River, south to North Bend, Coos County, Oregon. This Zone includes waters within 2

kilometers (1.2 miles) of the Pacific Ocean shoreline and extends inland a distance of up to 56 kilometers (35 miles) from the Pacific Ocean shoreline and coincides with the "Zone 1" boundary line described by the Forest Ecosystem Management Assessment Team, with minor adjustments (U.S. Department of Agriculture *et al.* 1993). The boundary encompasses all of the marbled murrelet critical habitat units designated (the boundary extends slightly beyond 56 kilometers (35 miles) in certain areas; see Appendix A, Figure 2).

This Zone includes the majority of known marbled murrelet occupied sites in Oregon. Marbled murrelet occupied sites along the western portion of the Tillamook State Forest are especially important to maintaining well-distributed marbled murrelet populations. Efforts should focus on maintaining these occupied sites, minimizing the loss of unoccupied but suitable habitat, and decreasing the time for development of new habitat. Relatively few known occupied sites occur north of the Tillamook State Forest. Recovery efforts should be directed at restoring some of the north-south distribution of marbled murrelet populations and habitat in this Zone. Maintenance of suitable and occupied marbled murrelet nesting habitat in the Elliott State Forest, Tillamook State Forest, Siuslaw National Forest, and Bureau of Land Management-administered forests is an essential component for the stabilization and recovery of the marbled murrelet.

1.4 Siskiyou Coast Range Zone (Zone 4).

The Siskiyou Coast Range Zone extends from North Bend, Coos County, Oregon, south to the southern end of Humboldt County, California. It includes waters within 2 kilometers (1.2 miles) of the Pacific Ocean shoreline (including Humboldt and Arcata bays) and, in general, extends inland a distance of 56 kilometers (35 miles) from the Pacific Ocean shoreline and coincides with the "Zone 1" boundary line described by the Forest Ecosystem Management Assessment Team with minor adjustments (U.S. Department of Agriculture *et al.* 1993). The boundary encompasses all of the marbled murrelet critical habitat units designated (the boundary extends slightly beyond 56 kilometers (35 miles) in certain areas - see Appendix A, Figure 3).

This Zone includes the marbled murrelet population occupying sites in Redwood National Park and several state parks (Jedediah Smith, Del Norte, Prairie Creek, Grizzly Creek, and Humboldt) in California. In addition, this Zone includes nesting habitat on private lands in southern Humboldt County. Additional marbled murrelet nesting habitat occurs at lower elevations in western portions of the Smith River National Recreation Area. State policies regarding protection of marbled murrelet occupied sites on private lands differ in the Oregon and California portions of this Zone.

Recovery actions should be focused on preventing the loss of occupied nesting habitat, minimizing the loss of unoccupied but suitable habitat, and decreasing the time for development of new suitable habitat. Much marbled murrelet nesting habitat is found in state and national parks that receive considerable recreational use. The need to maintain high quality marbled murrelet terrestrial habitat should be considered in planning any modifications to state or national parks for recreational purposes. Both highway and campground construction, including picnic areas, parking lots, and visitors centers, could present threats to the marbled murrelet through loss of habitat, nest disturbance, and/or increasing potential predation from corvids associated with human activities such as Steller's jays and crows. Implementing appropriate garbage/trash disposal may help decrease potential predator populations in high human use areas such as county, state and national parks.

This Zone has large blocks of suitable habitat critical to the three-state marbled murrelet population recovery over the next 100 years. However, the amount of suitable habitat protected in parks is probably not sufficient by itself to guarantee long-term survival of marbled murrelets in this Zone. On the other hand, a considerable amount of habitat is preserved in parks such that survival may be more likely in this Zone than in several other Zones. Private lands at the southern end of this Zone are important for maintaining the current distribution of the species. There is already a considerable gap in distribution between this area and the central California population in Zone 6. Efforts should be implemented to, at a minimum, not expand the current distribution gap.

1.5 Mendocino Zone (Zone 5).

The Mendocino Zone extends south from the southern boundary of Humboldt County, California, to the mouth of San Francisco Bay. It includes waters within 2 kilometers (1.2 miles) of the Pacific Ocean shoreline and extends inland a distance of up to 40 kilometers (25 miles) from the Pacific Ocean shoreline.

The very small nesting and at-sea population of marbled murrelets along the coast of Mendocino, Sonoma and Marin Counties is important to future reconnection of marbled murrelet populations in northern and central California, if they can survive over the short term. Almost all of the older forest has been removed from this area, although small pockets of old-growth forest occur in State parks and on private lands. Forests in southeast Marin County and in the Berkeley Hills (Alameda County) may have been used for nesting in the distant past, but these areas were logged from the early 1800's to the early 1900's. Much of the remaining marbled murrelet nesting habitat in this Zone is located on private lands.

The maintenance of this population will require considerable cooperation between State, Federal and private management representatives. Recovery efforts in this Conservation Zone could enhance the probability of survival and recovery in adjacent Conservation Zones by minimizing the current gap in distribution. The population is so small that immediate recovery efforts may not be successful at maintaining this population over time and longer term recovery efforts (e.g., developing new suitable habitat) may be most important. However, if this small population can be maintained over the next 50 years, it will greatly speed recovery in this Conservation Zone. Whether or not marbled murrelets can recolonize regenerated old-growth forests over such a large geographic area is not known.

1.6 Santa Cruz Mountains Zone (Zone 6).

The Santa Cruz Mountains Zone extends south from the mouth of San Francisco Bay to Point Sur, Monterey County, California. It includes waters within 2 kilometers (1.2 miles) of the Pacific Ocean shoreline, the waters of

Monterey Bay, and extends inland a distance of up to 24 kilometers (15 miles) from the Pacific Ocean shoreline.

The southernmost population of marbled murrelets in the North America occurs in this Zone. This population is important to maintaining a well-distributed marbled murrelet population in the three-state area. Because this population is small and isolated from other marbled murrelet populations, it is considered to be especially vulnerable.

This population uses nesting habitat found primarily on state park lands (Big Basin Redwoods, Butano, and Portola State Parks), although some habitat for this population also occurs on private land. The waters offshore of San Mateo and Santa Cruz counties are important foraging areas for this population in the breeding season. Marbled murrelets probably once nested on the Monterey County coast from south of Carmel through Big Sur.

In addition, numbers of marbled murrelets are found in Monterey Bay during the winter. Small numbers also may disperse slightly northward and occur off San Francisco and northern San Mateo counties (at the northern end of the Zone) as well as off southern Marin County (at the southern end of Zone 5) in winter. However, this population is largely resident off southern San Mateo and northern Santa Cruz counties in winter, best demonstrated by high levels of winter visitation to nesting areas. In winter, small numbers of marbled murrelets are found south of this Zone, from Point Sur to the U.S.-Mexico border. Marbled murrelets are not known to use the terrestrial environment in this area, however mortality from oil spills may represent a principal threat to marbled murrelets wintering in this area.

2. Delineate and protect areas of habitat within each Zone.

Areas within each Zone that are essential for marbled murrelet recovery should be delineated and protected, using a variety of means (e.g., designation as critical habitat, protection through Habitat Conservation Plans, management [as reserves] under the Forest Plan, other existing regulatory mechanisms, etc.).

2.1 Protect terrestrial habitat essential for marbled murrelet recovery.

There appears to be little opportunity for increases in marbled murrelet productivity as a result of forest maturation in the near future. Even under optimum conditions and with the successful use of various silvicultural techniques, it will take 50 to 100 years or more to develop new suitable nesting habitat within most reserve areas. Any further substantial reduction in occupied nesting habitat for the marbled murrelet would hamper efforts to stabilize the population and the recovery of the species.

Marbled murrelet population trends described above (also see Appendix B) have led the U.S. Fish and Wildlife Service to conclude that a number of areas, including nesting areas and feeding sites well-distributed throughout its terrestrial and marine range, are essential to the conservation of the species. Late-Successional Reserves, as described in the Forest Plan and the final rule designating critical habitat for marbled murrelets, will eventually contribute to recovery. However, these areas alone are insufficient to reverse the decline and maintain a well-distributed population. Thus, additional areas, including non-Federal lands and marine areas, should be protected using a variety of means including critical habitat, Habitat Conservation Plans, and other existing regulatory mechanisms as described below. If these areas are protected, there is a high likelihood that populations will stabilize.

A. Essential nesting habitats that occur on forest lands managed by the Federal government include:

(1) Any suitable habitat in Late-Successional Reserves located in the Forest Ecosystem Management Assessment Team Zone 1 (see pages IV-23 and IV-24 in U.S. Department of Agriculture *et al.* 1993 for a description of Zone 1);

(2) Any suitable habitat in Late-Successional Reserves in the Forest Ecosystem Management Assessment Team Zone 2 in Washington (see page IV-24 in U.S. Department of Agriculture *et al.* 1993 for a description of Zone 2). Approximately 10 percent of the stands sampled in the North Cascades were occupied within this Zone;

(3) All suitable habitat located in the Olympic Adaptive Management Area (AMA) identified in the FSEIS. The approximately 10,500 hectares (26,000 acres) of low elevation suitable habitat in the Olympic Adaptive Management Area is essential to conserve marbled murrelet populations in the Puget Sound area of Washington; and

(4) Other large areas of suitable nesting habitat outside of Late-Successional Reserves on Federal lands. For example, large areas of suitable nesting habitat occur on the Siskiyou National Forest, Oregon, the Six Rivers National Forest, California, and in Redwood National and State Park, California.

B. Essential nesting habitats that occur on forest lands under non-Federal management include:

(1) Large areas of suitable nesting habitat on state lands in California and Oregon within 40 kilometers (25 miles) of the coast. For example, in Oregon, large areas of suitable nesting habitat occur in the Elliott State Forest, the western side of the Tillamook State Forest, and State lands west of Corvallis and along the coast. In California, much nesting habitat occurs in State parks. These areas are critical for maintaining the distribution of suitable habitat.

(2) Suitable habitat within 64 kilometers (40 miles) of the coast on State lands in Washington. These areas are critical for improving the distribution of both the population and suitable habitat, especially in southwest Washington.

(3) Suitable nesting habitat on county park lands (e.g., Memorial and Sam MacDonald County Parks) within 40 kilometers (25 miles) of the coast in San Mateo and Santa Cruz Counties, California. These parks form some of the last remnants of nesting areas for the southernmost population of marbled murrelets, which is the smallest, most isolated, and most susceptible to extinction.

(4) Suitable nesting habitat on Pacific Lumber Company lands in Humboldt County, California. These areas are a significant portion of the currently available nesting habitat for the southern part of Zone 4. This area has known nest sites and is situated in a key area, close to the coast, with no Federal lands in the immediate area that are able to provide similar recovery contributions. Maintenance of suitable habitat in this area is also critical to avoid widening the gap between the central California population and the southern end of Humboldt County.

(5) Additional habitat essential for the conservation of the marbled murrelet occurs on private lands in Oregon and Washington, but these could be managed for the marbled murrelet if surveys for the marbled murrelet were required prior to timber harvest, and occupied sites (forest stands where marbled murrelet occupancy has been determined through surveys) were protected from timber operations. This management system is used effectively to protect many occupied marbled murrelet sites in California, it has recently been adopted in Washington, but not in Oregon.

Maintenance of marbled murrelet populations on private lands is critical in arresting the decline of the species in the next 50–100 years. This is especially true where additional nesting habitat is not expected to be available on nearby Federal lands. While the Endangered Species Act section 9 prohibition against unauthorized incidental take provides some protection for the marbled murrelet, this may not be sufficient to protect and enhance habitat on non-Federal lands in the long term. This is because a continuing decline in populations would be expected to eventually result in unoccupied habitat where the prohibition against take may not apply. This unoccupied, but suitable, habitat might then be harvested, continuing the erosion of habitat that is needed to recover the species. Habitat Conservation Plans with appropriate measures to minimize and mitigate incidental take in the short term while providing for maintenance or creation of habitat for the long term probably offer the best means for conservation of the species on non-Federal lands. Land acquisitions or exchanges by Federal or State agencies and

conservation organizations could also contribute to protection and enhancement of habitat.

2.2 Protect marine habitat essential for marbled murrelet recovery.

While some marbled murrelet feeding activities may take place on freshwater lakes and rivers and some adult mortality results from accidents or predation in the terrestrial environment, most of the marbled murrelet's biological and physical interactions occur at sea, usually within 2 kilometers (1.2 miles) of the shoreline. In addition, adult mortality from both natural causes and human activities occurs in the marine environment. Given the essential role the marine environment plays in the daily and seasonal life of the marbled murrelet, protecting the quality of the marine environment (task 2.2) and reducing adult and juvenile mortality in the marine environment (task 3.1.2) are integral parts of this marbled murrelet recovery effort.

The main threats to marbled murrelets identified in their marine habitat result in the loss of individuals through death or injury. Marbled murrelets are adversely affected by spills of oil and other pollutants. Although these events undoubtedly harm the marbled murrelet prey base, their principal adverse impact is the death of birds in the area of the event. The effects of these events on the marbled murrelet prey base are somewhat more difficult to predict than are the effects on any marbled murrelets that happen to be in the area. Even very small oil spills have resulted in the death of large numbers, perhaps large proportions of local populations, of marbled murrelets. Smaller incidents of oil discharge, such as those associated with the cleaning of bilges and oil tanks at sea, can cumulatively result in significant mortality to marbled murrelets.

Although several existing Federal laws and regulations address reducing the threats identified in the marine environment, they may be insufficient to protect the quality of the marbled murrelet's marine habitat. Under the provisions of section 7 of the Endangered Species Act, the U.S. Fish and Wildlife Service must be consulted when projects authorized, funded, or carried out by a Federal agency may affect the marbled murrelet habitats.

Improved coordination of marbled murrelet recovery efforts among cooperating individuals and organizations is needed to integrate protection of marbled murrelet nesting and foraging habitats. The U.S. Fish and Wildlife Service will continue to monitor marine threats to marbled murrelets in consultation with other agencies and may propose marine critical habitat in the future, if warranted.

Five marine areas support the highest concentrations of marbled murrelets during the breeding season in Washington, Oregon, and California. Concentration areas of breeding marbled murrelets in the nearshore marine environment essential for foraging and loafing areas and in need of protection include:

(1) All waters of Puget Sound and the Strait of Juan de Fuca in Washington, including the waters of the San Juan Islands and river mouths;

(2) Nearshore waters (within 2 kilometers [1.2 miles] of the shore) along the Pacific Coast from Cape Flattery to Willapa Bay in Washington, including river mouths;

(3) Nearshore waters (within 2 kilometers [1.2 miles] of the shore) along the Pacific Coast from Newport Bay to Coos Bay in Oregon, including Yaquina Bay and river mouths;

(4) Nearshore waters (within 2 kilometers [1.2 miles] of the shore) along the Pacific Coast from the Oregon-California border south to Cape Mendocino in northern California, including Humboldt and Arcata Bays, and river mouths (e.g., mouths of the Smith River, Klamath River, Redwood Creek, and Eel River); and

(5) Nearshore waters (within 2 kilometers [1.2 miles] of the shore) along the Pacific Coast in central California from San Pedro Point south to the mouth of the Pajaro River, including the mouths of Pescadero Creek, Waddell Creek, and other creeks.

Each of these locations support large concentrations of marbled murrelets at sea and are near important areas of suitable nesting habitat. Protection should extend 2 kilometers (1.2 miles) offshore and include estuaries, river mouths, and the ocean floor because the majority of observations of birds at sea during the breeding season occur within these areas; marbled murrelets can dive and forage to great depths within the water column in these areas; and many nearshore, bottom- and midwater-dwelling prey occur and/or spawn in these areas, particularly associated with estuaries, river mouths, and the ocean floor. All other coastal areas between these concentration areas are also used by marbled murrelets, especially in winter, including nearshore waters south of Zone 6 to the U.S.-Mexican border. It is important to manage these waters in such a way as to reduce or eliminate marbled murrelet mortality, since individuals using these areas contribute to marbled murrelet populations in their respective Conservation Zones.

2.3 Develop and implement a landscape management strategy for each of the six Conservation Zones.

Although many of the factors that have contributed to the decline of marbled murrelet populations in the three-state area are common to all zones, each zone presents unique challenges to the recovery of the species. For example, mortality resulting from incidental capture in net fisheries is a major concern in Zone 1, mortality from oil spills is a major concern in Zones 2 and 6, and potential loss of key suitable nesting habitat on non-Federal lands is of major concern for all Zones. A landscape management plan that addresses the unique circumstances of each Zone should be developed, taking into consideration all affected parties (Federal, state, tribal, private, etc.).

2.3.1 Develop and implement management plans that incorporate the needs of the marbled murrelet for each protected habitat area on Federal lands.

Each protected habitat area within a particular Zone may have unique ecological features and exists in a unique spatial context with lands that may be managed for a variety of values. It is important that these unique characteristics be addressed in the context of a management plan for each

of these areas, including the development of appropriate definitions of suitable marbled murrelet habitat for each Zone. In the development of these plans for each Zone, all managers should have an opportunity to be involved, regional issues must be considered, and recovery objectives must be addressed in a consistent manner throughout the range. In some cases, these management plans could be developed using information from the Late-Successional Reserve assessments called for in the Forest Plan Record of Decision.

Management plans should be based on the best available information on the biology and recovery needs of the marbled murrelet and should be able to adapt to new information as it becomes available. For example, a variety of management activities could decrease predation mortality at marbled murrelet nests (e.g., silvicultural practices designed to provide shelter to nest sites or to speed development of murrelet habitat; garbage removal from state and national parks). Efforts to reduce or eliminate these manmade food sources in state and national parks are currently being discussed. As successful strategies are developed to reduce predation at the nest, they should be incorporated into management plans for specific secured areas. An outline of specific management recommendations is provided in task 3.

2.3.2 Develop and implement management strategies (e.g., Habitat Conservation Plans) that incorporate the needs of the marbled murrelet for protected areas on non-Federal lands.

Protected areas on Federal lands are expected to eventually provide sufficient habitat to possibly sustain viable populations of marbled murrelets over the long term (50–100 years and beyond) for most Zones in the three-state area. However, the demographic bottleneck that the marbled murrelet population may experience during the next 50 to 100 years makes the maintenance of marbled murrelet populations not found within Federal lands (mainly on state and private lands) an important component of more guaranteed viability and eventual recovery over the coming decades and into the future. Specific management strategies should be developed (e.g., Habitat Conservation Plans, SYPs, etc.) for

occupied and other potential marbled murrelet nesting habitat on non-Federal lands. These strategies should incorporate the best biological information about the recovery needs of the marbled murrelet and actually contribute to the conservation of the marbled murrelet. An outline of specific management recommendations is provided in task 3.

3. Incorporate management recommendations for protected habitat areas.

Management recommendations for the marbled murrelet need to address two different biological time frames, which reflect (1) aspects of the murrelet's life history and demographic trends, and (2) the length of time required to develop the majority of new nesting habitat or improve current forest habitat conditions. Short-term actions must address the apparent rapid decline of current populations and the need for immediate stabilization. The ability of marbled murrelet populations to recover rapidly is low due to the low reproductive potential of the species. Long-term actions address the long time-frames required to cultivate or enhance mature forest habitat conditions or to improve marine habitat quality because of the nature and complexity of these ecosystems. Little additional older forest habitat will become available until after 2040.

3.1 Implement short-term actions to stabilize and increase the population.

3.1.1 Maintain/protect occupied nesting habitat and minimize loss of unoccupied but suitable nesting habitat.

3.1.1.1 Maintain occupied nesting habitat.

The loss of occupied nesting habitat appears to be the primary cause of marbled murrelet population declines in Washington, Oregon, and California. The low reproductive potential of this species, and lack of knowledge concerning its ability to locate and reestablish new nesting areas after elimination of nesting habitat, makes it imperative to maintain all occupied nesting habitat, as is being done, for the most part, through implementation of the Forest Plan on Forest Service and Bureau of Land Management lands.

On non-Federal lands the maintenance of all occupied sites also should be the goal. However, it is realized that through the Habitat Conservation Plan process, there may be some limited loss of occupied sites or unsurveyed suitable habitat. In the short-term (the next 5–10 years), until additional information is obtained, loss of any occupied sites or unsurveyed suitable habitat should be avoided or the potential impacts significantly reduced through a habitat evaluation and ranking process outlined in the Habitat Conservation Plan. Short-term trade-offs for long-term benefits should be evaluated very carefully at this early stage of marbled murrelet recovery and should be done on a case-by-case basis.

3.1.1.2 Maintain potential and suitable habitat in larger contiguous blocks while maintaining current north/south and east/west distribution of nesting habitat.

