Conservation of the Marbled Murrelet under the Northwest Forest Plan

MARTIN G. RAPHAEL

U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512, U.S.A., email: mraphael@fs.fed.us

Abstract: *The Marbled Murrelet (*Brachyramphus marmoratus*) was listed as threatened in 1992, primarily because of loss of its old-forest nesting habitat. Monitoring conducted over the first 10 years following implementation of the Northwest Forest Plan shows at-sea murrelet populations appear to be stationary, but recruitment is very low and demographic models project a 4–6% annual rate of decline. Monitoring of nesting habitat indicated there were about 1.6 million ha of higher-suitability nesting habitat on all lands at the start of the plan, about half of which occurred on federal lands. Most (88%) of higher-suitability habitat on federal lands was protected within reserves. Over the past 10 years, losses of habitat due primarily to fire have totaled about 2% on federal lands. Losses have been much greater (12%) on nonfederal lands, due primarily to timber harvest. Habitat is expected to accrue within reserves as younger forest matures and attains sufficient diameter to support nesting sites. At-sea estimates of population size are strongly and positively correlated with amounts of adjacent nesting habitat at a broad scale, supporting the idea that amounts of nesting habitat are a primary driver in wide-scale murrelet population distribution. Conditions at sea, however, such as temperature regimes, prey availability, and pollutants, continue to affect murrelet populations. The system of large reserves seems to have achieved the short-term objective of conserving much of the remaining nesting habitat on federal lands. These reserves are also likely to contribute to the long-term objective of creating large, contiguous blocks of nesting habitat. The plan has a primary role in conserving and restoring nesting habitat on federal land but will succeed in this role only if land allocations calling for such protection are in place for many decades.*

Key Words: *Brachyramphus marmoratus*, conservation planning, forest management

Conservación de *Brachyramphus marmoratus* mediante el Plan Forestal del Noroeste, E.U.A.

Resumen: *En 1992* Brachyramphus marmoratus *fue enlistada como amenazada debido principalmente a la pérdida de su hábitat de anidación en bosques maduros. El monitoreo llevado a cabo durante los 10 primeros años después de la implementación del Plan Forestal del Noroeste (el plan) muestra que las poblaciones de* B. marmoratus *en el mar parecen ser estacionarias, pero el reclutamiento es muy bajo y los modelos demográficos proyectan una tasa de declinación anual de 4-6%. El monitoreo del hábitat de anidación indicó que al inicio del plan había alrededor de 1.6 millones de ha de hábitat de anidación de buena calidad, la mitad de las cuales estaban en terrenos federales. La mayor parte (88%) del hábitat de buena calidad estaba protegida en reservas. Durante los últimos 10 años, las pérdidas de hábitat debidas principalmente al fuego totalizan cerca de 2% en terrenos federales. Las pérdidas han sido mucho mayores (12%) en terrenos no federales, principalmente por cosecha de madera. Se espera que el hábitat incremente dentro de las reservas a medida que los bosques jóvenes maduren y tengan diámetro suficiente para soportar nidos. En una escala amplia, las estimaciones del tamaño poblacional en el mar están fuerte y positivamente correlacionadas con la cantidad de hábitat de anidación adyacente, lo que sustenta a la idea de que la cantidad de hábitat de anidación es un conductor primario de la distribución de las poblaciones de* B. marmoratus. *Sin embargo, las condiciones en el mar, como los regímenes de temperatura, la disponibilidad de presas y los contaminantes, continúan afectando a las poblaciones de* B. marmoratus. *El sistema de reservas extensas parece haber alcanzado el objetivo a corto plazo*

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de conservar la mayor parte del hábitat de anidación en terrenos federales. Es probable que estas reservas también contribuyan al objetivo a largo plazo de crear extensos bloques contiguos de hábitat de anidación. El plan tiene un papel importante en la conservación y restauración del hábitat de anidación en terrenos federales pero sólo tendrá éxito en este papel si las asignaciones de terrenos protegidos persisten durante muchas décadas.