By maintaining occupied sites and suitable habitat in larger blocks with low levels of fragmentation, several objectives will be met. Larger stands will (1) have more nesting and hiding opportunities, (2) provide for multiple alternative nesting sites for individual pairs of birds over time, (3) facilitate nesting for multiple pairs of birds (and thus promote increased social contact), and (4) provide greater interior forest habitat conditions (to reduce potential nest and adult predation, increase protection of nests from windstorms and environmental changes, and reduce loss of habitat from windthrow and fire). Larger stands also may provide a core of birds to attract or develop sufficient activity and eventual nesting by subadults or nonbreeding adult birds to replace breeding adults lost from this habitat over time due to natural causes or human activities.

The more contiguous the habitat distribution, the lower the likelihood of future large gaps in distribution of the species due to catastrophic events such as oil spills or large wildfires. Preventing further erosion of the already patchily-distributed nesting habitat is a key element in buffering the species against such catastrophic events. This is especially important in areas where gaps already occur. Furthermore,

it is currently unknown how nesting success differs with distance from the coast, and far inland habitats may be as important to species survival as those nearer to shore. Therefore, it is important to maintain both north/south and east/west distribution of suitable habitat.

3.1.1.3 Maintain and enhance buffer habitat surrounding occupied habitat.

Maintaining buffers around occupied habitat will mediate the effects of edge by helping to reduce environmental changes within the stand, reduce loss of habitat from windthrow and fire, reduce fragmentation levels, increase the amount of interior forest habitat available, and potentially help reduce predation at the nest. To have the greatest benefits, buffer widths should be a minimum of 300–600 feet and should consist of whatever age stand is present, including existing plantations (which should be managed to provide replacement habitat).

3.1.2 Decrease adult and juvenile mortality.

3.1.2.1 Reduce mortality from net fisheries.

Net fisheries can lead to a significant increase in mortality to adults, subadults, and juveniles. Net mortality is currently highest in Puget Sound where intensive net fisheries occur over an extensive area of marine habitat.

Strategies to be investigated and used, where appropriate, include the exclusion of net fisheries from marbled murrelet concentration areas to help minimize by-catch mortality and the use of alternative or modified fishing gear to decrease the probability of mortality. A Public forum has been developed to discuss this issue between various Federal and state agencies and interest groups. Such forums were important in addressing similar problems in California in the 1980's (Salzman 1989). The situation is very complex and probably

will not be resolved immediately. The cumulative effects of net mortality and other threats facing marbled murrelets must be further examined, especially in Washington.

3.1.2.2 Minimize probability of oil spills and develop means to reduce impacts of oil spills and pollution.

The four areas with the greatest spill potential are Puget Sound, central California, southwest Washington, and northern California. Strategies to maintain marine environment quality should be developed including reduction of bird mortality from oil spills, development of contingency plans for damage assessments (including beached bird surveys, carcass examination and preservation, live oiled bird captures, and at-sea surveys), and oiled bird care (including rehabilitation and captive care techniques). Techniques for containing oil spills (e.g., booms) should be studied in marbled murrelet concentration areas. Protection of river mouths may benefit marbled murrelet prey species. Impacts of dispersants and hazing actions should be investigated before use. In particular, marine pollutants should be reduced, especially in the Puget Sound and Santa Cruz Mountains Zones.

3.1.3 Minimize nest disturbances to increase reproductive success.

Low juvenile:adult ratios have been documented throughout the three-state range of the marbled murrelet (Appendix B). Current evidence suggests that the cause of this low reproductive rate may be due to high rates of predation on eggs, young, and possibly adults at the nest site. Population modeling indicates that adjusted juvenile:adult ratios should be 15–22 percent at a minimum to result in stable or increasing populations. Current best estimates of unadjusted ratios average 5 percent (range 0.1–13.8 percent) and it is unlikely that adjustment will result in 4–10 times larger ratios. Breeding adult alcids in general are sensitive to nest site disturbance during the incubation period and the first few days of chick rearing. Disturbances near marbled murrelet nest sites that flush incubating or brooding adults from the nest site may expose adults and

young to increased predation or accidental loss of eggs or nestlings by falling or being knocked out of nests. Human activities near nesting areas that result in an increase in the number of predators also could lead to a greater likelihood of nest predation. The timing of disturbances should be adjusted to avoid disruption of marbled murrelet activities, such as courtship, mating, and nesting. Human activities should be modified to reduce attraction of predators to specific forest areas although this action may not reduce actual predator numbers over wider areas. Higher-than-normal predation levels are likely to occur in nesting habitat due to forest fragmentation and other causes in many cases.

3.2 Implement long-term actions to stop population decline and increase population growth.

3.2.1 Increase the amount and quality of suitable nesting habitat.

An increase in amount and quality of suitable nesting habitat is important in all zones. However, it is especially important in the western Washington Coast Range and the northern portions of the Oregon Coast Range Zones. In these areas, remaining patches of suitable nesting habitat are relatively small and fragmented, involve private and state lands, and are vitally important for maintaining the current small populations in these areas; thus, blocking up habitat is needed to increase patch size. It also would be desirable to increase and block up suitable nesting habitat in the Mendocino and Santa Cruz Mountains Zones. Little habitat remains outside parks in these two zones, such that an increase in the short term does not appear feasible.

3.2.1.1 Decrease fragmentation by increasing the size of suitable stands to provide a larger area of interior forest conditions.

The majority of suitable nest stands currently exist as small islands within a matrix of younger forests. Although these fragments will provide critically important habitat during the several decades required for younger stands to develop structural characteristics suitable for marbled murrelet nesting, they cannot be considered high

quality habitat because of vulnerability to wildfire and windthrow, and perhaps a higher abundance of avian predators. Research is needed to develop judicious ways to use silvicultural techniques such as thinning in young (nonhabitat) stands to hasten development of large trees and decrease vulnerability of habitat fragments to fire, wind, and perhaps predators. Consistent with the Forest Plan Record of Decision, thinning within Late-Successional Reserves should be restricted to stands younger than 80 years. However, the Record of Decision also permits thinning within Late-Successional Reserves up to age 110 in Coast Range lands administered by the Bureau of Land Management (Nestucca block) and in the Oregon and California Klamath Provinces (U.S. Department of Agriculture and U.S. Fish and Wildlife Service 1994b). Unthinned buffers should be left around any occupied stands. Precautions should be taken to reduce fire hazard from thinning slash and avoid soil compaction.

3.2.1.2 Protect "recruitment" nesting habitat to buffer and enlarge existing stands, reduce fragmentation, and provide replacement habitat for current suitable nesting habitat lost to disturbance events.

Stands (currently 80 years old or older) that will produce suitable habitat within the next few decades are the most immediate source of new habitat and may be the only replacement for existing habitat lost to disturbance (e.g., timber harvest, fires, etc.) over the next century. Such stands are particularly important because of the vulnerability of many existing habitat fragments to fire and wind and the possibility that climate change will increase the effects of the frequency and severity of natural disturbances. Such stands should not be subjected to any silvicultural treatment that diminishes their capacity to provide quality nesting habitat in the future. Within secured areas, these "recruitment" stands should not be harvested or thinned. In the matrix (on Federal lands), harvest in younger-aged stands should adhere to the techniques discussed in the following task (3.2.1.3) to more quickly develop into marbled murrelet habitat.

3.2.1.3 Use silvicultural techniques to increase speed of development of new habitat.

Nesting marbled murrelets select stands with large trees that provide suitable nesting platforms (large, protected branches, preferably with moss). When available, large stands appear to be preferred over small ones. Nests have been located in stands with a wide range of stocking densities, however the low rate of nesting success raises considerable uncertainty regarding what constitutes quality habitat. It is expected that since marbled murrelets require very specific structures in order to successfully nest, silvicultural techniques may be available to speed the development of these structures in stands of younger forest.

Several silvicultural techniques may be appropriate to increase the area of suitable nesting stands and the rate at which they develop (e.g., thinning, long rotations, etc.). Thinning accelerates tree growth and can be used as a tool to produce large trees more quickly than in normal stand development. However, simply growing large trees is not sufficient to obtain suitable marbled murrelet habitat. Trees must have large moss-covered, or mistletoed branches that provide nest platforms, something that is likely to be achieved only by growing at least some trees on long rotations. There are two alternatives for doing that (1) "Green-tree retention" designates approximately 20–40 trees per hectare to be retained at harvest, with a new crop of younger trees established beneath the older tree canopy. Leaving trees on site and allowing them to grow to an older age will likely produce marbled murrelet nest trees and eventually produce coarse woody debris (important habitat for numerous other species). As younger trees mature, a multilayered canopy develops, which is also an important structural attribute of older forest habitat; and (2) evidence available at this time indicates that growing whole stands on long rotations will produce higher quality habitat in the long-term than green tree retention, which may create sink habitat for a number of bird species. Long rotations have other ecological and economic benefits as well. Landscapes with a higher proportion of older stands should be less susceptible to catastrophic wildfire (providing reduced

hazard from thinning slash). Because thinned Douglas-fir maintains good growth well into its second century, silviculturists now conclude that long rotations are economically viable in the Douglas-fir region.

3.2.2 Improve Distribution of Nesting Habitat.

3.2.2.1 Improve and develop north/south distribution of nesting habitat.

Improving the distribution of nesting habitat helps to buffer existing populations against poor breeding success and catastrophic loss and probably facilitates gene flow among separated populations. Three major gaps in existing habitat are particularly apparent: (1) from the southern Olympic Peninsula in Washington to Tillamook in northwestern Oregon; (2) between Patrick's Point and southern Humboldt Bay in northern California (see Figure 1); and (3) throughout most of the Mendocino Zone and the northern part of the Santa Cruz Mountains Zone (between southern Humboldt County and central San Mateo County). These three geographic gaps represent probable partial barriers to gene flow across them. They include large areas of second-growth forests that originated after logging, from fire (parts of northwestern Oregon), or from natural discontinuities of nesting habitat (especially parts of northern and central California). Gap areas often have a high proportion of private lands and little or no Federal land. State lands cover significant portions of northwest Oregon (the Tillamook and Clatsop State Forests) and southwest Washington. Silvicultural techniques to create suitable habitat at both the stand and landscape level (discussed in task 3.2.1.3) may be particularly beneficial to marbled murrelet recovery in the long term if applied in these areas.

Portions of the Mendocino Zone and Santa Cruz Mountains Zone also contain blocks of unsuitable habitat that probably naturally created small gaps in the murrelet's terrestrial range. Again, loss of suitable habitat around these small natural gaps has greatly widened them. These gaps have probably grown together and eliminated suitable

nesting habitat over a large section of their range. The existence of small natural gaps in suitable habitat must be recognized when designing ways to improve and develop north/south distribution of nesting habitat.

3.2.2.2 Improve and develop east/west distribution of nesting habitat.

Improving east-west distribution means filling in habitat gaps within the Conservation Zone boundaries described earlier. Many portions of the species' range no longer have large amounts of suitable nesting habitat close to the coast and marbled murrelets must fly considerable distances inland to nest. In addition to the north-south gaps discussed above, opportunities exist on the Olympic Peninsula, Puget trough, and along virtually the entire California coast within the murrelet's range to improve the current east/west distribution of habitat. An important step in developing methods to improve this distribution will be the complete identification of the inland boundary of suitable nesting habitat for the three-state area and identification of factors determining these boundaries in different regions.

4. Initiate research necessary to guide recovery efforts.

Much remains to be discovered about the behavior, ecology, and population status of the marbled murrelet in order to correct and reverse factors affecting population decline and growth, and to refine approaches for recovering its populations. The recovery of the marbled murrelet will depend to a large extent on the protection and wise management of the marine and terrestrial habitats upon which it depends. These habitats are directly exploited by humans for natural resources and affected indirectly by pollution and other management activities. Their management also has been hampered by a lack of biological information about the marbled murrelet. Well-conducted, strategic research will be necessary to achieve recovery goals and maximize management benefits.

4.1 Monitor marbled murrelet populations and habitat.

Accurate and repeatable inventory and monitoring of marbled murrelet populations and marine and terrestrial habitat is essential in order to evaluate population trends and the effectiveness of specific recovery actions. At present, much suitable marbled murrelet nesting habitat remains uninventoried for use by marbled murrelets. Nesting habitat has been identified for only a small fraction of the at-sea population of marbled murrelets. At-sea population size and distribution must be measured over many years to best assess population trends. The demography of marbled murrelet populations must be refined to improve our understanding of the species' status and population trends. These demographic parameters can only be determined through intensive and extensive inventory and monitoring, as well as through the development of new techniques. Inventory and monitoring efforts should be conducted in both terrestrial and marine environments that are important to marbled murrelet recovery in the short and long term.

4.1.1 Develop and refine protocols for monitoring population trends, productivity, and distribution.

Determining and monitoring the trends, distribution and annual breeding success (e.g., correlated to the rate of recruitment of young into the adult breeding population) of populations are basic to understanding the status of the marbled murrelet and the factors that influence population growth. Problems with the current techniques used to estimate productivity, population density, and population size make the current estimates of those parameters less accurate than would be desirable. Marine sampling methodologies should be further refined and tested.

4.1.2 Standardize and conduct at-sea surveys for inventory and monitoring of population size and distribution.

Because of the difficulty of censussing marbled murrelets in their terrestrial environment, at-sea surveys offer the best opportunity to monitor overall population size and distribution of marbled murrelets. Previous at-sea surveys have used a variety of survey protocols, which has

made comparison of results from different surveys difficult. Once the protocol has been refined, it should be standardized and made comparable for both survey and analysis techniques. Additional survey effort should occur at offshore water areas that may provide highly productive foraging locations for marine birds beyond the coastal near- shore zone. As important, a standard protocol must be developed and followed to measure at-sea population size and distribution. Obtaining population trend data (on population density and/or distribution) should be given the highest priority in marbled murrelet at-sea inventories because this information is the ultimate measure of population status.

Surveys to estimate population trends must be conducted throughout the range of the marbled murrelet and should be standardized. No standardized protocol has yet been established. A workshop was held in November 1996 to address this issue and develop the needed standard protocol.

4.1.3 Standardize and conduct at-sea surveys and nest studies to monitor breeding success.

Knowledge of breeding success for populations of marbled murrelets is critical to demographic models. As for population size and distribution, breeding success can be determined using at-sea surveys in late summer that determine a juvenile:adult ratio. This ratio is correlated with breeding success, but exact relationships are still forthcoming. Breeding success also can be determined directly at any nests found although these have been few in any one year. Over several years, or if more nests can be discovered annually, larger sample sizes can be obtained and compared to at-sea estimates of breeding success, based on juvenile:adult ratios. However, both techniques require standardization of data collected and study design. Gathering information on breeding success in all Conservation Zones is important. Breeding success is a strong predictor of future decline or increase and thus will provide important predictive information on future population status and help measure the long-term success of conservation measures.

4.1.4 Develop a definition of suitable marbled murrelet habitat for each Conservation Zone.

A definition of suitable marbled murrelet habitat should be developed for each Conservation Zone to better determine and map appropriate areas for murrelet recovery. Although the components of suitable marbled murrelet habitat are generally known, a description of suitable marbled murrelet habitat for each Conservation Zone is lacking. Once these definitions have been developed, mapping marbled murrelet habitat can be accomplished with greater accuracy.

4.1.5 Determine and map potential breeding habitat, including recruitment and replacement habitat.

Despite recent efforts by Federal and state agencies and the public and private sectors to map late-successional forests within the range of the marbled murrelet, the distribution and amount of suitable breeding habitat for the marbled murrelet remains incompletely known. Only a fraction of all potential suitable nesting habitat has been surveyed for marbled murrelets. Many of the characteristics of suitable nesting habitat, especially large horizontal limbs providing nest platforms, are difficult to predict using remote sensing techniques. Refining the landsat cover classes and correlating these classes to marbled murrelet habitat features will be an important part of this task. The development of a geographic data base of the locations of known and potential nesting habitat is an essential first step to developing management strategies and plans for the marbled murrelet in its terrestrial environment. Mapping and related ground-truthing of both recruitment habitat (stands capable of becoming marbled murrelet habitat within 25 years) and replacement habitat throughout Washington, Oregon, and California should be completed as soon as possible.

4.1.6 Survey potential breeding habitat to identify potential nesting areas.

All aspects of marbled murrelet recovery in the terrestrial environment depend on identification of nesting habitat. Nesting habitat is any suitable habitat where marbled murrelet use has been documented. Use by

marbled murrelets includes "occupied" and other behaviors or detections indicative of local breeding activity by marbled murrelets. At present the locations of actual nesting habitat are known for only a small fraction of the at-sea population.

Potential habitat should be surveyed for marbled murrelets regardless of whether it is considered near-coastal or far inland habitat (e.g., within Zones 1 and 2 as described by the Forest Ecosystem Management Assessment Team). A lack of information about the relative importance of these sites to the recovery of the species currently exists. Stands should not be designated as unsuitable habitat because they have (1) small patches of habitat or a few remnant old-growth trees; (2) smaller limb sizes; (3) little moss cover on tree branches; (4) poor access conditions for birds; or (5) particular aspects may cause suitable habitat to go unsurveyed. Field assessments prior to determining habitat suitability are of vital importance to the conservation and protection of marbled murrelet breeding sites.

For areas within a Conservation Zone where no marbled murrelets have been detected, intensive surveys should be conducted to identify nesting areas and delineate the inland boundary of nesting habitat. These surveys could relieve land managers from future constraints of Forest Plan implementation. These surveys could be cooperative efforts with other landowners in the area to reduce costs to any single landowner.

If delineating new inland range boundaries is an objective for an area, the use of survey efforts and analytical methods similar to the study recently completed by the Six Rivers National Forest in California (Hunter *et al.* 1997) is recommended. The survey intensity and statistical rigor used in this study should produce reliable and accurate results in other similar studies, leading to the best management decisions possible. The objectives of these studies should be to not only demonstrate where birds are absent, but attempt to locate the regions where the birds begin to use the landscape. Focusing on single ownership issues may lead to narrow conclusions that have less benefit to all land managers in a region.

Recovery of the species depends on preventing its extinction during the next 50 to 100 years, before additional suitable nesting habitat will be developed in many secured areas. This can only be done if the locations of most, if not all, occupied nesting habitat is known. Considerable effort is, therefore, justified to identify the location of sites currently used by marbled murrelets, regardless of their distance inland. Because many different agencies are likely to be involved in surveys for potential nesting areas, it is important that standard protocols be used when surveying for site use. Similarly, structural and floristic characteristics of sites should be gathered in some detail to facilitate the job of assessing the suitability of unsurveyed sites for use, based solely on habitat characteristics and proximity to other surveyed sites.

4.1.7 Evaluate terrestrial survey protocol.

A better understanding is needed of what the different kinds of marbled murrelet behaviors indicate about nesting status. Little is understood about the year-to-year variation in detection rates and whether the terrestrial survey protocol requires sufficient census effort to be able to detect site occupancy when surveyed under El Niño conditions and to determine the relationship between detection rates and numbers of birds, use of flight corridors, and landscape-level flight behavior.

4.2 Refine and validate the current marbled murrelet population model.

4.2.1 Utilize at-sea surveys conducted in 4.1.2 above to refine estimates of current population size and distribution, and to verify trends for each of the six Conservation Zones.

Verified trend information is necessary for meeting interim delisting criteria, helping establish more specific delisting criteria, and assisting in determining existing and projected population status (see Appendix B).

4.2.2 Develop survivorship estimates for the marbled murrelet.

Little is known directly about the survivorship of marbled murrelets. Similar to other alcids, marbled murrelets are likely to be relatively long-

lived and changes in survivorship rates will have important effects on population fluctuations and results from population modeling. Mark and recapture studies (which may include telemetry) or the development of new techniques are needed to develop estimates of annual survival. Monitor survivorship of adults and juveniles at nest sites.

4.2.3 Refine estimates of breeding success from juvenile:adult ratios.

Juvenile:adult ratios can be converted to estimates of fecundity for use in population models (Appendix B). Better estimates of juvenile:adult ratios should result from monitoring conducted in task 4.1.3, but would be enhanced with more information on the timing of fledging from nests and better knowledge of the timing and nature of dispersal of juveniles and adults/subadults.

4.3 Determine the genetic structure of marbled murrelet populations and if differences exist among the six Zones.

The genetic structure of a population indicates the amount of time that populations may have been separated from each other, how much dispersal takes place among subpopulations, and whether genetic differences exist among subpopulations. Nothing is currently known about genetic variation of marbled murrelets, although significant genetic differences due to the recent separation of populations in the Pacific Northwest are unlikely. Molecular population genetic approaches should be employed.