Palabras Clave: *Brachyramphus marmoratus*, gestión forestal, planificación de la conservación

Introduction

In the early 1990s ongoing conflict over harvest of old-growth forest and its effects on forest ecosystems and associated fish and wildlife species resulted in court-imposed injunctions and forest management gridlock. In response, President Clinton convened a team of experts to develop a range of forest-management options that might provide for some level of harvest to support timber-dependent communities while conserving and restoring habitat to support viable populations of fish and wildlife. In designing these land-management options, the Forest Ecosystem Management Assessment Team (FEMAT) was directed to take an ecosystem approach to forest management and particularly to address maintaining and restoring biodiversity (FEMAT 1993; Thomas 1994; Thomas et al. 2006 [this issue]). More specifically, the FEMAT was directed to maintain or restore habitat conditions on federal lands that would provide for viability of species associated with older forest, including two species of birds listed as threatened under the U.S. Endangered Species Act: the Northern Spotted Owl (*Strix occidentalis caurina*) and the Marbled Murrelet (*Brachyramphus marmoratus*). Here I describe the degree to which the plan is meeting its objectives for conserving murrelet nesting habitat in Washington, Oregon, and California and implications for murrelet persistence.

The Marbled Murrelet is a small seabird of the family Alcidae whose summer distribution along the Pacific Coast of North America extends from the Aleutian Islands of Alaska to Santa Cruz, California. Murrelet population size decreases from north to south. Estimated population size is about 859,000 in Alaska, 55,000–78,000 in British Columbia, and 17,000–27,000 in Washington, Oregon, and California (McShane et al. 2004). Murrelets forage primarily on small schooling fish, but also on large pelagic invertebrates (especially during nonbreeding seasons) in the near-shore (0–5 km) marine environment (Burkett 1995; Becker 2001). Unlike other alcids, which nest in colonies on the ground or in burrows at the marine-terrestrial interface, Marbled Murrelets nest solitarily and most often in large trees (>100 cm dbh) in larger patches of coniferous forests (Nelson 1997; Meyer et al. 2002; Ripple et al. 2003). They travel up to 80 km inland to reach suitable habitat (most often <40 km). Marbled Murrelets depend on marine conditions for foraging and resting and on forests for nesting, so both marine and forest conditions affect murrelet numbers. Because of population declines attributed to a combination of loss of mature and old-growth forest from harvesting, low recruitment of young, and mortality at sea, the Marbled Murrelet was federally listed as threatened in Washington, Oregon, and California in 1992 (USFWS 1997) and listed as threatened in British Columbia in 1990 (Rodway 1990).

Nesting Habitat

The plan is conservative in its approach to Marbled Murrelet habitat. The system of reserves was not designed, as it was for the Northern Spotted Owl, with specific goals for the number and spacing of clusters of birds (Thomas et al. 1990; Noon & Blakesley 2006 [this issue]). Rather, the system of congressionally reserved lands, late-successional reserves, and other lands withdrawn from timber harvest was meant to encompass a high proportion of habitat thought to exist on federal lands (USDA Forest Service & BLM 1994*a*). In addition, surveys of murrelets before timber harvest on federal lands outside of reserves were mandated. If a survey detected murrelet behaviors indicating likely nesting, then that site would be classified as "occupied" and all contiguous existing and recruitment habitat (defined as stands that could become nesting habitat within 25 years) within a 0.8-km radius was protected. These occupied sites were designated as small reserves, denoted LSR3, and were managed to retain and restore murrelet nesting habitat.

Expected Trends

The stated objective of the plan was to maintain or restore nesting habitat conditions that would provide for viability of murrelet populations, well-distributed along their current range on federal lands (FEMAT 1993). The expectation was that the plan "...would eventually provide substantially more suitable habitat for Marbled Murrelets than currently [at the time the plan was implemented] exists on federal lands" (USDA Forest Service & BLM 1994*a*, 1994*b*).