4.4 Determine the relative contribution of various factors limiting marbled murrelet population growth.

Recovery of the marbled murrelet depends on determining the role of different factors that could limit the growth of marbled murrelet populations (see Appendix B). Human-caused disturbance can adversely affect the marbled murrelet in both the terrestrial and marine environments. The significance of these disturbances has not been studied, although in general the effects are anticipated to be much less than loss of nesting habitat. If disturbances have a significant negative impact on either nesting success or adult energetics, their

control will become an important part of the recovery strategy for the species. Research is needed to determine the impact of human disturbances on marbled murrelet biology.

4.4.1 Improve understanding of limiting factors in forest nesting habitats.

The quality of the forest environment is closely related to marbled murrelet reproductive success, which appears to be very low. Studies should determine the various terrestrial factors that might account for the low productivity.

4.4.1.1 Improve understanding of factors affecting nesting success.

It is important to find more nests and monitor them carefully to determine nesting success, improve estimates of predation effects on nesting success, and refine our knowledge of the causes of nest failure. This includes an understanding of how nesting success and predator populations are affected by forest fragmentation, distance from the nest to the edge of the stand, stand size, stand structure, canopy closure, and distance from the sea. Research on nest behavior and success should be given high priority because of its direct relevance to the development of a recovery strategy.

4.4.1.2 Improve understanding of nesting habitat limitations.

Refined measures of nest site structure and selection by marbled murrelets, and the availability of nesting habitat are needed. Nest site selection must be related to site and landscape characteristics such as age and branching structure of trees, overhead cover, canopy closure, distance inland, distance from the nearest nest, nest site fidelity, and stand vulnerability to catastrophic disturbance.

4.4.1.3 Evaluate the effects of disturbance of forest management activities on nesting marbled murrelets.

Forest management activities create visual, acoustic, and air quality disturbances that may affect nest site selection. They may also cause nest abandonment or nest failure through adult avoidance of nest sites near the sources of disturbance. Even less invasive silvicultural practices, such as helicopter logging, result in the production of visual, acoustic and air disturbances that may negatively effect marbled murrelet nesting success. Burning and smoke production may also affect marbled murrelets. Research is needed to quantify what effect these disturbances may have on marbled murrelet nesting biology.

4.4.2 Determine limiting factors in marine habitats.

Marbled murrelet population growth may be affected in some portions of their range by mortality from net fisheries and oil spills, or by reduced breeding success or lower survivorship due to possible variations in prey availability.

4.4.2.1 Determine the relative importance of human activities (e.g., net fisheries, oil spills) on adult/subadult mortality.

In a small portion of the range of the marbled murrelet in the Pacific Northwest, marbled murrelets may die from entanglement in nets. Oil spills and other marine pollution may affect marbled murrelets throughout the range, although the frequency of oil spills varies between areas. Studies should quantify these risk factors.

While direct mortality from encounters with boat traffic in the marine environment is likely to be rare, disturbance by passing boats could result in lower foraging success, birds not foraging in certain disturbed areas, and increased energy expenditure during avoidance reactions. Research on the sensitivity of marbled murrelets to disturbance and the effects of disturbance on foraging and nesting

success should be carried out. In addition, disturbance effects on marbled murrelets from frequent escape-diving from boats, commercial machinery, and recreational activities (e.g., jet skis) in nearshore environments should be investigated and quantified.

Studies should examine the effects of marine pollution on marbled murrelets, their breeding success and prey species. In particular, Puget Sound and Santa Cruz Mountains populations should be checked known contaminant loading in these areas.

In addition to pollution and net fisheries' mortalities and possible overfishing of prey resources, other human activities should be studied carefully to prevent impacts to marbled murrelet prey resources and their habitats, including (1) changes in estuarine dynamics through currents, salinity, and water quality; (2) changes in nearshore physical environments (e.g., coastline topography, bathymetry, and bottom substrates and sediments), especially through dredging or shoreline development (i.e. shoreline filling, erosion control, construction of marinas, breakwaters, highways, railroads, and other developments); (3) changes to nearshore marine food chains; and (4) various forms of pollution that can affect water quality pollution.

Impacts of human activities on prey resources and feeding conditions could contribute cumulatively to other better-known impacts (including nesting habitat loss, oil spills, and net mortalities) and together contribute to serious population declines or extirpations. However, impacts of human activities should be well-established through additional study before extensive efforts should be expended on efforts to protect prey resources on behalf of maintaining marbled murrelet populations or assisting recovery efforts.

4.4.2.2 Determine how natural or human-enhanced variability in, or depression of, food resources affect survivorship of marbled murrelets or productivity.

Studies of the relationships between the variability in prey populations due to natural causes (e.g., El Niño events) and human activities (e.g., pollution, sedimentation, overfishing, etc.) and marbled murrelet survival and productivity are needed. Prey research should evaluate the potential impacts of human activities on prey resources and their habitats (as currently known) considered by Federal and state agencies involved in coastal management issues. At present levels, fishing harvest of certain prey species (e.g., northern anchovy, Pacific sardine, Pacific herring, smelts) have not been documented to cause overall prey reductions for marbled murrelets on the west coast. However, extensive past fishing pressure certainly contributed to declines in Pacific sardines. Most marine biologists do not consider catch statistics alone to adequately reflect the status of prey resources (especially when not adjusted for catch effort, market prices, and changes in fishing regulations), even though catch can at times mirror changes in fish populations. High fishing effort or the development of new fisheries on known or potential prey species should be considered as having potential effects requiring further study. Such studies will require more knowledge of marbled murrelet diet than is currently available on the west coast.

4.5 Conduct basic life history studies.

Much of the life history of the marbled murrelet is poorly known. Its nesting habitat was a mystery until very recently, only a few samples are available to suggest its food habits, and little is known about its demographics. Although recent research has provided sufficient insights into the biology of the marbled murrelet to strongly suggest a considerable decline in population numbers and inadequate recruitment for long-term survival of the species, much remains to be learned about the marbled murrelet through continuing research on basic aspects of its life history.

4.5.1 Conduct studies on food habits of marbled murrelets.

Additional research is necessary for (1) determining the diet of marbled murrelets (through non-lethal means), (2) studying the ecology and status of marbled murrelet prey species (especially Pacific sand lance), and (3) maintaining prey resources at adequate levels to sustain marbled murrelet populations and assist recovery throughout the three-state area. Diet studies are needed to determine marbled murrelet prey species. In addition, studies of abundance, distribution, and biology of prey species are needed to better understand marbled murrelet distribution and ecology at sea, and to ensure continued levels of prey availability, prevent impacts of human activities that may affect prey (i.e., overfishing, pollutants, coastal development, etc.), and maintain other aspects of marine habitat quality (e.g., reduce disturbance).

Information about marbled murrelet diet can come from examination of stomach contents or by observing food items held in the bills of birds at sea or brought to the nest by adults. Isotope analyses also have been useful for determining the trophic level of marbled murrelets. Because adult and nestling diets often differ, the abundance and availability of prey items of different types may have effects on both adult survival and breeding success. Although difficult, research on food habits of the marbled murrelet is essential for a better understanding of possible relationships between fluctuations in prey densities and marbled murrelet nesting success and adult survivorship.

4.5.2 Conduct studies on population immigration/emigration and colonization of nesting areas by marbled murrelets.

There are many unanswered questions about the dispersal ability and movement habits of the marbled murrelet. Dispersal of juveniles, nest site fidelity, and colonization of unoccupied habitat all require further research, both within and between populations. Several aspects of the recovery strategy for the marbled murrelet would benefit from better knowledge of marbled murrelet movements. It is especially important to determine how readily unoccupied forest habitat will be colonized, and to identify the factors that contribute to or hinder successful colonization of unoccupied habitat. Unoccupied habitat should include older forest areas adjacent to

occupied habitat (which may be used periodically), older forest areas disjunct from occupied habitat (which may be used periodically), and second-growth forests approaching older forest conditions (both adjacent and disjunct from occupied habitat). Considerable emphasis has been placed on the development of habitat for marbled murrelets in Late-Successional Reserves over a period of decades. Research on movement of marbled murrelets is needed to determine the extent that Late-Successional Reserves will contribute to marbled murrelet recovery.

4.5.3 Conduct studies on marine habitat use by marbled murrelets.

Despite recent at-sea surveys for the marbled murrelet, little is known about the exact distribution of marbled murrelets in the marine environment and how it varies between years and throughout the year. Most marbled murrelets are found in nearshore waters, especially juvenile marbled murrelets, but more research is necessary to determine the use of various portions of the marine environment by the marbled murrelet. This work would include any relationships between location of food items and underwater features, differential use of various marine habitats by age class, and the use of waters farther than 2 kilometers (1.2 miles) off shore by marbled murrelets.

5. Establish a Regional West Coast Data Center for the marbled murrelet.

The range of the threatened marbled murrelet extends across three states and lands administered by a multitude of entities. Research, inventory and monitoring activities are carried out by individuals representing those entities:

Federal agencies

- U.S. Department of the Interior
  - Fish and Wildlife Service
  - Bureau of Indian Affairs
  - Bureau of Land Management
  - National Park Service
  - Geological Survey (Biological Resources Division)

U.S. Department of Agriculture
Forest Service
U.S. Department of Commerce (National Oceanic and Atmospheric Administration)
National Marine Fisheries Service
Monterey Bay National Marine Sanctuary
Gulf of the Farallones National Marine Sanctuary
Olympic Coast National Marine Sanctuary

State agencies
Washington Department of Fish and Wildlife
Washington Department of Natural Resources
Oregon Department of Fish and Wildlife
Oregon Department of Forestry
California Department of Fish and Game
California Department of Forestry
California Department of Parks and Recreation

Universities
University of Washington
Humboldt State University
Oregon State University
University of California Santa Cruz
University of California Berkeley
Moss Landing Marine Laboratory
Mark O. Hatfield Marine Science Center

Tribes
Indian Nations and Tribal Groups

Private
Pacific Seabird Group
Private timber companies
Private research and consulting groups
Environmental groups

Through the cooperation of scientists involved in efforts through the Pacific Seabird Group and the interagency marbled murrelet conservation assessment, much progress has been made toward collating existing data and developing consistent standardized data collection techniques, greatly facilitating future comparisons between different areas or years. Despite this progress, there is no central repository for historical, current or future inventory or monitoring data gathered by researchers. As a result, each agency has tended to develop its own costly and incomplete data management and retrieval system. Because of multiple jurisdictions involved, this approach to data management results in considerable duplication of effort and many sources for partial data sets, none of which is designed to answer critical questions about range wide status, trends, or terrestrial or marine distribution of the marbled murrelet. Much data have remained unavailable, despite recent efforts to collate information.

As data continue to be gathered to answer critical questions about marbled murrelet status, distribution, and population trends in response to various recovery and management activities, it is important that those groups developing the overall recovery strategy have access to all historical and current, range-wide research results and raw data. To meet this need, establishment of a West Coast Marbled Murrelet Data Center (Data Center) is recommended, whose mission will be to maintain contact with various marbled murrelet research, inventory, and monitoring activities and assemble range-wide results of these activities. This Data Center would most appropriately be the responsibility of the U.S. Geological Survey (Biological Resources Division) or an interagency group like the Marbled Murrelet Cooperative (Appendix C) similar to that established to assist in implementation of the Forest Plan. There is little doubt that continuing research by investigators throughout the range of the marbled murrelet will provide data that can enhance adaptive management decisions made for the recovery effort. Unless these data are centralized and analyzed on a region-wide basis, those groups responsible for recovery will be denied access to some of the best available scientific information on the species throughout its three-state range. In addition, some data will not otherwise become archived and will be lost and not usable by future managers and researchers. The establishment of a permanent Data Center is a precursor to long-term recovery actions based on the best currently available scientific data.

PART III. LITERATURE CITED

"... a species must be saved *in many places* if it is to be saved at all."

- Aldo Leopold, *A Sand County Almanac and sketches here and there*

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Part IV. Implementation Schedule

"The rapidity of change and the speed with which new situations are created follow the impetuous and heedless pace of man rather than the deliberate pace of nature."
Rachel Carson, Silent Spring

IV. IMPLEMENTATION SCHEDULE

The table that follows is a summary of scheduled actions and costs for this recovery program. It is a guide to meet the interim recovery objectives. This table indicates the scheduling priority for each task, which agencies are responsible for performing these tasks, and the estimated costs to perform them. Implementation of all tasks listed in the Implementation Schedule will lead to recovery. Initiation of these actions is subject to availability of funds.

Priorities in column two of the implementation schedule are assigned as follows:

1. **Priority 1:** An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2. **Priority 2:** An action that must be taken to prevent a significant decline in population or habitat quality, or some other significant negative impact short of extinction.

3. **Priority 3:** All other actions necessary to meet recovery objectives

ACRONYMS USED IN THE IMPLEMENTATION SCHEDULE

AMA	=	Adaptive Management Area
BLM	=	Bureau of Land Management
BRD	=	Biological Resources Division, U.S. Geological Survey
CDF	=	California Department of Forestry and Fire Protection
CDFG	=	California Department of Fish and Game
FS	=	U.S. Forest Service
FWS	=	U.S. Fish and Wildlife Service
HCP	=	Habitat Conservation Plan
LSR	=	Late-Successional Reserve
NMFS	=	National Marine Fisheries Service
NOAA	=	National Oceanic and Atmospheric Administration
NPS	=	National Park Service
ODF	=	Oregon Department of Forestry
ODFW	=	Oregon Department of Fish and Wildlife
PVT	=	Private ownership
ROD	=	Record of Decision
TBD	=	To be determined (TBD[1] = costs included in ongoing actions)
USCG	=	U.S. Coast Guard
WDFW	=	Washington Department of Fish and Wildlife
WDNR	=	Washington Department of Natural Resources
Continual	=	Task will be implemented on an annual or periodic basis once it is begun.
Ongoing	=	Task is currently being implemented and will continue until actions are no longer necessary for recovery.

Recovery Plan Implementation Schedule for the Marbled Murrelet.

Task #	Priority #	Task Description	Task Duration (yrs)	Responsible Party	Total Cost	Cost Estimates ($1,000)				
						FY 1997	FY 1998	FY 1999	FY 2000	Comments
2.1	1	Protect terrestrial habitat essential for murrelet recovery	Ongoing	FWS BLM FS WDNR ODF CDF PVT	TBD[1]					FWS designated critical habitat on May 24,1996. Several HCPs have been completed on State and private lands that provide additional habitat protection.
2.2	1	Protect marine habitat essential for murrelet recovery	Ongoing	FWS NOAA	TBD TBD					
2.3.1	1	Develop and implement management plans for protected habitat areas on Federal lands	3-5	FWS BLM FS	500 1,000 1,000	100 200 200	100 200 200	100 200 200	100 200 200	LSR management plans are, and will be, developed by the BLM and FS as required in the ROD, with assistance from FWS; they will include murrelet management actions.
2.3.2	1	Develop and implement management strategies for protected habitat areas on non-Federal lands	3-5	FWS WDNR WDFW ODF ODFW CDF CDFG PVT	1,000 TBD[1] TBD[1] TBD[1] TBD[1] TBD[1] TBD[1] TBD[1]	200 TBD TBD TBD TBD TBD TBD TBD	250 TBD TBD TBD TBD TBD TBD TBD	250 TBD TBD TBD TBD TBD TBD TBD	200 TBD TBD TBD TBD TBD TBD TBD	HCPs are currently being worked on by state agencies and private companies/individuals in all three states that involve murrelets. These are anticipated to continue for at least the next several years.
3.1.1.1	1	Maintain occupied nesting habitat	10	BLM FS WDNR WDFW ODF ODFW CDF CDFG PVT	TBD[1] TBD[1]					BLM and FS, in compliance with the ROD, will maintain all occupied murrelet nesting habitat. Non-Federal agencies, companies, and individuals have begun to address occupied murrelet habitat through the HCP process and Forest Practice Rules.

Recovery Plan Implementation Schedule for the Marbled Murrelet.

Task #	Priority #	Task Description	Task Duration (yrs)	Responsible Party	Total Cost	Cost Estimates ($1,000)				
						FY 1997	FY 1998	FY 1999	FY 2000	Comments
3.1.1.2	1	Maintain potential and suitable habitat in larger contiguous blocks while maintaining north/south and east/west distribution of nesting habitat	10	BLM FS NPS WDNR ODF CDF	TBD[1] TBD[1]					This should be accomplished for BLM and FS, in part, by compliance with the ROD for potential and suitable habitat inside LSRs and adjacent to occupied sites in the matrix.
3.1.1.3	1	Maintain and enhance buffer habitat surrounding occupied habitat	10	BLM FS NPS WDNR ODF CDF	TBD[1] TBD[1]					This should be accomplished for BLM and FS, in part, by compliance with the ROD for potential and suitable habitat inside LSRs and adjacent to occupied sites in the matrix.
3.1.2.1	1	Reduce mortality from net fisheries	Ongoing	FWS WDFW TRIBES NMFS	TBD TBD TBD TBD	TBD TBD TBD TBD	TBD TBD TBD TBD	TBD TBD TBD TBD	TBD TBD TBD TBD	Observer programs, alternate gear testing, and fishing closure areas are currently being investigated
3.1.2.2	1	Minimize probability of oil spills and develop means to reduce impacts of oil spills and pollution		NOAA	TBD					
3.1.3	1	Minimize nest disturbances to increase reproductive success	10	BLM FS NPS WDNR ODF CDF State Parks						
4.1.1	1	Develop and refine protocols for monitoring population trends, productivity, and distribution	3	FWS BLM FS ODFW WDFW CDFG	60 25 25 15 15 15	25 10 10 5 5 5	25 10 10 5 5 5	10 5 5 5 5 5		

Recovery Plan Implementation Schedule for the Marbled Murrelet.

Task #	Priority #	Task Description	Task Duration (yrs)	Responsible Party	Total Cost	Cost Estimates ($1,000)				
						FY 1997	FY 1998	FY 1999	FY 2000	Comments
4.1.2	1	Standardize and conduct at-sea surveys for inventory and monitoring of population size and distribution	Continual	FWS BLM FS WDFW ODFW CDFG	1,000 250 750 250 250 500	100 25 75 25 25 50	100 25 75 25 25 50	100 25 75 25 25 50	100 25 75 25 25 50	It is anticipated that the at-sea surveys would be conducted yearly or every other year for the first 10 years. A workshop was held in 1996 to begin survey standardization.
4.1.3	1	Standardize and conduct at-sea surveys and nest studies to monitor breeding success	Continual	FWS BLM FS WDNR WDFW ODF ODFW CDF CDFG	750 250 750 TBD TBD TBD TBD TBD TBD	75 25 75	75 25 75	75 25 75	75 25 75	
4.4.1.1	1	Improve understanding of factors affecting nesting success	5	FWS BRD BLM FS WDNR WDFW ODF ODFW CDF CDFG	TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD					

Recovery Plan Implementation Schedule for the Marbled Murrelet.

Task #	Priority #	Task Description	Task Duration (yrs)	Responsible Party	Total Cost	Cost Estimates ($1,000)				
						FY 1997	FY 1998	FY 1999	FY 2000	Comments
4.4.1.2	1	Improve understanding of nesting habitat limitations	5	FWS BRD BLM FS WDNR WDFW ODF ODFW CDF CDFG		50				
3.2.1.1	2	Decrease fragmentation by increasing the size of suitable stands	10	BLM FS NPS WDNR ODF CDF	TBD[1] TBD[1]					This is being done by BLM and FS in LSRs through compliance with the ROD standards and guidelines.
3.2.1.2	2	Protect recruitment nesting habitat to buffer and enlarge existing stands	10	BLM FS NPS WDNR ODF CDF	TBD[1] TBD[1]					This is being done by BLM and FS in LSRs and around known occupied sites in the matrix through compliance with the ROD standards and guidelines.
3.2.1.3	2	Use silviculture to increase speed of development of new habitat	10	BLM FS WDNR ODF CDF	TBD[1] TBD[1] TBD[1] TBD[1] TBD[1]					Various silvicultural techniques are being proposed and utilized in both AMAs and LSRs to speed development of late-successional forests. State HCPs are also incorporating silvicultural techniques to speed development of new habitat.
4.1.4	2	Develop a definition of suitable marbled murrelet habitat for each Conservation Zone								

Recovery Plan Implementation Schedule for the Marbled Murrelet.

Task #	Priority #	Task Description	Task Duration (yrs)	Responsible Party	Total Cost	Cost Estimates ($1,000)				
						FY 1997	FY 1998	FY 1999	FY 2000	Comments
4.1.5	2	Determine and map breeding habitat, including recruitment and replacement habitat	5	BLM FS WDNR WDFW ODF ODFW CDF CDFG	250 500 TBD TBD TBD TBD TBD TBD	50 100	50 100	50 100	50 100	
4.1.6	2	Survey potential breeding habitat to identify potential nesting areas	Ongoing	BLM FS WDNR WDFW ODF ODFW CDF CDFG PVT	TBD[1] TBD[1] TBD TBD TBD TBD TBD TBD TBD					BLM and FS are surveying suitable habitat in the matrix as part of compliance with the ROD. Various State agencies and private individuals and companies are also conducting murrelet surveys
4.1.7	2	Evaluate terrestrial survey protocol	3	FWS BLM FS WDNR WDFW ODF ODFW CDF CDFG	30	10	20			
4.2.1	2	Utilize at-sea surveys conducted in 4.1.2 to refine estimates of current population size and distribution	Continual	FWS	80		20			Estimates refined every 2-3 years over a 10-year period

Recovery Plan Implementation Schedule for the Marbled Murrelet.

Task #	Priority #	Task Description	Task Duration (yrs)	Responsible Party	Total Cost	Cost Estimates ($1,000)				
						FY 1997	FY 1998	FY 1999	FY 2000	Comments
4.2.2	2	Develop survivorship estimates for the marbled murrelet	Continual	FWS	40		10			Survivorship estimates refined every 2-3 years over a 10-year period
4.2.3	2	Refine estimates of breeding success from adult:juvenile ratios	Continual	FWS	40		10			Estimates of breeding success refined every 2-3 years over a 10-year period.
4.4.2.1	2	Determine the relative importance of human activities on adult/subadult mortality	3	FWS WDFW USCG						
3.2.2.1	3	Improve and develop north/south distribution of nesting habitat	10	BLM FS WDNR ODF CDF	TBD[1] TBD[1] TBD[1] TBD[1] TBD[1]					These efforts are partially being accomplished through implementation of the Forest Plan and development of HCPs.
3.2.2.2	3	Improve and develop east/west distribution of nesting habitat	10	BLM FS WDNR ODF CDF	TBD[1] TBD[1] TBD[1] TBD[1] TBD[1]					Same as above.
4.3	3	Determine the genetic structure of murrelet populations	3	TBD						

Recovery Plan Implementation Schedule for the Marbled Murrelet.

Task #	Priority #	Task Description	Task Duration (yrs)	Responsible Party	Total Cost	Cost Estimates ($1,000)				
						FY 1997	FY 1998	FY 1999	FY 2000	Comments
4.4.2.2	3	Determine how natural or human-enhanced variability in, or depression of, food resources affect survivorship or productivity	10	BRD	900		100	100	100	
4.4.1.3	3	Evaluate the effects of disturbance of forest management activities on nesting murrelets	5	FWS BLM FS NPS WDNR WDFW ODF ODFW CDF CDFG	100	30	30	15	15	
4.5.1	3	Conduct studies on food habits of marbled murrelets	5	BRD	400		50	100	100	
4.5.2	3	Conduct studies on population immigration/emigration and colonization of nesting areas by marbled murrelets		FWS BLM FS						
4.5.3	3	Conduct studies on marine habitat use by marbled murrelets		BRD						
5.0	3	Establish a Regional West Coast Data Center for the marbled murrelet	Continual	FWS NBS BLM FS NPS WDNR WDFW ODF ODFW CDF CDFG	1,950 TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD	50 TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD	200 TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD	200 TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD	200 TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD TBD	Agency contributions would depend on agency needs and management direction

Part v. Appendices

"[A] thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."
- Aldo Leopold, *A Sand County Almanac and sketches here and there*

V. APPENDICES

APPENDIX A: Designated Marbled Murrelet Critical Habitat

Table 1. Designated Critical Habitat by State, Ownership, and Land Allocation

Washington	Hectares	Acres
Federal Lands		
Congressionally Withdrawn Lands	740	1,800
Late-Successional Reserves	485,680	1,200,200
Non-Federal Lands		
State Lands	172,720	426,800
Private Lands	1,020	2,500
Oregon		
Federal Lands		
Late-Successional Reserves	541,530	1,338,200
Non-Federal Lands		
State Lands	70,880	175,100
County Lands	440	1,100
Private Lands	350	900
California (Northern)		
Federal Lands		
Late-Successional Reserves	193,150	477,300
Non-Federal Lands		
State Lands	71,040	175,500
Private Lands	16,360	40,400
California (Central)		
State Lands	14,080	34,800
County Lands	3,230	8,000
City Lands	400	1,000
Private Lands	1,720	4,200

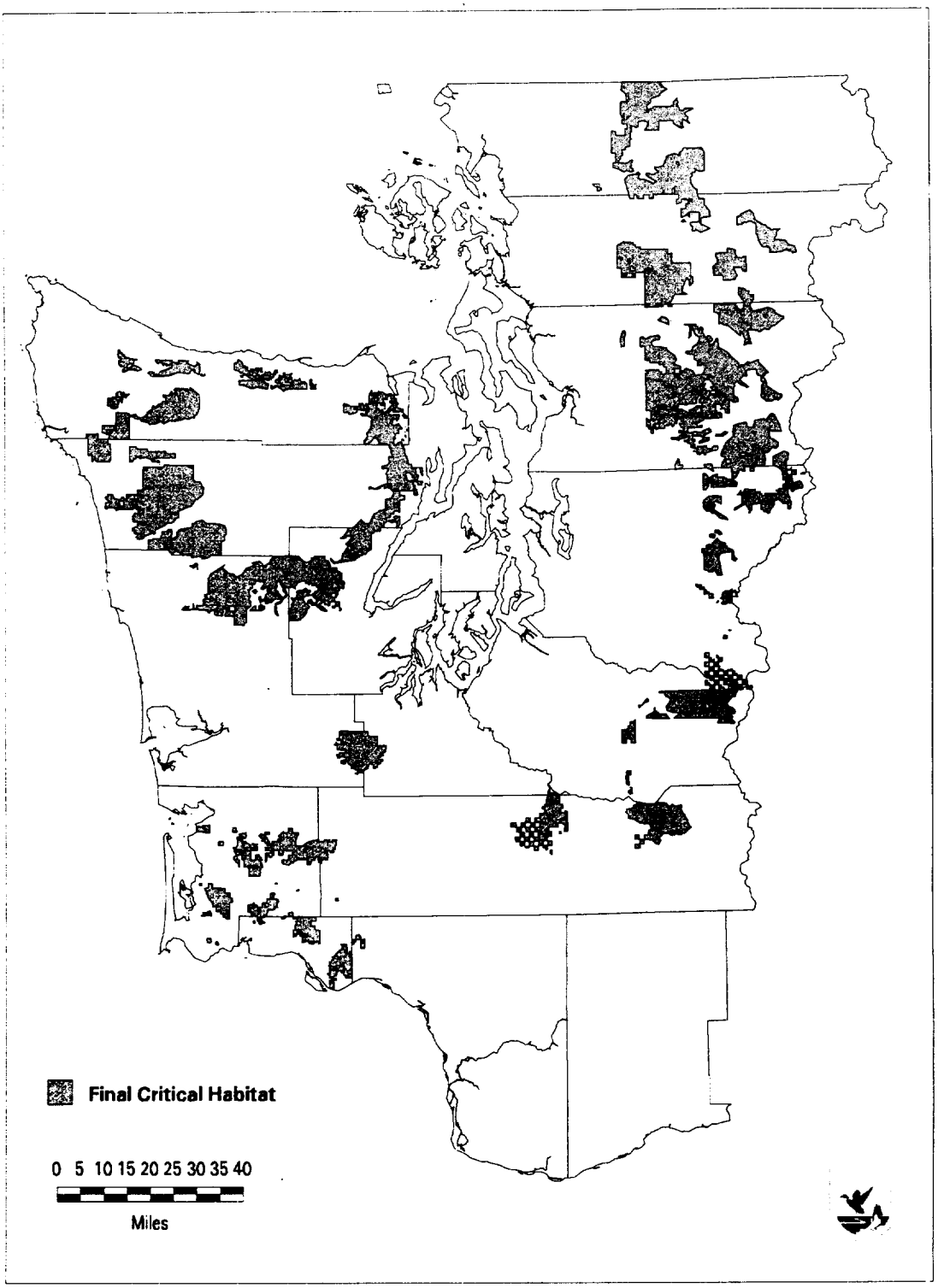

Figure 1. Map of Critical Habitat Units in Washington.

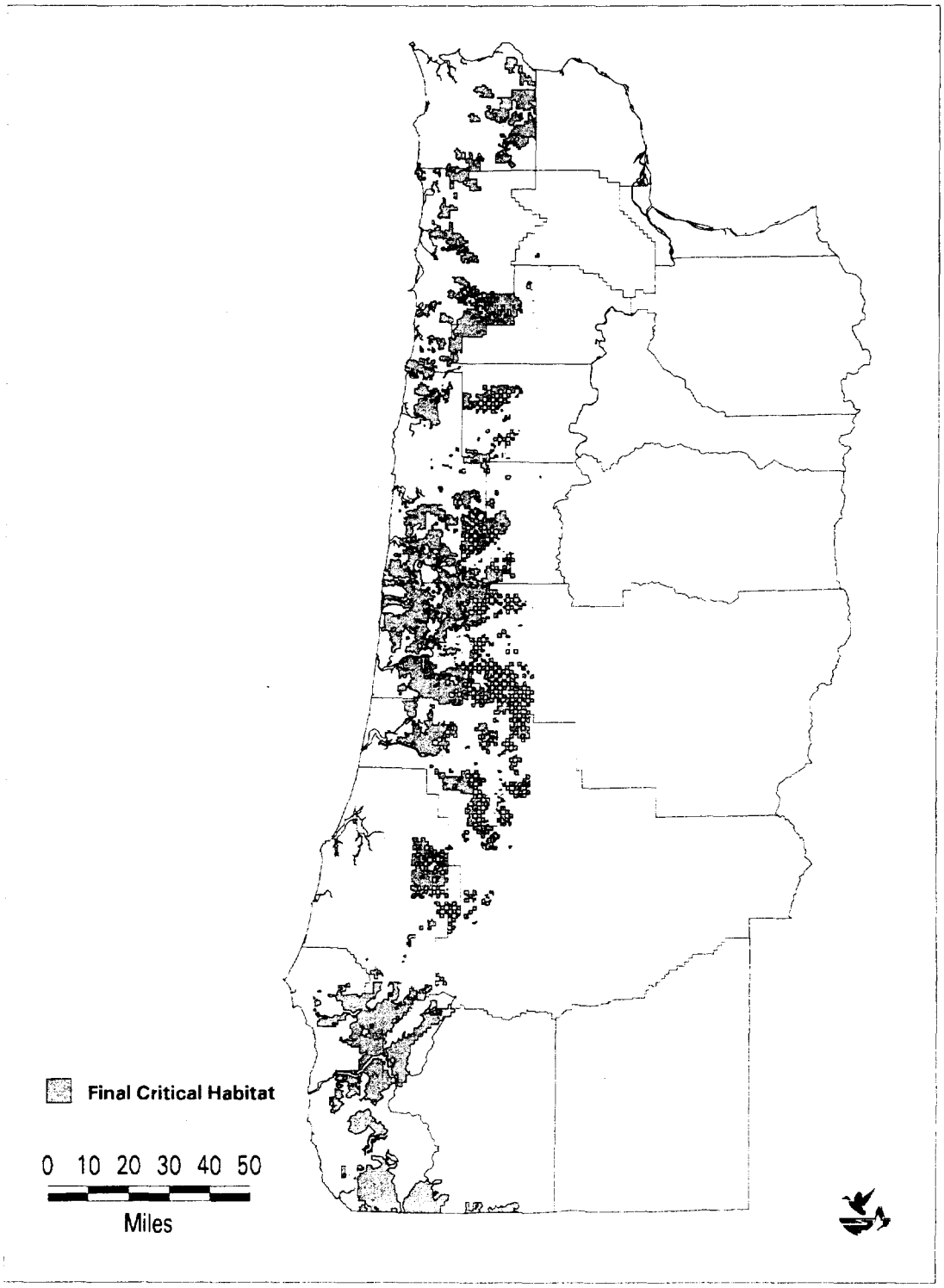

Figure 2. Map of Critical Habitat Units in Oregon.

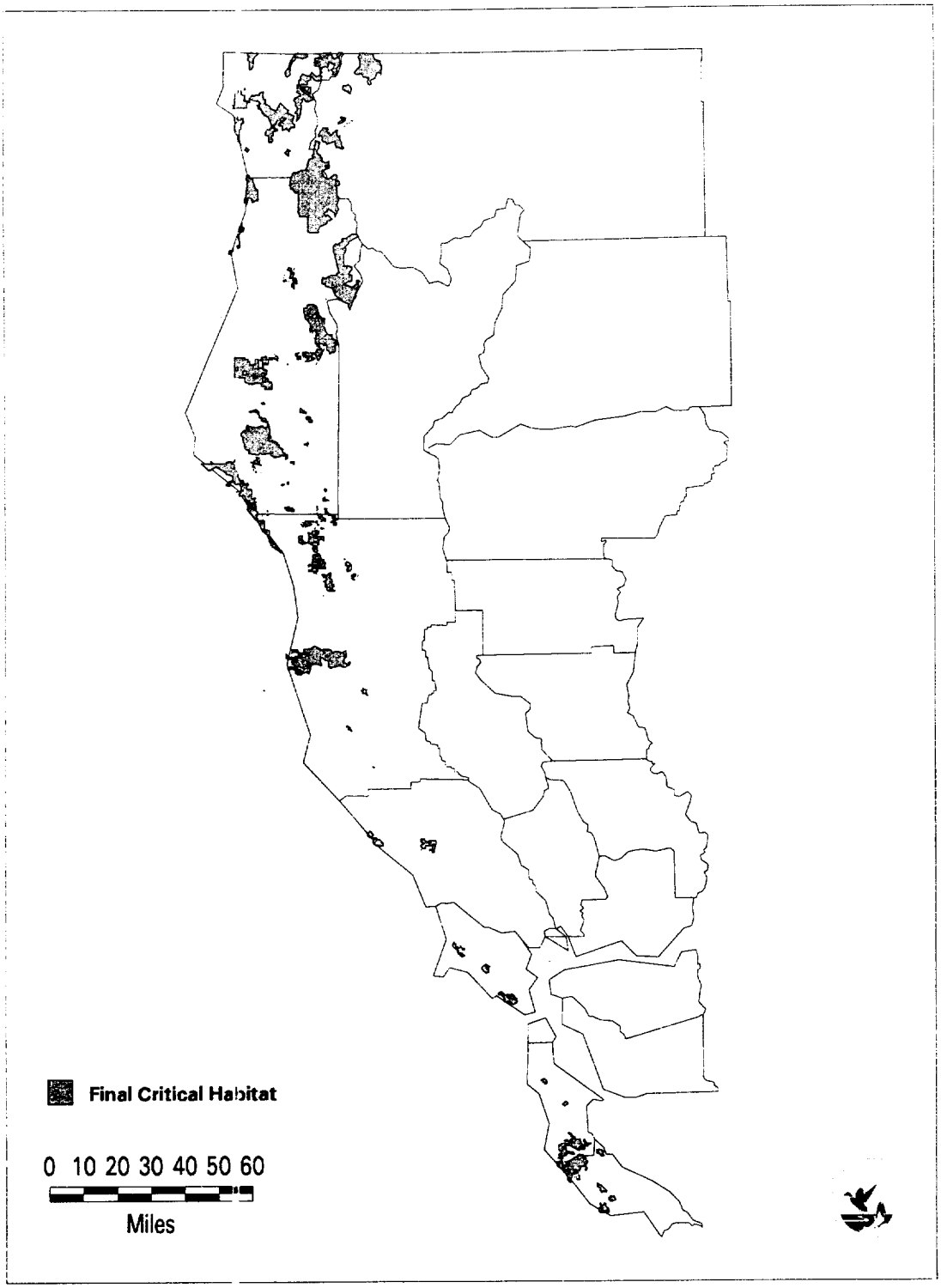

Figure 3. Map of Critical Habitat Units in California.

APPENDIX B: Population Trends of the Marbled Murrelet Projected From Demographic Analysis[1,2]

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Introduction.--Recovering a threatened or endangered species depends on determining its rate of population change and correcting the factors that limit population growth (Caughley 1994). Despite the important information on the biology and life history of the marbled murrelet (*Brachyramphus marmoratus*) that has been brought together in this recovery plan and in other volumes (Carter and Morrison 1992, Ralph *et al.* 1995), population trends for the murrelet remain elusive. Little long-term data are available to indicate population changes. Christmas bird counts from five sites in Alaska found a 50 percent decline in the population over a 20 year period (Piatt and Naslund 1995), and censuses conducted in Clayoquot Sound, British Columbia 10 years apart found a 40 percent decline (Kelson *et al.* 1995). Comparison of historic and current data suggests that the murrelet has disappeared or become very rare in large portions of its nesting range in California, Oregon, and Washington (Carter and Erickson 1992, Leschner and Cummins 1992, Nelson *et al.* 1992, Ralph 1994). But current population trends in the Pacific Northwest remain unknown.

Demographic modeling can give indications of likely population trends and play an important role in the conservation of the marbled murrelet. Simple demographic models based on estimates of annual survival and fecundity can be used to estimate the rate of decline or increase of a species. They can also help focus attention on critical demographic information that needs to be gathered for future studies.

Unfortunately, only a little is known about the demography of the murrelet. There are no estimates of survivorship for birds of any age. Reproduction is slightly

better understood Clutch size is known to be one egg, and a substantial proportion of nests are known to fail (Nelson and Hamer 1995). However, neither the age of first breeding nor the proportion of adults that breed is known. The ratio of young-of-the-year (hereafter juveniles) to after-hatch-year birds (subadults and adults) has been monitored at-sea and is often very low (e.g., Ralph and Long 1995, Strong 1995a).

This appendix presents a model of the demography of the marbled murrelet to explore likely population trends in the Pacific Northwest. It updates information and expands analyses published previously (Beissinger 1995). Although few data are available, there is enough reproductive data for murrelets to use, in conjunction with predictions of survivorship derived from life history analyses of past studies of auks, to yield crude estimates of the rate and direction of change of the murrelet population.

Model Structure.--The model was structured to take advantage of the one population parameter that could be best estimated from field data - fecundity. Fecundity is the average number of female offspring produced in a year per adult female in the population.

In the absence of detailed life history data, the simplest way to model the murrelet population is based on three life stages: adults (birds that are breeding age or older), subadults (birds that exceed one year of age but are younger than the age of first breeding) and juveniles (fledged young that have reached the ocean but have not yet survived their first year of life). The latter stage takes particular advantage of one of two estimates of productivity available from field data - namely the ratio of young to after-hatch-year (AHY) birds surveyed at sea. The virtue of this scheme - simplicity - is also its weakness as undoubtedly there may be age variation among the demographic rates of murrelets, as there is with other alcids (Hudson 1985, Wooller *et al.* 1992, Gaston *et al.* 1994). But without any specific

information on the age structure of vital rates, assigning age structure to them would be arbitrary.

The simplified population life cycle given in Figure 1 is based on postbreeding season censuses with a projection interval of one year (Caswell 1989, Noon and Sauer 1992) and is typical for long-lived monogamous birds (McDonald and Caswell 1993). Postbreeding, rather than prebreeding, censuses were used to coincide with the timing of at-sea surveys of juvenile and AHY murrelets. The flow of events is (1) censuses are conducted at the end of the breeding season, (2) birds must then survive to the next breeding season or die, (3) all surviving individuals are aged one year, (4) surviving adults then breed, and (5) postbreeding censuses are conducted again. Circles or nodes (Caswell 1989, McDonald and Caswell 1993) represent the stage classes: juveniles (0), subadults (1), and adults (2). P_0 is the probability of annual survival for fledglings that have reached the ocean. P_1 is the annual survivorship of subadults. Note that this stage may take several years for birds to mature and additional nodes would need to be added for each year that the age of first breeding exceeded 2 years old. The annual rate of adult survival is given by P_2. By definition only adults breed and their average annual fecundity (i.e., the number of female young reaching the ocean per adult female) is given by F_2.

Only the simplest deterministic version of the model was explored because no data yet exist on the magnitude of fluctuations of demographic characteristics from year to year. Thus, a population viability model that projected populations 50 to 200 years into the future using stochastic changes in fecundity and survival to yield estimates of extinction (Soulé 1987) was not attempted because the data were too weak to support such an exercise (see Appendix D, response to Issue 6). The model assumed: (1) survivorship and fecundity would change little from year to year; (2) populations were near a stable age structure; (3) a 1:1 sex ratio, which

is supported by Sealy (1975); (4) no density dependence; and (5) no senescence occurs and adult birds have no maximum life span. Such assumptions, although violated to varying extent in real populations, are typical for models of this nature (Lande 1988, Noon and Biles 1990). Usually such models are constructed only for females, since it is often difficult to know much about male fecundity without the use of DNA analyses to assign parentage. Thus, all rates needed for Figure 1 were expressed on a per female basis.