The FEMAT used an expert panel to assess the likelihood that habitat on federal lands would support stationary and well-distributed populations of the Marbled

Murrelet. The murrelet panel assigned an 80% likelihood that habitat would be of sufficient quality, distribution, and abundance to allow the murrelet population to stabilize and become well distributed across federal lands over the next 100 years under the plan. In recognition of the major influence of marine conditions on population viability, however, including mortality from oil spills and (to a limited extent in northern Washington) gill netting, and considering the potentially important role of nonfederal lands, the murrelet panel conducted a second set of ratings that accounted for the cumulative effects of these other factors. In this case, the panel assigned a lower likelihood (60%) that the murrelet population on federal lands would be stationary and well distributed.

Observed Trends

BASELINE HABITAT

Over the short term (<3 decades) the plan's objective was to conserve much of the best remaining habitat on federal land. Over the longer term (>3 decades) the objective was to restore currently unsuitable habitat to provide for larger, more contiguous blocks of habitat (FEMAT 1993). A Marbled Murrelet effectiveness monitoring group developed a new map of nesting habitat based on a consistent vegetation base (derived from analyses of satellite imagery; see Moeur et al. 2005) across all ownerships throughout the murrelet range (Raphael et al. 2006). This habitat classification was based on estimates of patch size, conifer cover, mean tree diameter, canopy structure, slope, aspect, and distance from coast.

Based on these data, Raphael et al. (2006) developed a spatially explicit habitat suitability map with suitability scores ranging from 0 (least suitable) to 100 (most suitable). They used a cutoff of suitability scores >60 to portray higher-suitability nesting habitat in tables and maps. The total amount of this higher-suitability nesting habitat was 1.63 million ha over all ownerships within the area termed "Marbled Murrelet zone 1" (a strip of land of variable width along the coast). Most (52%) of this higher-suitability habitat was on nonfederal lands (0.85 million ha), and 0.79 million ha (48%) was on federal land. Within federal land, 0.68 million ha was in reserved land allocations (42% of total higher-suitability nesting habitat, Fig. 1). Thus the plan appears to have encompassed much of the existing higher-suitability nesting habitat on federal land into its reserve system, but more than half the remaining higher-suitability habitat was on nonfederal land.

HABITAT LOSSES

The intent of the plan was to conserve most of the remaining murrelet nesting habitat and to prevent the subsequent loss of any habitat occupied by nesting birds on federal lands. The amount of habitat was expected

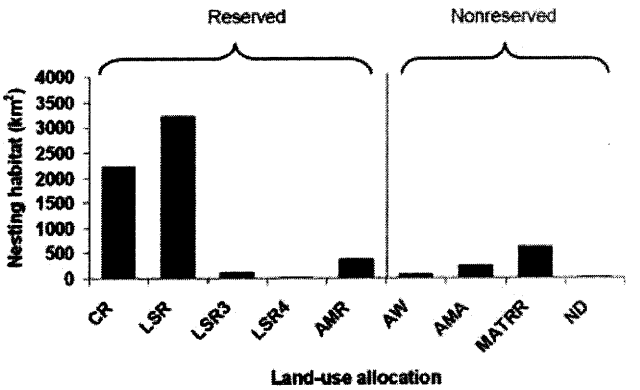

Figure 1. Distribution of higher-suitability Marbled Murrelet nesting habitat in reserved (no harvest) and nonreserved (some harvest allowed) land-use allocations under the Northwest Forest Plan (CR, congressionally reserved land-use allocations; LSR, late-successional reserve; LSR3, Marbled Murrelet reserved areas; LSR4, Spotted Owl core areas; AMR, adaptive management areas that are in reserves; AW, administratively withdrawn nonreserved allocations; AMA, adaptive management areas that are not reserved; MATRR, matrix that might contain riparian reserves; ND; no designation). Habitat data were summarized from databases provided by Raphael et al. (2006).

to increase over time, but the rate of increase would be very slow and changes might not be observed for many decades (FEMAT 1993). In the meantime some unoccupied habitat would be lost from timber harvest and some losses might be caused by wildfire and other disturbances.