Methods.--To estimate fecundity, we need to determine the average number of female young produced annually by a female that has reached or exceeded the age of first breeding. Two kinds of data can be used to estimate the reproductive potential of the marbled murrelet: ratios of juveniles to AHY birds in the ocean (hereafter called the "juvenile ratio"), and estimates of nesting success (the number of young fledging per nesting attempt). Information on nesting success was derived from Nelson and Hamer (1995).

Arguably the best data on reproductive potential are ratios of juveniles from at-sea surveys. If measured at the end of the breeding season, these ratios act like a "snapshot" census of recruitment rates because they implicitly incorporate all of the parameters needed to estimate fecundity: clutch size, the proportion of nests fledging young, the proportion of birds nesting, the number of nesting attempts per year, and the survivorship of fledglings to the sea until the time of census. Similar ratios have been used to examine population trends in a variety of other wildlife studies (e.g., Hanson 1963, Paulik and Robson 1969, Roseberry 1974, Lambeck 1990).

At-sea surveys should be conducted before subadults and adults begin to molt into winter plumage and become difficult to distinguish from young-of-the-year (Carter and Stein 1995). In most years, molting adults and subadults are first

detected in mid- to late August (Carter and Stein 1995, Ralph and Long 1995). Thus, we generally used survey data collected before the end of August. However, fledging of young can occasionally occur until late September (Hamer and Nelson 1995). When the at-sea surveys were conducted, it is likely that some young had not yet fledged (and thus would not be detected), but that most adults were surveyed since they were in the ocean gathering food to feed young, although some adults are likely to go undetected if they were away from sea tending nests. Most likely, this ratio will tend to underestimate recruitment. To correct for this problem, the cumulative frequency distribution for estimates of "known" fledging dates for all nests or young found throughout the range (Hamer and Nelson 1995) was used to estimate the proportion of young that would have fledged by the mid-point of the census date. The juvenile ratio is then adjusted upwards by dividing the number of juveniles detected by this factor and using the result to recalculate the juvenile ratio. Lack of fledging data precluded constructing cumulative frequency distributions for specific regions in the range of the murrelet.

Using juvenile ratios to estimate fecundity also requires correction for the relative abundance of subadults or the stage structure of the population. Fecundity is the number of female young per *adult female* produced annually, but during at-sea surveys *subadults* incapable of nesting can not be distinguished from adults that are capable of breeding. Therefore, just using the ratio of juveniles to AHY birds from the surveys will tend to underestimate fecundity because the proportion of adults will be overestimated. Fortunately, the estimate of fecundity derived from the juvenile ratio can be corrected by iteratively and incrementally increasing fecundity until the matrix (or population projection) yields the ratio of juveniles to AHY birds equivalent to that observed during at-sea surveys.

Alcids typically exhibit delayed ages of first breeding (Croxall and Gaston 1988, Hudson 1985). One of the earliest recorded ages of first breeding is for Cassin's auklet (*Ptychoramphus aleuticus*), where some birds begin at 2 years but most start at 3 years of age (Croxall and Gaston 1988). Hudson (1985) estimated 5 years in general for Atlantic alcids but the age of first breeding of individuals ranged between 3 and 15 years (e.g., Harris *et al.* 1994). Given its small body size, it is unlikely that the murrelet would require 5 years to reach sexual maturity, although it could require longer to obtain a nest site if sites were limiting. On the other hand, historically nest sites were probably much more abundant than they are today as a result of deforestation. Thus, in comparison to seabirds that nest colonially on islands, where obtaining a breeding site can sometimes be difficult (Hudson 1985), it seems likely that the marbled murrelet would have a young rather than old age of first breeding. Age of first breeding was suspected to be 3 years, but ages 2 to 5 were also explored in the model.

Survivorship estimates were derived from a life history analysis of the literature, because there have been no long term studies of individually-marked murrelets. A comparative analysis of survivorship of auks was conducted to infer the average annual survival rate for marbled murrelets based on life history theory. It is well known that adult survival is positively related to body mass and negatively related to clutch size and annual reproductive rate in birds (Croxall and Gaston 1988, Gustafsson and Sutherland 1988, Gaillard *et al.* 1989). Regressing estimates of annual survival against body mass and annual reproductive rate (clutch size times the number of broods per year) were developed to infer survivorship for marbled murrelets, assuming an adult body size of 222 grams (Sealy 1975), a clutch size of 1 egg, and a nesting rate of 1 brood per year. Allometric relationships and multiple regression models were made using Stata 3.0 (Computing Resource Center 1992). Log-transformed values for body mass and survival, and square-root transformed values for reproductive rate were used to normalize the data and linearize the relationship between independent and dependent variables.

We gathered all available survivorship data for the Alcidae. Data for five species were listed in Hudson (1985). In addition, survival estimates were obtained for the: Cassin's auklet (*Ptychoramphus aleuticus*) from Speich and Manuwal (1974), Emslie *et al.* (1992) and Gaston (1992); least auklet (*Aethia pusilla*) and Crested auklet (*Aethia cristatella*) from Jones (1992); ancient murrelet (*Synthliboramphus antiquus*) from Gaston (1990); and pigeon guillemot (*Cepphus columba*) from Nelson (1991). Data on body mass were from Dunning (1992). All alcids except Cassin's auklets have only a single brood per year. In the Farallon population, but not the British Columbian population, of Cassin's auklets, a second brood is sometimes attempted (Ainley and Boekelheide 1990, Emslie *et al.* 1990) so a reproductive rate of 1.25 was used for the California birds. Survival estimates were averaged when several studies reported values for a species because species were the units of observation. The exception was the Cassin's auklet because both fecundity and survivorship differed between each population.

Few studies report values for juvenile or subadult survival for any seabird, although some do give the likelihood of surviving to breeding age (Hudson 1985). These values are hard to estimate and can often be underestimated due to emigration. Hudson (1985) gives a range for the probability of surviving to first breeding of 13-53 percent, with a mean close to 30 percent, but this is for large-bodied birds with late ages of first breeding. Interpretation of these data are complicated by differences in the age of first breeding within and among the species considered. Thus, we concentrated on estimating survival separately for the first two years of life (age classes 0-1 and 1-2). We assumed that survival of older age classes would approach that of adults, as has been shown for other alcids and larids (Mead 1974, Hudson 1985, Spear *et al.* 1987, Nur *et al.* 1993).

We estimated juvenile and subadult survival as a proportion of adult survival based on analyses of data for common and thick-billed murres (*Uria aalge* and *U.*

lomuia) from Birkhead and Hudson (1977). Following their approach, annual survivorship for each age class was estimated from band recovery data for five different populations. For each age class, we averaged survival across populations and then calculated survival as a proportion of adult survival, assuming an average adult survival of 0.925 for common murres and 0.910 for thick-billed murres (Hudson 1985). To adapt the proportional survival estimates of murres for the marbled murrelet, they must be scaled relative to age of first breeding, because murrelets probably begin breeding one or two years earlier than murres (3 versus 4 or 5 years). For first-year murrelets, we calculated juvenile survival as the geometric mean of proportional survival estimates for 1 year old and 2 year old murres, and for second year murrelets we used the geometric mean of proportional survival of 2 year old and 3 year old murres. The advantage of this approach is that juvenile and subadult survival are expressed as proportions of adult survival in the model and this greatly simplifies the combinations of variables that need to be evaluated. Results of the model were not very sensitive to changes in subadult and juvenile survival (Beissinger 1995), which further justified this approach.

Once demographic traits were selected, values were used to calculate lambda (the expected annual growth rate of the population) and the stable stage distribution. Populations decline when lambda is less than 1 and increase when lambda exceeds 1. The stable stage distribution is the proportion of the total population that is comprised of each stage class under constant survivorship and fecundity schedules, and can be used to yield an expected juvenile ratio. Lambda and the proportion of juveniles in the stable age distribution were calculated: (1) analytically by constructing Leslie matrices and solving for the dominant eigenvalue and right eigenvector (Caswell 1989) using MATLAB (1992); and (2) numerically using spreadsheets to project population changes over 25 years (Burgman *et al.* 1993). We used these same methods to explore what levels of adult survival and fecundity were required to yield estimates of lambda equal to 1

for different ages of first breeding and the juvenile ratios that these combinations would produce

RESULTS

Estimating Fecundity.--Reproduction in the marbled murrelet appears to be highly asynchronous. The cumulative frequency distribution for estimated dates of fledging throughout the range of the murrelet shows a regular increase during the breeding season (Figure 2). Fledging has occurred as early as the first week in June and very rarely as late as September, although 94 percent of the nests had fledged by the end of August. Fledging finished by the end of August in Alaska, British Columbia, and Washington, but in Oregon and California extended into September (see Figure 3 in Hamer and Nelson 1995). A linear model fit the data well, especially through the middle portions of the range of fledging dates (Figure 2). This model was used to estimate the cumulative proportion of nests that had fledged to adjust juvenile ratios for differences in the date of surveys.

Table 1 summarizes replicated at-sea surveys of the ratio of juveniles to AHY murrelets for different localities. Surveys dates were grouped to avoid repeatedly counting the same individuals, but in some cases it was not possible. Several important patterns emerged from these data. First, the juvenile ratio tended to increase during the breeding season in most locations with repeated surveys. For 37 consecutive pairs of surveys conducted in the same year, the juvenile ratio of the second count increased in 26 (70.3%) instances, remained the same 4 times (10.8%) and decreased 7 times (18.9%). Increasing ratios occurred more often than expected by chance alone (Sign test, $P = 0.021$). An increasing juvenile ratio should occur if nests in a population were asynchronously fledging young (Figure 2), and juveniles, subadults and adults remained in the general vicinity (i.e., transects were long enough that entire populations were being surveyed). The

general increase in juvenile ratios during the breeding season indicates that juvenile ratios may be useful tools for tracking productivity of these populations. Second, sequential surveys often yielded similar juvenile ratios after the percentage of juveniles observed was adjusted for different survey dates using the linear model in Figure 2. The most similar values generally occurred for surveys conducted from late July through mid-August (Table 1). Thus, juvenile ratios appear to be sensitive to seasonal change, yet provide repeatable measures for estimating fecundity.

Juvenile ratios from at-sea surveys of marbled murrelets conducted toward the end of the nesting season throughout the Pacific Northwest are summarized in Table 2. The ratio of juveniles to AHY birds varied from about 0.01 to 0.14. Juvenile ratios for Puget Sound and northern Oregon (typically 0.08-0.14) tended to be highest, southern Oregon and northern California had intermediate ratios (0.02-0.07), and central Oregon and central California consistently had the lowest juvenile ratios (0.01-0.04). Year to year differences in juvenile ratios are also evident. Most regions had low ratios in 1993, while 1994 and 1995 were more productive years.

The ratios of young-of-the-year murrelets to AYH birds were adjusted for both date of survey and the proportion of subadults to yield estimators of fecundity (Table 2). Time and stage adjusted juvenile ratios ranged from about 0.02-0.19. One-third of adjusted ratios were greater than 0.10, but half were less than 0.05.

Fecundity can also be estimated from studies of nesting success but this is more difficult to do for the murrelet because nests are so hard to find and monitor. A total of 22 nests have been found in the Pacific Northwest (see Table 2 in Nelson and Hamer 1995). Only 36 percent of them successfully fledged young. This would yield an estimate of 0.36 young produced per nesting pair (since murrelets

can fledge only 1 young), or 0.18 female young per nesting female, assuming half of the young fledging would be males based on the sex ratio found by Sealy (1975). This estimate serves as an upper bound for fecundity for several reasons. It is unlikely that all females attempt to nest every year and a significant proportion of the population (5-16 %) may be nonbreeders (Hudson 1985). Also, the estimate of fecundity for the postbreeding model assumes that the young have safely reached the ocean. The long flight from the nest to the ocean can be expected to be hazardous for nestlings, as exemplified by grounded young birds that have been found (Carter and Erickson 1992, Rodway *et al.* 1992). Thus, to arrive at a fecundity value, the number of female young per nesting female (0.18) would have to be corrected by multiplying it by the estimated proportion of adult birds nesting (averaged from the estimates of Hudson cited above to yield 0.9), the proportion of young that survive from fledging to until the time of census (anybody's guess but 0.9 might be a reasonable estimate), and the number of nesting attempts per pair per year (assumed to be 1). This would result in a fecundity value around 0.146, similar to the highest values found from at-sea surveys (Table 2).

Estimating Survivorship.--The annual probability of survival for adults (P_2) was positively related to body size for 10 species of Alcids (Figure 3). Adult survivorship ranged from about 0.75-0.77 for small-bodied least auklets and ancient murrelets to 0.91-0.94 for large-bodied Atlantic puffins (*Fratercula arctica*), and common and thick-billed murres. Body mass alone counted for nearly one-half of the variation in survivorship (Figure 3). Adult survivorship was negatively related to annual reproductive rate ($P = 0.023$) after controlling for the effects of body size. Likewise, survivorship was significantly related to body mass ($P = 0.009$) after controlling for the effects of reproductive rate. Thus, the two variables make statistically independent contributions in explaining variation in adult survival (Figure 4). When entered into a multiple regression, these two

variables together accounted for 72 percent of the variation in annual survivorship among the 10 species (P = 0.006) and yielded the equation

$$\ln(P_2) = [0.069 \times \ln(M) - (0.229 \times \mathrm{sqrt}(R)) - 0.310] \qquad (1)$$

where P_2 is annual adult survival, M is body mass and R is annual reproductive rate. This resulted in an estimate of annual survival of 0.845 for the marbled murrelet. Two standard errors of the estimate for the prediction, encompassing 95 percent of the likely values for typical murrelet survivorship (Steel and Torrie 1960), fell between 0.811 and 0.880. We used 0.85 for adult survival and also explored the possibility that the average annual probability of survival might be as high as 0.90, a value typical for larger Atlantic alcids (Hudson 1985). Values of survivorship as low as 0.81 were not considered because they would have required extremely high fecundity values for populations to persist.

Survival of juvenile and subadult common and thick-billed murres was consistent across populations (Table 3). Average survivorship of common murres was remarkably consist to survivorship of thick-billed murres. By the end of their third year, murres had nearly reached or exceeded survivorship levels equivalent to adults in all populations. For both species of murres, survival through the first year of life was about 60 percent that of adults, had increased on average to 82 percent of adult survival from years 1 to 2, and was nearly equivalent (94-97%) to adult survival by the end of the third year. Scaling the survivorship of murres to the life history of the marbled murrelet by taking the geometric mean of the upper and lower age class estimates of survival for both species yields a first year survival of 70.1 percent of adult survival and a second year survival of 88.8 percent of adult survival (using 0.945 as the average proportional survival for age classes 2-3). These proportions were used for juvenile and subadult survival estimates in the model.

Predicted Murrelet Population Trends.--Figure 5 shows the possible combinations of adult survival and fecundity for populations experiencing no growth (lambda equal to 1) for different possible ages of first breeding. Combinations of survival and fecundity above the lambda isobar result in increasing populations and combinations below the lambda isobar result in declining populations. For the marbled murrelet, fecundity may not exceed 0.5 because females are thought to lay only 1 egg per year and on average only half of the young that fledge would be females. Note that the lambda isobars for different ages of first breeding converge as survivorship increases and fecundity declines. As fecundity values drop below 0.20 and survivorship rises above 0.90, our assumption of the age of first breeding will have little effect on the predicted population trends.

Likely combinations of adult survivorship and fecundity are shown for the murrelet on Figure 5. These estimates are well below the lambda isobars, and indicate that murrelet populations in the Pacific Northwest are likely to be declining in most years. Given an annual survivorship of 0.85-0.90, murrelet fecundity would have to range from 0.20-0.46 to result in stable populations for different ages of first breeding. Such values would result in J:AHY ratios of 0.176-0.279 at the end of the breeding season. When back adjusted for date of census and the range of possible ages of first breeding, J:AHY ratios for stable populations would need to be 0.110- 0.174 for a survey midpoint of 1 August, 0.123-0.195 for midpoint of 7 August, and 0.140-0.221 for 15 August surveys. Even the highest J:AHY ratios for at-sea surveys in Puget Sound and northern Oregon did not reach these values, although occasionally they were close, and elsewhere in the Pacific Northwest juvenile ratios were well below those values.

Fecundity values resulting in juvenile ratios sufficient to sustain murrelet populations appear to be typical for other auks, which generally experience nesting success of about 70-75 percent (Hudson 1985). For example, if murrelets

experienced 75 percent nesting success, nests were attempted by 90 percent of the potential breeding population each year, and 90 percent of the young survived to reach the ocean, then fecundity = 0.75 x 0.9 x 0.9 x 0.5= 0.304. Murrelet populations with a fecundity of 0.3 would grow when adult survivorship exceeded 0.862-0.894, values that fall well within the expected range of survivorship values. Unfortunately, even the most favorable estimate of fecundity conceivable from current field data for the marbled murrelet (i.e., uncorrected nesting success = 36%) would require survivorship values to exceed 0.908-0.924 for populations to grow. Such survivorship values may occur during some years, but seem likely to be higher than the long term average expected for this species (Figures 3 and 4).

The above analyses suggest a predicted rate of decline for the murrelet population that is substantial. Using estimates of survival from our comparative analysis and estimates of fecundity obtained from at-sea surveys of juveniles and adults, likely combinations of demographic rates and their resulting annual change in population size are given in Table 2 and are illustrated in Figure 5. All estimates of lambda were less than 1.0, although the three highest estimates (0.989, 0.964, and 0.961) may be within the bounds of error for a stable population given the accuracy of the model. The average across all years and locations for lambda was about 0.93 and 0.88, assuming an annual survivorship of 0.90 and 0.85, respectively. Using an average survival rate of 0.90, lambda averaged 0.96 for Puget Sound and northern Oregon populations, 0.93 for southern Oregon and northern California, and 0.92 for central Oregon and central California. The highest estimate for lambda comes from uncorrected nesting success and would result in a value of 0.98 for an age of first breeding of 3 years. Thus, it appears that reproductive success of murrelet populations throughout the Pacific Northwest is insufficient to sustain populations, which are likely to be declining at least 2-4 percent per year and conceivably even 2-3 times faster (Table 2).

DISCUSSION

Model Parameter Estimates.--There are a number of sources of uncertainty in the parameter estimates that may have affected model outcomes. Estimates of survival have the greatest uncertainty, since they were not derived from field data but instead were based on comparative analyses of allometric models. Nevertheless, there are reasons for confidence in the estimates evaluated. Survivorship is often strongly related to both body size and reproductive effort in birds (e.g., Saether 1988, Gaillard *et al.* 1989), and this trend was also strong in the Alcidae. The range of annual survivorship values for adults evaluated in the model (0.85-0.90) included more than two standard errors for the upper bound of the prediction from the regression, which should encompass more than 95 percent of the variation in potential mean estimates. Higher annual survival rates (0.90-0.94) are typical only for three species of auks with body masses exceeding 600 grams, three times the size of the marbled murrelet. Survivorship ranges from 0.75-0.88 for seven alcid species with medium and small body sizes (< 600 grams); only the Atlantic puffin (*Fratercula arctica*) had annual survival rates routinely above 0.90.

It is likely that annual survivorship for marbled murrelets will be among the upper range of values evaluated in this model (e.g., 0.87-0.90), because the murrelet's inherently low reproductive rate (1 egg per nesting attempt) requires high survivorship for populations to grow. On the other hand, the murrelet's unusual life history strategy of nesting in old-growth forests often far from the sea may cause it to face higher mortality risks than other seabirds. Field studies to determine survival rates are needed, and are becoming more feasible as marking and telemetry techniques are perfected for this bird (Quinlan and Hughes 1992; L. Priest and R. Burns, pers. comm.).

All measures of fecundity from field data for the marbled murrelet appear to be low. Arguably the most complete measures of fecundity were derived from juvenile ratios based on extensive at-sea surveys corrected for the date of survey and stage structure of the population (Table 2, Figure 2). These surveys have universally produced low juvenile ratios (Tables 1 and 2). Low juvenile ratios indicate poor reproductive success that could be due to high nest failure rates from predation (Nelson and Hamer 1995), or to a low proportion of adults attempting to breed, perhaps because they are unable to find suitable, old-growth nest sites. Poor reproductive success in some years, like 1993, could also have been partly due to El Niño effects on food supplies. Although there is ample evidence that El Niño affects nesting success of seabirds that nest and forage offshore (Ainley and Boekelheide 1990), there is no evidence that fish populations within 2 kilometers (1.2 miles) of shore, which murrelets mostly utilize, are affected.

Some uncertainty in the measure of fecundity derived from juvenile ratios is associated with the timing of surveys. To convert juvenile ratios to a fecundity estimate, ratios had to be increased to account for nests fledging after the survey date by using the cumulative frequency distribution for fledged nests with known dates (Figure 2). This distribution was comprised of nests from Alaska to California, because sample size was not large enough to partition nests among portions of the murrelet's range. Variation in the fledging dates exists between Alaska, British Columbia, and the Pacific Northwest (Hamer and Nelson 1995), although there is much overlap. Future research might employ bootstrapping techniques (Crowley 1992) to calculate an error estimate for the cumulative frequency by date, as one way to determine the inherent variability of the correction factor.

Other approaches to estimating fecundity also yielded low values but are likely to have too many biases to be useful yet. Estimates of fecundity from nesting

success are likely to be less useful than juvenile ratios because they must be corrected for many factors that are difficult to measure for the murrelet: the proportion of adults nesting, fledgling survival to the ocean, and renesting frequencies. Furthermore, for the foreseeable future fecundity estimates based on nesting success are likely to depend on small sample sizes because of the difficulty in finding nests.

Predicted Rates of Decline of Murrelet Populations.--The demographic model predicted that murrelet populations are likely to be declining (Table 2, Figure 5). The estimated rate of decline varied from 1-14 percent per year, depending on the parameter estimates used. Based on the discussion of the parameters above, the most likely rate of decline would be based on fecundity values from juvenile ratios used with an estimate of survival closer to 0.90 than to 0.85. Such estimates for lambda would suggest a rate of decline around 4-8 percent per year.

A predicted decline of 4 percent per year in Puget Sound and northern Oregon (Table 2) is in close agreement with population declines documented in two field studies of murrelets. A 50 percent decline in murrelets detected over 20 years of Christmas Bird Counts in Alaska (Piatt and Naslund 1995), despite an increase in observer effort during this period, would represent a 3.4 percent average annual decline. Similarly, the 40 percent decline in the Clayoquot Sound murrelet population in British Columbia over 10 years (Kelson *et al.* 1995) would average to a 5 percent annual decline. These studies are based on either periodic but intensive sampling during few annual periods (British Columbia), or low intensity but extensive sampling every year (Alaska). Despite, the sampling shortcomings inherent in these two studies, the population trends that they have documented are in good agreement with trends predicted by the model in this paper.

Model results suggest that murrelet populations may even be declining at greater rates (Table 2). A 7-8 percent annual decline from central Oregon to central

California would be predicted from juvenile ratios in conjunction with high estimates of survival. It is conceivable that these murrelet populations could be declining at 7-12 percent per year (Table 2). Although this rate of decline is so high that it seems unlikely to go unnoticed by field researchers, most at-sea survey designs currently in use have a low power to detect declines of these magnitudes because they are not replicated often enough (Becker *et al.* 1997). Nevertheless, declines of that magnitude are based on the most pessimistic combinations of fecundity and survivorship. We interpret the model predictions, in conjunction with the field evidence, to suggest that murrelet populations are likely to be declining at least 4 percent per year and perhaps as much as 7 percent per year.

Use of Juvenile Ratios for Murrelet Conservation.--Conservation efforts for marbled murrelets have been hampered in part because of a lack of reliable biological information. Demographic characteristics have been especially difficult to measure because nests are very hard to find and monitor, murrelets fly long distances both over the ocean and across land, and the birds are difficult to capture, mark and telemeter (Quinlan and Hughes 1992). Juvenile ratios provide one estimator of murrelet population health that may be reasonably measured in the field.

Juvenile ratios have great potential as estimators of productivity. It is easy to obtain large sample sizes of juvenile ratios compared to the difficulty of finding and monitoring nests. It will be many years before enough nests are found to yield sample sizes sufficient for accurate estimates of nesting success. Additional information needed to convert nesting success into annual fecundity (the proportion of birds that nest and the number of attempts per year) will perhaps be even more difficult to obtain. Juvenile ratios implicitly incorporate these factors.

Research will need to determine optimal protocols for sampling juvenile ratios at-sea that take into account potential differences in habitat use by juveniles and adults (Beissinger 1995), as well as other factors that could bias these ratios.

Changes in juvenile ratios could be a useful tool to understand factors limiting murrelet population growth. Juvenile ratios could be monitored in a regional areas (e.g., 50-100 kilometers of shoreline) and compared to landscape characteristics to determine the effects of forest management and other land use practices. Juvenile ratios may also be useful for monitoring murrelet population trends. However, changes in juvenile ratios can be caused either by changes in recruitment (increased nesting success results in greater proportions of juveniles) or changes in adult survivorship (decreased survivorship results in greater proportions of juveniles). Whether juvenile ratios change due to improved recruitment or decreased adult survivorship should be apparent by examining year-to-year changes in population size. Increases in juvenile ratios coupled with increased population size should indicate increased productivity, but if coupled with decreased population size would indicate decreased adult survivorship.

For making sound conservation decisions based on population trends and demography, there is no substitute for good field data based on direct estimates of population change, survival and fecundity. For the marbled murrelet, such information is likely to remain scarce. Future research should explore the strengths and weakness of using the ratio of juveniles to after-hatch-year birds as a proxy for direct demographic measurements.

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Table 1. The numbers of juveniles (Juvs.), after-hatch-year (AHY) and juvenile ratios (J:AHY) for Marbled Murrelets from at sea surveys repeated two or more times during the breeding season. Tim adjusted ratios were corrected for the survey date except for June which was excluded because few juveniles have fledged by then and the cumulative function did not fit well at the extremes (Figure 2).

State	Region	Year	Date	No. AHY	No. Juvs	J:AHY	Time Adjusted J:AHY	Source
OR	North: Seaside-Lincoln	1995	10-11 July	253	3	0.012	0.033	Strong 1995b
			22-23 Aug.	145	20	0.138	0.157	
		1993	26 June	56	0	0.000	-------	
			20-21 July	587	10	0.017	0.035	
		1992	25-26 June	153	4	0.026	-------	
			14 July	60	1	0.017	0.040	
			11 Aug.	440	34	0.077	0.102	
	Central: Lincoln-Lane	1995	9 June	541	1	0.002	-------	Strong 1995b
			9 July	853	2	0.002	0.007	
			12 July	973	6	0.006	0.016	
			14 Aug.	533	1	0.002	0.002	
			24 Aug.	218	5	0.023	0.025	
		1993	23 June	847	1	0.001	-------	
			28 June	410	1	0.002	-------	
			10 July	360	1	0.003	0.008	
			18 July	325	0	0.000	0.000	
			29 July	564	7	0.012	0.021	
		1992	15 June	820	1	0.001	-------	
			27 June	1245	1	0.001	-------	
			13 July	1239	2	0.002	0.004	
			23 July	642	3	0.005	0.009	
			2 Aug.	367	1	0.003	0.004	
			6 Aug.	143	1	0.007	0.010	
	South: Coos Bay-Curry	1995	13 June	367	2	0.005	-------	Strong 1995b
			15 Aug.	243	4	0.016	0.021	
			2 Sept.	335	18	0.054	0.054	
		1994	15-16 Aug.	194	5	0.026	0.033	
			24-25 Aug.	138	10	0.072	0.080	

State	Region	Year	Date	No. AHY	No. Juvs	J:AHY	Time Adjusted J:AHY	Source
OR	South: Coos Bay-Curry (cont.)	1993	16-18 June	151	0	0.000	-------	Strong 1995b
			12-13 July	175	3	0.017	0.045	
		1992	19 June	33	0	0.000	-------	
			19-20 July	967	20	0.021	0.043	
CA	Northern: Oregon to Shelter Cove	1995	18-23 June	379	0	0.000	-------	CCR/MRB 1996
			21-23 July	1046	9	0.009	0.017	
			28-29 July	313	7	0.022	0.039	
			3-6 Aug.	429	11	0.026	0.039	
			10-11 Aug.	687	3	0.004	0.006	
			16-17 Aug.	408	8	0.020	0.024	
			29-30 Aug.	450	17	0.038	0.039	
		1994	29-30 June	693	10	0.014	-------	CCR/MRB 1996
			19-23 July	596	30	0.050	0.102	
			2-5 Aug.	746	58	0.078	0.120	
			8-11 Aug.	775	56	0.072	0.100	
			14-19 Aug.	533	24	0.045	0.056	
		1993	15-31 July	355	5	0.014	0.027	Ralph & Long 1995
			15-30 Aug.	192	4	0.021	0.023	
	Central: Año Nuevo Region	1995	9-23 June	79	0	0.000	-------	Becker et al. in rev.
			1-14 July	252	0	0.000	0.000	
			15-31 July	342	2	0.006	0.011	
			1-15 Aug.	207	2	0.010	0.014	
			16-20 Aug.	99	1	0.010	0.012	

Table 2. The numbers of juveniles (Juvs.), after-hatch-year (AHY) and juvenile ratios (J:AHY) for Marbled Murrelets from at sea surveys for different regions of the Pacific Northwest. Ratios were adjusted for survey date (Time; see Figure 2) and stage structure (Stage) to yield an estimate of fecundity (number of female young per adult female). These were used to estimate lambda assuming adult survival of 0.85 and 0.90, and an age of first breeding of 3 years.

State	Region	Year	Date	No. AHY	No. Juvs.	J:AHY	Time adjusted J:AHY	Time and Stage Adjus. J:AHY	Lambda 0.85	Lambda 0.90	Source
WA	Puget Sound	1995	1-18Aug.	617	49	0.079	0.108	0.124	0.908	0.961	Nysewander & Stein unpub
		1994	1-12Aug.	395	31	0.078	0.113	0.131	0.911	0.964	
OR	North: Seaside-Lincoln	1995	22-23Aug.	145	20	0.138	0.157	0.192	0.934	0.989	Strong 1995b
		1994	20-22Aug.	147	12	0.082	0.094	0.106	0.900	0.953	
		1993	20-21July	587	10	0.017	0.035	0.037	0.869	0.920	
		1992	11Aug.	440	34	0.077	0.102	0.119	0.905	0.959	
	Central: Lincoln-Coos Bay	1995	13-24Aug	1154	27	0.023	0.028	0.029	0.865	0.916	Strong 1995b
		1994	6-23Aug.	755	15	0.020	0.025	0.026	0.863	0.914	
		1993	23-30July	1460	13	0.009	0.016	0.016	0.858	0.909	
		1992	1-10Aug.	1032	36	0.035	0.050	0.055	0.877	0.929	
	South: Coos Bay-Brookings	1995	12Aug.-2Sept.	728	33	0.045	0.053	0.057	0.878	0.930	Strong 1995b
		1994	14-25Aug.	555	19	0.034	0.041	0.044	0.872	0.923	
		1993	12-13July	175	3	0.017	0.045	0.048	0.874	0.925	
		1992	19-20July	967	20	0.021	0.044	0.047	0.874	0.925	

Table 2 (cont.)

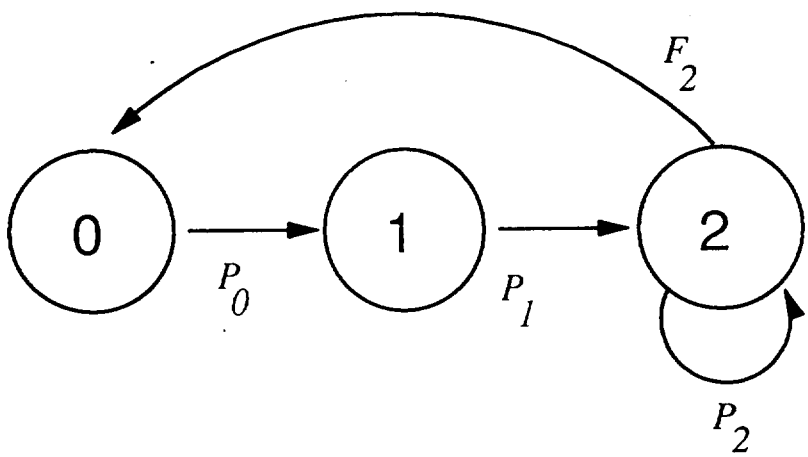
State	Region	Year	Date	No. AHY	No. Juvs.	J:AHY	Time adjusted J:AHY	Time and Stage Adjus. J:AHY	Lambda 0.85	Lambda 0.90	Source
CA	Northern: Oregon to Shelter Cove	1995	29-30Aug.	450	17	0.038	0.039	0.041	0.871	0.921	CCR/ MRB 1996
		1994	8-11Aug.	775	56	0.072	0.100	0.114	0.903	0.957	
		1993	15-30Aug.	192	4	0.021	0.023	0.024	0.862	0.913	Ralph and Long 1995
	Central: Ano Nuevo Region	1995	1-15Aug.	207	2	0.010	0.014	0.015	0.858	0.908	Becker et al. 1996

Table 3. Annual and proportional survival rates of four population of common murres and one population of thick-billed murres calculated for different age classes from band recovery data in Birkhead and Hudson (1977). N is the number of birds banded in the initial cohort. Proportional survival is the annual survival of the age class divided by the average annual adult survival for the species (0.925 for common murres and 0.910 for thick-billed murres).

Species	Location	N	0-1	1-2	2-3
Common Murre	First Island, Canada	319	0.61	0.76	0.90
	Norway	157	0.47	0.77	0.87
	O. Gannet Island and South Britain	113	0.47	0.73	0.87
	Witless Bay, Canada	301	0.67	0.79	0.84
	Mean survival	-	0.56	0.76	0.87
	Mean proportional survival	-	0.60	0.82	0.94
Thick-billed Murre	Blot Island and Greenland	92	0.55	0.75	0.88
	Mean proportional survival	-	0.60	0.82	0.97

Simplified Marbled Murrelet Demographic

Stage Life Cycle



Stage 0 = Juveniles
Stage 1 = Subadults
Stage 2 = Adults

Figure 1. A simplified life cycle diagram for the marbled murrelet used in developing predictions of demographic trends.

Fledging Dates for 74 Murrelet Nests

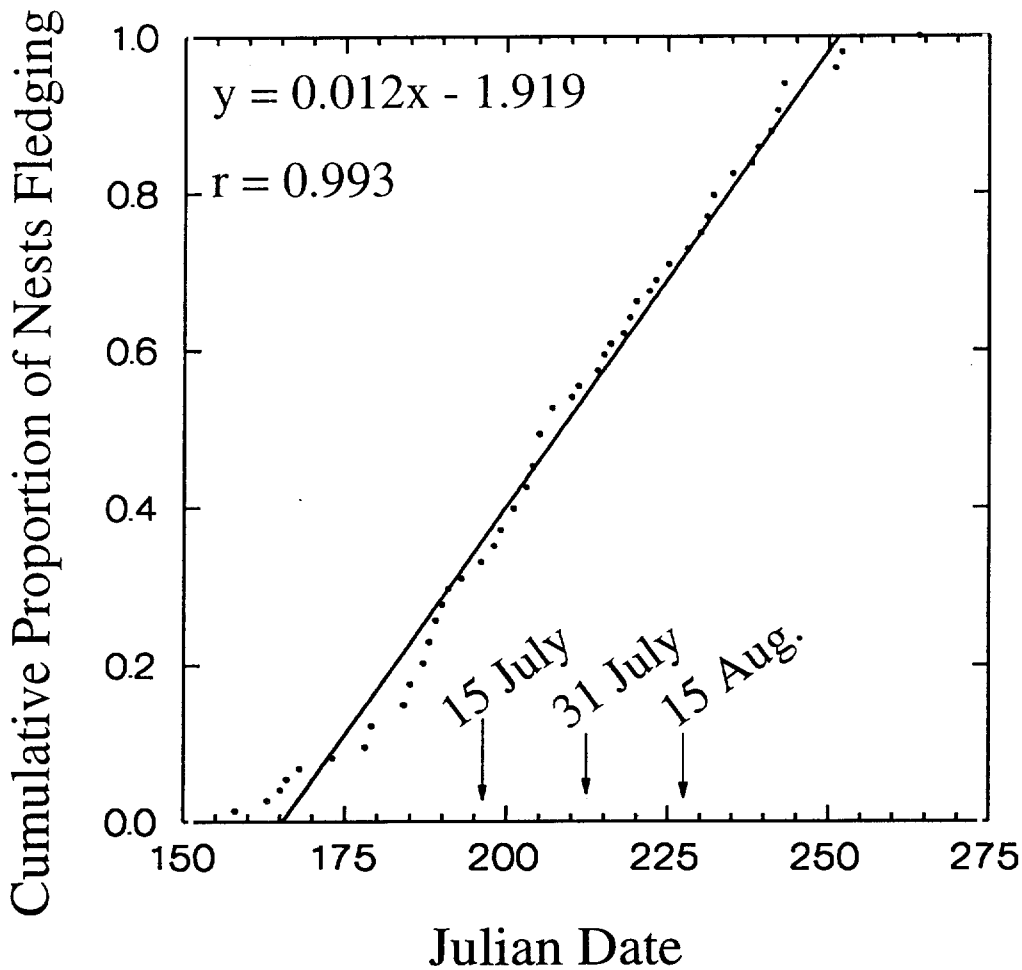


Figure 2. The cumulative probability distribution function for fledging dates of 74 marbled murrelet nests. Results of a linear regression of Julian date (x) on the cumulative proportion of nests that fledged (y) was fit to data are given. No probability value can be calculated for the regression because cumulative fledging values are not independent. Data are from Hamer and Nelson (1995). Dates shown refer to the end point of censuses used to adjust the juvenile ratio.

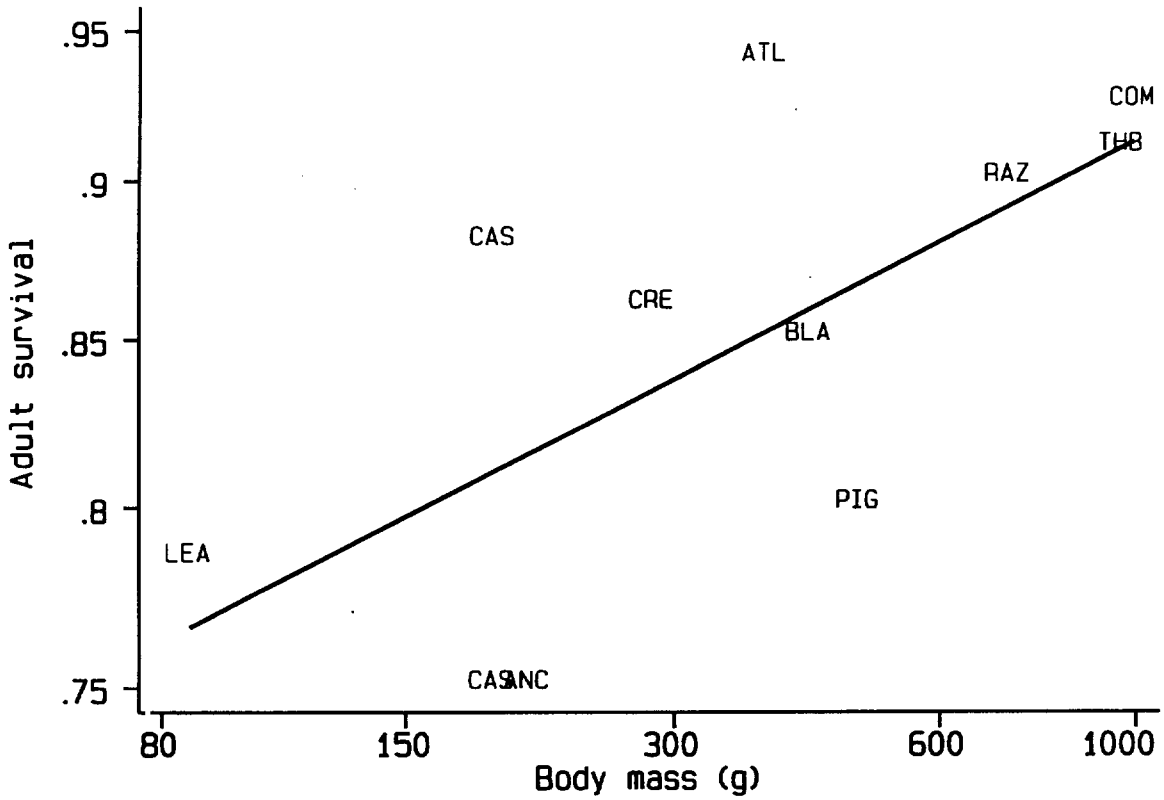


Figure 3. Relationship between adult survival and body mass for the Alcidae. Both variables have been $\log_e$ transformed in the statistical analyses and are plotted on logged scale. The line indicates the least squares fit to the data. Three letter codes depict species: LEA=Least Auklet, CAS=Cassin's Auklet, ANC=Ancient Murrelet, CRE=Crested Auklet, ATL=Atlantic Puffin, BLA=Black Guillemot, PIG=Pigeon Guillemot, RAZ= Razorbill, THB=Thick-billed Murre, and COM=Common Murre.

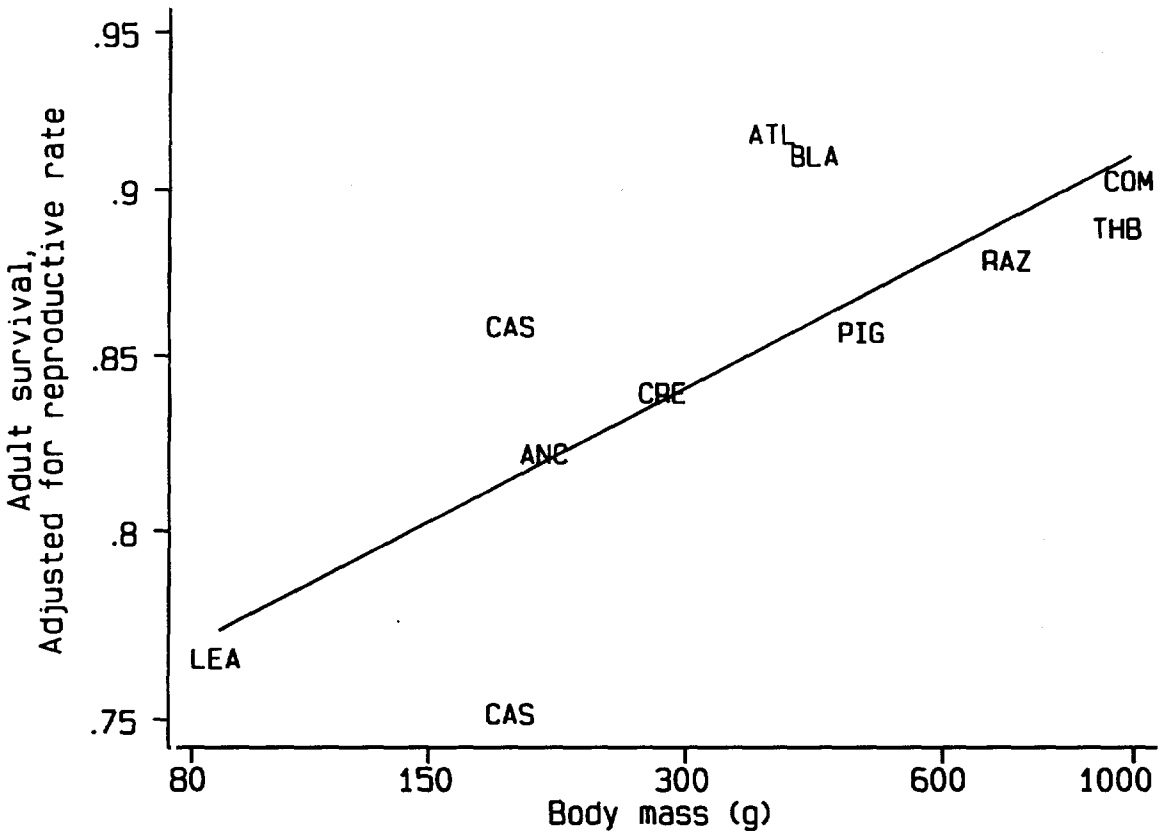


Figure 4. The relationship between adult survival adjusted for the square root of reproductive rate and body mass for the Alcidae. Both axes have been $\log_e$ transformed. The line indicates the least squares fit to the data. Three letter codes depict species as in Figure 3.

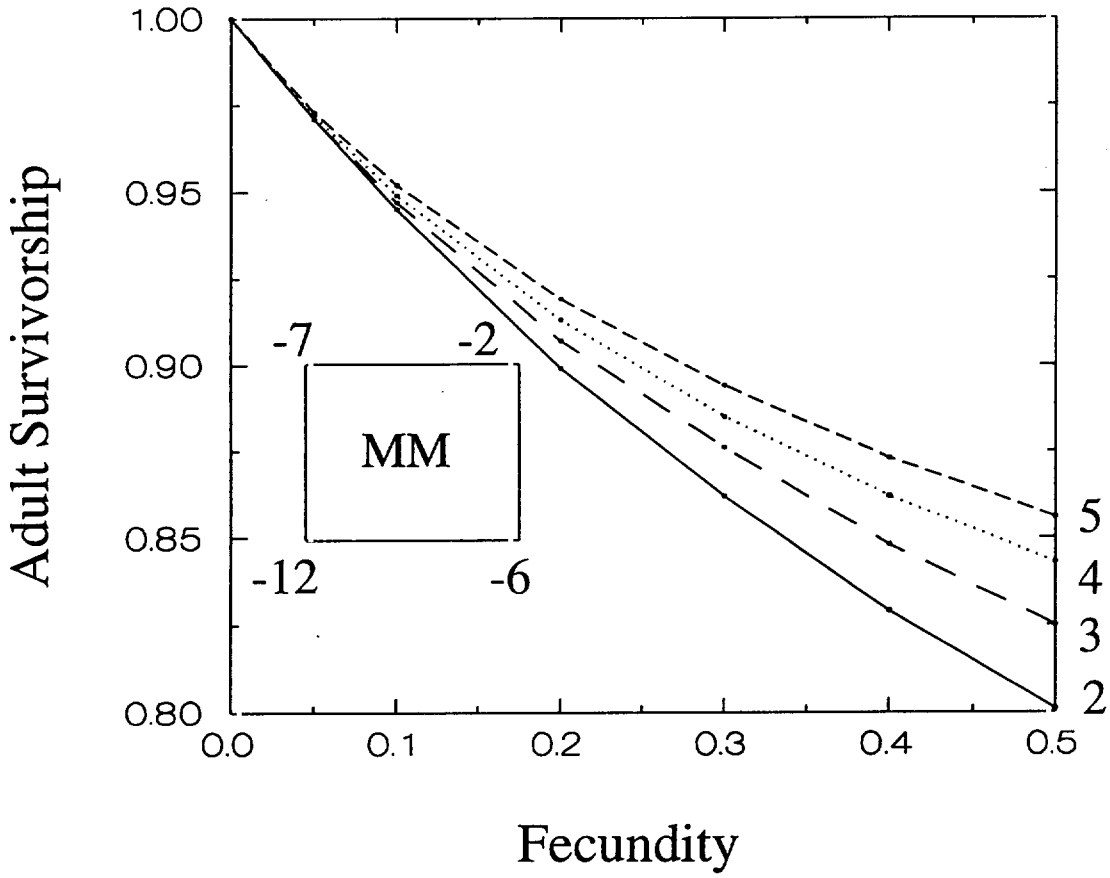


Figure 5. Sets of isobars where lambda equals 1 (i.e. populations are neither increasing or decreasing) for different combinations of fecundity and annual survivorship. Above the isobars populations should increase and below the isobars populations should decline. Lines are shown for ages of first breeding from 2 to 5 years.. Likely marbled murrelet values for survivorship and fecundity are given by the box. Average annual adult survivorship is expected to fall between 0.85 and 0.90. Maximum fecundity was set by uncorrected nesting success (0.18) and minimum fecundity from low at-sea ratios (0.06). All likely values of reproduction and fecundity for the marbled murrelet (MM) fall within the rectangle and indicate declining populations. The annual percentage decline for the four corners of the rectangle is shown.

APPENDIX C: Marbled Murrelet Cooperative Research Process to Coordinate Monitoring Efforts and Large Scale Studies

Summary.--Research and monitoring on the marbled murrelet (*Brachyramphus marmoratus*) has been difficult to conduct due to the biology of the bird, has been poorly funded, and has occurred in an uncoordinated fashion. This has resulted in few answers to the many problems faced by regulators and land managers. We propose to develop and guide a cooperative effort among researchers and cooperators throughout the range of the murrelet in the Pacific Northwest. This effort would help to fund the strategic studies that need to be done at a regional level, ensure that the work was relevant to pressing management decisions, promote the use of standard survey and research methods, help fund and coordinate monitoring efforts, and help coordinate databases among the three states. Especially emphasized would be management problems that can not be solved without making comparisons across a range of landscape and marine habitats, questions that require intensive efforts, and large-scale monitoring programs. A large-scale project envisioned during the first five years would coordinate a regional study to examine the relative importance of forest landscape conditions and marine influences on the productivity and population trends of the murrelet. The design will also serve as a regional monitoring program for the murrelet, as suggested in the research and monitoring section of FEMAT. Because of the size, geographical range, costs and scope of this study and other desired regional research and monitoring programs, tremendous coordination among a team of cooperators will be needed. Coordination and leadership can best be accomplished through the expertise and venue of the Marbled Murrelet Recovery Team with cooperation of the U.S. Fish and Wildlife Service (Service).

Introduction.--Information on the biology of the marbled murrelet for forest management decisions is incomplete. As a result, the Service, including the Marbled Murrelet Recovery Team, and other wildlife management agencies, have

had to employ conservative approaches to conservation planning and resource protection. New and better information on the ecology and demography of the marbled murrelet can only lead to the relaxation of current management recommendations, fewer conflicts over resource management, and gains for forest managers, wildlife managers, the forest products industry and the net fisheries industry.

Research on the marbled murrelet has resulted in few firm answers to the many problems faced by regulators and resource managers for several reasons. First, this species has been difficult to study due to its biology. Murrelets are difficult to capture, their nests in the canopy of older forests have been extremely difficult to locate, and their movements are poorly known because the bird can fly up to 80 kilometers (50 miles) daily to and from the ocean where it spends most of its time. Second, research on murrelets has been poorly funded. Funding levels have been low and studies typically are funded on a year-to-year basis, which makes it difficult to plan studies to obtain valuable multi-year information and to establish intensive studies that would result in break-throughs in the understanding of murrelet ecology. These types of studies are needed to discover and develop a range of forest management options for nesting habitat and better understand the demographic characteristics of the population. Third, research has occurred in mostly an uncoordinated fashion. Census and data analysis techniques are not always standardized and often poorly understood, and duplication of efforts has occurred. There has been insufficient coordination among state, Federal, and private organizations conducting studies. Fourth, there is a real schism and a deficiency in relating research efforts and results obtained in the forest environment and those conducted at-sea, even though both habitats are critical to the life history of the murrelet. Finally, much of the data already collected is unavailable for use in analyses and decision-making by state and Federal officials, and often is not incorporated into central databases (e.g., surveys on private lands,

and state surveys). Much of this data is available as data sheets from a wide range of agencies, but has not been entered into computer databases or compiled in a usable format. For those data that are available in computer databases, file formats have not always been standardized to enable compilation between regions.

Unlike the spotted owl, which often requires thousands of acres of habitat to support a breeding pair, marbled murrelets have been documented to sometimes utilize small stands as nesting habitat. In addition, their nesting habitat is often found in low elevation conifer forests, with near-coastal habitat possibly playing an important role in sustaining populations. For these reasons, nesting habitat found on non-Federal ownership in certain areas may support a significant portion of the population and contribute to recovery in a meaningful way. Therefore, it is important to promote the cooperation of non-Federal entities in the information gathering/monitoring efforts for this species and have them participate in using the results to develop forest and marine management options for the marbled murrelet.

Some of the most important information needed for management decisions is likely to come from studies of murrelets at large scales - at both land and sea. For example, there is a need to understand the effects of forest landscape and stand characteristics on reproductive success, the extent of older forest that needs protection, or the role of oil spills and net fisheries in the population decline. The fastest route to answer these and similar questions will be to make comparisons of the health of murrelet populations at-sea among areas with different forest landscape and marine characteristics. Such large scale and complex studies will never happen without a well coordinated and well funded cooperative effort among researchers, managers, and other involved parties. In addition, the cooperative could ensure that monitoring efforts are carried out in such a way as

to examine specific hypothesis about murrelet population trends or the factors that limit marbled murrelet populations.

During the time that the Team gathered information to write a Recovery Plan, it became apparent that management decisions and recovery efforts for the murrelet were most restricted by incomplete information. Thus, the Team determined that one of the best ways it could assist recovery was to catalyze an effort to obtain the biological information that was critical for making wise management decisions and contributed to identifying key goals and objectives to focus recovery efforts.

The Marbled Murrelet Recovery Team would develop and guide a regional cooperative of researchers throughout the range of the murrelet in the Pacific Northwest. This effort would help to fund the strategic studies and monitoring that need to be done, and ensure that the work was relevant to pressing management decisions. The lifetime of this cooperative effort is expected to be 10 years. This period should be long enough to relate population trends to forest and marine habitat conditions, and to obtain key information on important unknown aspects of the murrelet's life history. Especially emphasized would be management problems that can not be solved without making comparisons across a range of landscape and marine habitats, questions that require intensive efforts, and efforts involving regional data collection or analysis to examine population level questions. In addition, the cooperative would help ensure that funding was available to complete critical long term studies (3-10 years) and monitoring by pooling resources from various participants with similar research and monitoring needs and using the combined resources of the cooperators to obtain additional funding. The cooperative would also function to ensure that all available murrelet data was deposited in central and state database centers, and assist in database management.

Participants in the Cooperative.--As a prerequisite to be involved in the cooperative, potential participants must actively bring something of value to the cooperative or be willing to conduct or participate in an activity that is beneficial to completing the goals of the group. This involvement could be funding contributions to specific projects, biological expertise, contributions of personnel or equipment to research and monitoring projects, or the sharing or cooperative collection of data pertaining to the needs of the group. The concept is that each party needs to actively contribute or participate in a meaningful way in order to gain the benefits of the association. All parties must be willing to share information with the other parties involved.

Cooperators should include, but are not limited to, state and Federal agencies participating in the Regional Interagency Executive Committee (RIEC) and Regional Ecosystem Office (REO), such as the U.S. Forest Service, Bureau of Land Management, U.S. Geological Survey (Biological Resources Division), National Park Service, State Wildlife Agencies, State Agencies with forest management responsibilities, tribes, Bureau of Indian Affairs, and the National Marine Fisheries Service. Additional cooperators would include representation from the Pacific Seabird Group, members of the private forest industry and related organizations such as the National Council of the Paper Industry for Air and Stream Improvement (NCASI) and Northwest Forestry Association.

As part of the Northwest Forest Plan, monitoring was considered a key component of adaptive management and a required activity for ecosystem management, implementation of conservation strategies, and compliance with forest management laws and policies. The Forest Plan recommended that Federal agencies should develop a multi organizational resource monitoring system that is adequately funded and with organizational responsibilities that are clearly defined. In addition it was recommended that Federal agencies in collaboration with state

and private interests should encourage the design and implementation of landscape-scale research and monitoring projects that would enhance scientific knowledge of particular species, develop analytical tools for ecosystem management and expand the resource productivity options for Pacific Northwest Forests. This has become a high priority for the REO. We feel this regional cooperative fulfills many of these obligations and objectives and should help meet the expectations established for murrelets by the RIEC and REO.

Organization of the Cooperative.--The steering committee would be composed of members of the Recovery Team and representatives of industry, the tribes, Federal agencies, state agencies, and other cooperators and would work closely with each other in the decision-making process. Among its other duties, the Team is responsible for guiding and accelerating the recovery of the marbled murrelet throughout the Pacific Northwest, and for determining criteria to delist the species. The Recovery Team would act to guide and help coordinate the monitoring and research activities of the cooperative as members of this committee (Figure 1). This organization would help ensure that the monitoring and research activities being conducted or proposed could be executed in such a manner as to have some benefits to recovery efforts and objectives. This is not to say that all activities of the cooperative need to carried out with the information needs of the recovery effort as a primary goal. But many projects may be able to gather critical information needed for recovery without much additional effort just by clearly knowing the goals and objectives of the Recovery Plan.

Members of the steering committee must represent comparable levels of authority within their organizations or agencies, have the authority to make decisions for their organization, and be held accountable for their decisions to their constituencies. These members should also have adequate resources of time and funding to be involved in the cooperative in a meaningful way. Steering

committee members would be selected by appointment from each cooperator through the Service's Regional Office. These members should have an understanding of the science involved in this issue and preferably have research related backgrounds.

The major role of the Service would be to facilitate formation of the cooperative and establish a database management center. The primary role of the steering committee would be to encourage and promote collaborative processes among the cooperators. In addition they would help identify potential participants, encourage the participation of cooperators, and ensure their representation in the process. The steering committee would also function to enhance communication between parties by ensuring all participants are kept informed of the information goals, project developments, and results of the monitoring and research conducted by the cooperators. The committee would also promote jointly conceived investigations and provide incentives for cooperation by helping negotiate/coordinate joint funding allocations. The cooperative is not envisioned as a funding source but a way to better utilize current funding and coordinate funding efforts. The result of all these activities is to build partnerships, promote cooperation and establish a strong foundation for continued cooperation.

To carry out these goals the steering committee would first obtain feedback from all the cooperators on their specific monitoring and research needs and then summarize these needs. Using this summary, the committee would then inform the cooperators of overlaps in information needs, look for ways to coordinate these needs between groups, and encourage cooperative efforts between these groups. Discussions of the goals of the research and monitoring would take place using the expertise of the steering committee and the research working group in order to further clarify the needs of the participants and provide feedback on whether the goals can be met by conducting particular activities or suggest project

alternatives. This process would help the parties identify and focus their interests and information needs and should occur on an annual basis. Promotion of cooperative efforts would reduce costs for obtaining the information for each individual participant, encourage standardization of research and monitoring techniques, avoid duplication of effort (except when duplication is desired) provide opportunities for large scale studies that could not be conducted without intensive efforts of a larger group, and encourage regional level studies.

Two working groups would be formed under the steering committee (Figure 1), the research working group and the funding working group. The research working group would be responsible for developing research and monitoring study plans based on the common information needs of the cooperators as summarized by the steering committee. After these plans are completed they would be given to the steering committee for review. After review, the steering committee would then make recommendations on how to modify study designs to better meet the needs of cooperators, suggest ways of making the design better suited to meeting the monitoring and research needs of the species, or make suggestions on how the plans could be designed to be carried out as regional level projects. The research working group would then review the plans to see if modifications can be made. The role of the steering committee is to obtain the best peer review of proposed projects from the research group and provide feedback on the quality of the projects and their priority to the cooperators. Both the research working group and the steering committee set priorities for projects to be completed. Once final study plans are completed, the steering committee would provide the plans and associated budgets to the funding working group.

The research working group would be comprised of experts on wildlife research and monitoring techniques, statistical methods, and study design. We envision utilizing the best experts in certain fields for this group including a seabird

ecologist, forest ecologist, marine ecologists or oceanographer, statisticians familiar with the problems of population sampling and wildlife study design, and marbled murrelet biologists. Particular study designs may include experts from other fields. Many of these scientists would be available from the agencies participating in the cooperative. If they are unavailable, outside expertise in each discipline will be sought. Members of the research working group may also be participating in the field research. This group is also responsible for analyzing the research and monitoring data collected from jointly funded projects and reporting to the steering committee on the results. The steering committee would then make these results available to all cooperators.

The funding working group would be comprised of administrative level personnel made available by the cooperators that have the authority and responsibility for making funding decisions regarding the research and monitoring of threatened and endangered species. Their responsibility will be to help obtain the necessary funding for the projects developed by the steering committee and research working group, lobby for funding from appropriate sources, coordinate collaborative funding efforts, and ensure that multi-year studies have continued support to complete their projects.

The steering committee would hold semi-annual meetings with the cooperators to report on progress and decisions made by the committee and the two working groups, and to encourage communication and feedback from the cooperators to the cooperators as a whole. It is envisioned that most cooperators would have personnel on the steering committee or positioned in one of the two working groups.

A central database and coordinator would be established by the Service to gather, collate, store, and make available the research and monitoring data now being

collected by a small army of independent sources throughout the three-state area. This coordinator would facilitate information exchange, help develop standard inventory, monitoring, and data collection techniques and make data available for range-wide analysis. The job would also entail standardizing various data sources for compilation and ensuring appropriate archiving of collected information for future researchers. The day-to-day coordination and central database management would be done by Service employees including a coordinator and 1-2 staff members. This group would report to the steering committee on its activities. The establishment of a West Coast Marbled Murrelet Data Center is a precursor to long-term recovery actions based on the best data available.

Individual researchers and principle investigators would retain the rights to information collected from their projects for a 2-year period after project completion to publish results. In this manner individuals would retain control of data for a limited period before making the data available to the database staff and the larger cooperative. This process should speed up the availability of information and information exchange. Once the data is available, the steering committee could make recommendations on how to incorporate the information into a regional analysis. Regional analysis would be coordinated by the steering committee using the expertise of the research working group. This group would oversee the analysis and interpretation of the data. During the organization of the cooperative, the steering committee will develop guidelines for data sharing, data ownership, and data interpretation that will be fair and equitable for all participants involved. This will be an important first step in successful formation of this group since issues of data analysis and interpretation will be critical to define. The goal will be to include all parties in this process and have everyone benefit from wider discussions and alternative approaches. Open access to all data soon after analyses are completed will be a priority objective and be coordinated by the database staff.

Once members of each working group and the steering committee are selected, conflicts of interest will be identified and the steering committee will develop ways to resolve these conflicts. Conflicts of interest of the majority of the members will be unavoidable. It is a part of forming a broader cooperative effort that involves all participants with varying interests and agenda's. Many participants will have conflicts of interest in one or more areas. Managers and heads of research organizations will obviously want to have particular research or monitoring projects conducted through their organization. Individual researchers with certain interests and expertise, and consultants, may also want to carry out particular research projects.

The design of the cooperative is not to approve or disapprove of particular research projects or to discourage independent research or local projects. Its main function is to promote intensive large-scale research and monitoring projects that could not be conducted by anyone party and promote the wisest, most cost efficient use of funds and information as possible by encouraging collaborative projects, and stimulate funding.

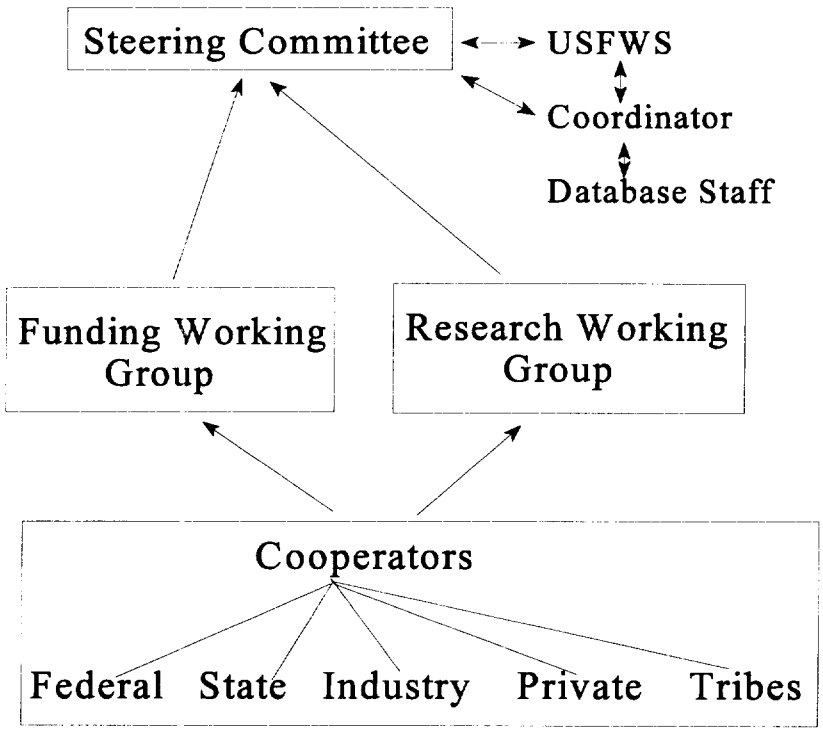


Figure 1. Structure of the Marbled Murrelet Research Group.

Appendix D: Summary of the Agency and Public Comment on the Draft Marbled Murrelet Recovery Plan.

I. Summary of the Agency and Public Comment on the Draft Marbled Murrelet Recovery Plan

In August 1995, the Service released the draft recovery plan for the marbled murrelet (Washington, Oregon, and California Populations) for a 60-day public comment period, ending on October 10, 1995 (60 FR 40851). Over 400 copies of the draft plan were sent out for review during the comment period. Also, during the public comment period, five informational meetings (held in Washington, Oregon, and California) were provided to potentially affected parties to address both proposed critical habitat and the draft recovery plan.

A total of 222 letters/comments was received, each containing varying numbers of issues. Many specific comments reoccurred in letters. Many of the specific comments related to wording, clarity, and issues were incorporated, where appropriate, into the final plan and are not addressed in the following section. Issues/comments raised during the public comment period that were not addressed or incorporated into this final plan are discussed below.

This section provides a summary of general demographic information, including the total number of letters/comments received from various affiliations and states. It also provides a summary of the major comments. A complete index of the those providing comments, by affiliation, is available from the U.S. Fish and Wildlife Service, Oregon State Office, 2600 SE 98th Avenue, Suite 100, Portland, Oregon 97266. All letters of comment on the draft plan are kept on file in the Oregon State Office.

Demographic Information

The following is a breakdown of the number of letters received from various affiliations:

Federal Agencies	6
State Agencies	5
Local Governments	1
Business/Industry	5
Environmental/Conservation Organizations	10
Academia/Professional	5
Individuals	190

II. Summary of Major Comments and Service Responses

Issue 1: One commenter had concerns that the boundaries for the Marbled Murrelet Conservation Zones (MMCZ) and the inland extent of proposed critical habitat were not the same. They wanted the differences reconciled so that all designated critical habitat falls within the final designation for the MMCZ.

Response: The Service designated critical habitat on May 24, 1996. The inland boundaries of the Marbled Murrelet Conservation Zones have been adjusted to include all murrelet critical habitat.

Issue 2: One commenter felt the plan needed to define 'potential nesting stands' and the size limit to trigger application of the recommended buffer. As written, it would encompass any stand that met the nesting structure parameters regardless of occupancy status and regardless of size. At a minimum, it is recommended that a stand size limit be specified.

Response: This task (3.1.1.3) has been clarified so that it reads "maintain and enhance buffer habitat surrounding occupied habitat".

Issue 3: Several commenters had concerns that marine critical habitat was not designated as was recommended by the Recovery Team.

Response: A summary of the final rule designating critical habitat is provided in this final recovery plan (see "Marbled Murrelet Critical Habitat" under "G. Current Regulatory Mechanisms and Management of Marbled Murrelet Habitat"), including a discussion of marine areas and their importance.

Issue 4: One commenter felt buffering occupied stands was an excellent recommendation. As replacement habitat, however, these buffers would likely be as susceptible to catastrophic habitat loss as the rest of the buffered stand. To protect the population against catastrophic habitat loss, some replacement habitat should also be developed in areas away from currently occupied stands.

Response: Through implementation of the Northwest Forest Plan and the completion of HCPs, etc., replacement habitat will be developed away from currently occupied stands. This would include regrowth of both suitable and buffer habitat in the Late-Successional Reserves where none currently exists.

Issue 5: A couple of commenters had concerns that low juvenile:adult ratios could also result if the murrelet population is in a non-equilibrium condition. If this is the case, much of the adult population would be comprised of non-breeding birds, resulting from habitat loss. Once habitat loss has been eliminated and the population is allowed to equilibrate with the amount of remaining nesting habitat, the juvenile:adult ratio would increase due to decreases in the adult population size. Consideration of this possibility appears to be lacking in the draft recovery plan and in the modeling work by Beissinger (1995a).

Response: At this point in time, we don't know the exact mechanism for the low juvenile ratios in murrelets, other than reproductive success is poor relative to the size of the potential breeding population. Low juvenile ratios could be due to (1) a low percentage of adults finding nest sites, (2) low nesting success due to predators or a lack of food or other factors, (3) poor survivorship of young flying from the nest to the ocean, (4) complex and poorly understood patterns of dispersal and mortality of juveniles at sea and dispersal and movements of adults at sea, or (5) most likely a combination of the four prior factors. No assumption of equilibrium or non-equilibrium dynamics is made in the population model. The population model makes predictions only of the short-term rate of population change. The distinction between equilibrium and non-equilibrium dynamics mainly relates to long-term population dynamics—that is, the juvenile ratio might increase as the overall population declines to the point that a greater percentage of birds are nesting successfully when the population declines to a smaller size. Over the long term, it should be possible to see this if juvenile ratios increase while population size decreases, but many years of data will be needed before it will be possible to see if this is happening.

Issue 6: A couple of commenters felt that population models should also be evaluated under non-equilibrium conditions. Additionally, catastrophic habitat loss, and catastrophic population reductions (i.e., mortality events that do not result in long-term habitat loss) should be incorporated into the population modeling. Although frequency, severity, and spatial locations of catastrophic events are hard to predict, simulations could incorporate ranges for these parameter values. Modeling of this type could help determine the pattern of catastrophic events that would threaten recovery prospects for the next 100-200 years and give a better indication of long-term population security.

Response: Population models are best used for management decisions when there is some good data to be incorporated. Ideally, population models for the marbled

murrelet might be constructed to include the effects of catastrophes like oil spills, changing carrying capacity based on forest loss and regrowth, and year-to-year variation in reproductive success and survivorship to make long-term (100-200 year) estimates of the viability of the population. Unfortunately, the creation of such models are less defendable for the murrelet than the approach taken. They would be based on rough estimates of the effects of oil spills on birds, the carrying capacity and site occupancy of murrelets in forests that are not based on any defendable criteria, and estimates of the variance in reproductive success and survivorship from other birds. Each error in estimation of parameters might be compounded hundreds of times as the model projects murrelet populations 100-200 years into the future. There would be less confidence in the estimated rates of extinction from such a model and no way to verify the model. It is clear from the model used that marbled murrelets are likely to be declining, perhaps rapidly, and that current rates of reproduction are typically less than what is needed to replace populations. This indicates a population decline due to extrinsic factors. The effects of random, naturally- occurring environmental events, catastrophes, and additional habitat loss can only act to accelerate the expected rate of decline. As the population model is currently constructed, average survivorship rates had to be estimated from the literature using life history theory. This certainly is less accurate than estimates of survivorship based on data for murrelets and it is possible that our estimates for lambda are weak. For this reason, we examined a range of values likely to be typical for the murrelet, as indicated from studies of other sea birds.

Issue 7: One commenter felt that the statement "Population modeling indicates that adjusted juvenile:adult ratios should be 15-22 percent at a minimum to result in stable populations" could easily form the basis of an interim recovery goal.

Response: At this point, it may be premature to set interim recovery goals on the basis of a population model. More confidence in the quantitative predictions from the population model will emerge when some parameters in the model are better known (e.g., age of first breeding and survival rates). Adjusted juvenile ratios conceivably be incorporated in recovery goals in the next 5-10 years.

Issue 8: One commenter felt that although the draft plan identified existing gaps in nesting habitat, and some probable causal factors, it failed to provide much guidance on what should be done to improve the distribution of such habitat.

Response: During the development of management plans (Federal, state, private), the existence of these gaps should be recognized and ways to lessen the gaps incorporated into planning/conservation efforts (e.g., HCP mitigation, consultation with Federal agencies, land exchanges, etc.). Ways to address these gaps are identified in various sections of "Narrative Outline for Recovery Actions."

Issue 9: A couple of commenters felt that captive care (and research) should be a higher priority than described in the draft plan. Several reasons were provided, including education, understanding important life history parameters, improving field research techniques, rehabilitation, and captive breeding.

Response: The Service does not disagree that captive care can be one component of a successful recovery program. It can provide certain benefits for better understanding certain aspects of murrelet biology. However, given limited funding for recovery efforts, it is still recommended that at this time, the limited government funds should go to studies of murrelets in the wild (see page 10).

Issue 10: One commenter felt the Pacific Northwest column on Table 2 was somewhat unclear. The table header states that for some locales the sample size was too small to calculate the mean, or no data exist, but it is unclear if this is the reason some sample sizes do not add up. In addition, it was unclear how the stand age was calculated. Is it the age of the oldest tree in the stand? Is it the average age of trees in the stand? Is it the time since the stand was initiated?

Response: For some states, or the Province of British Columbia, there was not a sufficient sample to calculate a mean or standard deviation for some characteristics. However, for the Pacific Northwest column, there was always a sufficient sample when all states and provinces were combined. Therefore, this column sometimes shows a higher sample of nest sites. Related to stand age, that information was obtained from the various researchers and was calculated by them using several different methods. Stand ages were calculated by (1) using increment bores on the most dominant trees in the stand, (2) using data from forest inventory databases which typically estimate stand origin for the most common dominant trees within the stand, or (3) estimating the age of trees in the stand.

Issue 11: A couple of commenters felt the draft plan did not include the most recent information available or that the information, if used, was used selectively.

Response: Every effort has been made to review the most recent information available and incorporate that information, where appropriate, into this final recovery plan. Specific references mentioned in the comments were evaluated and sections, including Appendix B, were updated using this new information.

Issue 12: Several commenters felt that marine influences and potential effects (including prey species, global warming, El Niño events) were largely ignored and also that the threat of oil spills and net fisheries were dismissed without supportive data.

Response: The final recovery plan has addressed this concern by providing additional discussion in several sections on all aspects of the marine environment and potential influences/effects on marbled murrelets (see especially "Possible Changes in Prey Abundance and Distribution"). There is also considerable discussion on the threat of oil spills and net fisheries, and they have been evaluated as to their contribution to the problems facing the murrelet. However, based on all of the information available, the primary threat to the marbled murrelet is the loss and fragmentation of nesting habitat.

Issue 13: The draft recovery plan relies heavily on implementation of the President's Forest Plan to accomplish recovery of murrelets. However, several commenters felt that this underlying assumption needs to be reassessed in the revised recovery plan. A careful analysis is needed of how the Forest Plan is altered by the recent Salvage Logging Bill and how those alterations affect marbled murrelet recovery.

Response: An analysis was completed by the Regional Ecosystem Office (REO) for the effects of the timber sales released under Section 2001(k) of Public Law 104-19 (Salvage bill). The REO considered the amount and distribution of the impacts of the relevant sales, including sale acres, location, and land allocation. Rescission sales were dispersed over five different provinces and represented a very small loss of habitat relative to the overall Forest Plan. Recession Act sales not previously accounted for in the 1994 biological opinion on the Forest Plan totaled 1,269 acres. Related to murrelets, the government's position, which was upheld by the Ninth Circuit Court of Appeals, was that section 2001(k)(2) of P.L. 104-19 expressly forbid the harvest of identified nesting sites. Therefore, all 2001 (k) sales that were determined to be occupied were not released for harvest. Based on this analysis, the underlying assumptions of the Forest Plan as they related to murrelets were not significantly altered by the Salvage Logging Bill.

Issue 14: Definitions of suitable and recruitment habitat should be included in the plan. This should include a comparison of stand characteristics and habitat characteristics between stands with high levels of occupied behavior, low levels, presence only, and no detections (similar to Hamer *et al.* 1994; Forest Habitat Relationships of Marbled Murrelets in Western Washington, WDFW).

Response: Including definitions of suitable and recruitment habitat for marbled murrelets within the plan by conducting comparisons of occupied stands to stands with presence and absence is an excellent suggestion. Unfortunately, to undertake the task for each Conservation Zone and Physiographic Province for the three-state area would have been extremely time-consuming. In addition, for some regions, the habitat data to accomplish this is not available. This would be good information to include in any revision to the plan. It has been added as a recovery task (4.1.4).

Issue 15: One commenter stated that the plan should include current amounts and distribution of nesting and recruitment habitat, combined with GIS simulations of the future amounts and distribution of potential nesting, recruitment, and replacement habitats throughout the range.

Response: The Service agrees that this information would be valuable to have, but it currently is not available for all areas. Through continued implementation of the Forest Plan and the required monitoring efforts and completion of tasks outlined in the recovery plan, the necessary information may be available in the future so that the types of simulations recommended could be completed. However, there is the possibility that remotely-sensed data may not be adequate to describe appropriate murrelet habitat characteristics. Pilot studies have been initiated to evaluate this type of information.

Issue 16: Several commenters felt the plan needed to provide more specific delisting criteria now, even though we acknowledge it will probably change. They felt that if there was enough information to list the species, the Service should know what is necessary to delist it.

Response: Delisting criteria should not be established without careful consideration of the biological realities and a better understanding of the murrelet population trends and year-to-year variability in demographic parameters than currently exist. Currently, there are many unknowns with murrelet demographic parameters.

Issue 17: One commenter felt that interim targets should be set for the maximum allowable by-catch of murrelets based on the demographic model by Beissinger (1995a).

Response: Additional details, which suggest that estimates of murrelet by-catch in the Pacific Northwest have been small, are given in the revised version of the plan. The population model developed in Appendix B is not capable of setting allowable by-catches because it suggests that in most years murrelet populations are likely to be declining. Nevertheless, the model does indicate that declines in adult mortality have a disproportionally important effect on the rate of murrelet population change (lambda). These two model predictions indicate that every effort should be made to minimize by-catch of murrelets.

Issue 18: One commenter recommended that the Conservation Zones for Washington be changed to better meet conservation and recovery objectives. This should include having three zones instead of two, taking into account similarities in the Straits of Juan de Fuca and other inland waters, the unique habitats of the western Olympic Peninsula, and the almost exclusive state and private lands in southwest Washington.

Response: Zone 1 has been changed to include most of the Straits of Juan De Fuca. The portion that is not included is adjacent to Cape Flattery with conditions very similar to the open ocean. We did not separate out southwest Washington or northwest Oregon into separate conservation zones to ensure conservation efforts in those areas. Although the break between southwest Washington and northwest Oregon is mainly based on a state boundary, differences in state management were considered in establishing some of the Zone boundaries.

Issue 19: A couple of commenters had concerns that the 0.5 mile protection guideline in ROD does not provide sufficient protection to occupied sites on Federal lands.

Response: The 0.5-mile protection boundary around occupied sites outlined in the ROD is centered on the occupied behavior observed or designed to include the most contiguous habitat available around the detection. Therefore, if additional occupied behaviors are observed nearby, additional 0.5-mile circles would be established around these sites so that the final amount of habitat protected could be very large and not limited to just one 0.5-mile protection zone. When the

guidelines are administered in this manner, your concerns about the 0.5-mile guideline not protecting contiguous habitat, nearby occupied sites, or large occupied stands in the matrix would be handled. Therefore, the guidelines should not result in increasing fragmentation or a decrease in stand sizes.

Issue 19: Several commenters felt that the draft recovery plan failed to comply with the Endangered Species Act. It failed to describe site-specific management actions, measurable delisting criteria, and an estimate of the time and cost required to carry out those measures.

Response: Site-specific management actions are provided in the recovery plan. Specific areas are identified as essential to the species recovery (e.g., Late-successional Reserves, National and State Parks, etc.) and both short-term actions and long-term actions are identified for these areas under the section "Narrative Outline for Recovery Actions." The Recovery Objectives section and delisting criteria section have been modified; however, see response to Issue 16. Because an anticipated delisting date cannot be estimated, figures have been provided for the recovery costs over the next 10 years. It is anticipated that this interim plan will be revised within that time frame and both more specific delisting criteria and a date and estimated cost for recovery can be provided at that time.

Issue 20: One commenter felt the recovery plan was a significant action requiring an Environmental Impact Statement or at least an Environmental Assessment.

Response: Implementation of a recovery plan is not mandatory. A recovery plan only lays out actions that, if implemented, should lead to the recovery of the species. Only when the actions are actually carried out should compliance with the National Environmental Protection Act be necessary.

Issue 21: One commenter felt that since the Service did not know historic numbers and distribution of murrelets and a lot of other facts about marbled murrelets, more information should be gathered before any action (designating critical habitat or developing a recovery plan) take place.

Response: In addressing most threatened and endangered species, all the information you would like to have to determine critical habitat and appropriate recovery goals and objectives is not available. The Service must make its decisions based on the best scientific and commercial information available at the

time. Recovery planning must proceed and many of the actions identified in the recovery plan, once completed, will provide the necessary information to help revise initial actions and objectives.

Issue 22: One commenter felt that the Service had not assessed the need to exceed state requirements on non-federal lands.

Response: Current state laws have not prevented habitat loss for the marbled murrelet. Habitat loss is considered to be one of the primary factors that has contributed to the need to not only federally list the murrelet, but to also state list the murrelet in Washington, Oregon, and California.

Issue 23: A couple of commenters felt that the Marbled Murrelet Cooperative described in Appendix B was unnecessary as that particular function would be better served through the Regional Ecosystem Office implementing the Forest Plan. Other commenters strongly supported the Cooperative concept and wished to be included as a cooperator.

Response: This appendix has been modified in response to comments related to its tie with the associated long-term regional study. The Service acknowledges that while some of the actions discussed in the appendix (now Appendix C) will be covered by a regional monitoring effort on Federal lands through implementation of the Forest Plan, there is still a need to have a coordinated effort that covers all aspects and entities involved in marbled murrelet research and recovery efforts. The only way a successful recovery effort will work is if there is an extremely cooperative effort put forth, taking advantage of all of the current and anticipated future efforts in a coordinated fashion. Because of the complexity of ownerships, issues, and the substantial costs necessary to recovery this species, no one group will be able to succeed on their own.