The observed trends were in line with these expectations. Raphael et al. (2006), based on analysis of satellite imagery and change detection methods (see Moeur et al. 2005), estimate losses of 12,000 ha (out of the baseline estimate of 0.85 million ha) of higher-suitability nesting habitat on federal lands over the past 10 years, mostly from fire and most of that in one event, the Biscuit fire of 2002 (southwestern Oregon). Losses from timber harvest totaled 1,100 ha, 74% of which was outside reserves. Losses to fire and other stand-replacing events totaled 10,900 ha, and 93% was in reserves. Total losses represented 1.5% of nesting habitat on federal land over the 10 years, or a loss of 0.15%/year. Rates of loss have been much greater on nonfederal lands: Raphael et al. (2006) estimate that more than 100,600 ha of higher-suitability nesting habitat, or about 12% of total higher-suitability habitat on nonfederal land, have been lost because of timber harvest on nonfederal lands over the past 10 years.

As part of a recent status review for the Marbled Murrelet, McShane et al. (2004) compiled agency records (almost all from federal lands) to estimate losses to harvest and fire and developed an independent estimate of

amounts and losses of nesting habitat. They estimate total losses from 1992 to 2003 of 9100 ha: 2200 ha from harvest and 6900 ha from fire and windstorms. They estimate a total of 0.9 million ha of suitable habitat under all ownerships; losses represent 1.1% of that amount, or 0.11% per year. Despite using different data sources (primarily U.S. Fish and Wildlife Service consultation records), McShane et al. (2004) estimate a rate of loss from nonfederal lands of about 10% over the past 10 years, similar to the rate reported by Raphael et al. (2006). The Raphael et al. (2006) and McShane et al. (2004) estimates apply to all habitat, occupied or unoccupied. I have no estimate of the loss of occupied habitat, so I cannot say whether the plan objective of no loss of occupied habitat from timber harvest was met.

HABITAT INCREASES

The long-term expectation was a gradual increase in the amount of suitable habitat as forests mature (FEMAT 1993). Lands within the designated reserves had much unsuitable habitat at the start of the plan, and some proportion of this unsuitable forest will mature and become suitable nesting habitat. Of 9120 km^2 of forest in the federal reserve system, 5500 km^2 (60%) was in lower-suitability condition and has the potential to develop into higher-suitability nesting habitat (Fig. 2).

Some evidence shows that the net amount of forest with large-diameter trees (>76 cm dbh) has increased over the first 10 years of the plan, based on remeasurement of inventory plots on national forest lands in the plan area (M. Moeur, unpublished data). Moeur tallied the distribution of plots by mean tree diameter during two remeasurement cycles, averaging 3.8 years apart. She estimated a net annual increase of the largest tree diameter class (≥76 cm dbh) of 0.38%/year. I do not know how much of this increase represents suitable nesting habitat. Certainly not all of it does because nesting platforms (the key attribute defining suitable nesting habitat) do not generally form until trees reach diameters of 100 cm or more (Raphael 2004). Further work will be needed to verify how much of this increase represents suitable murrelet habitat.

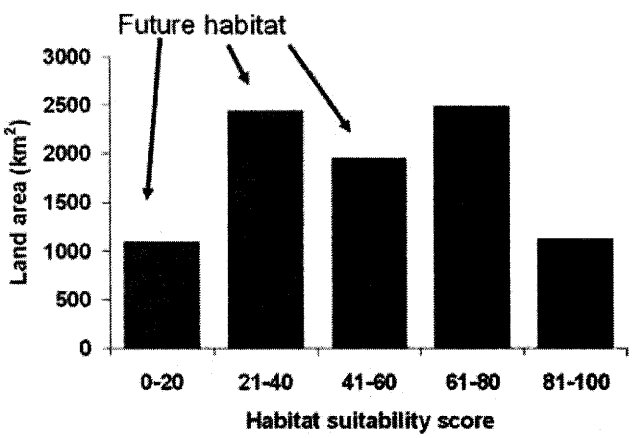

Figure 2. Distribution of forest by habitat suitability score within late successional reserves on federal lands within the range of the Marbled Murrelet. Forest with scores <60, although currently less suitable as nesting habitat, may develop suitable characteristics over time as these stands mature. Habitat data were summarized from databases provided by Raphael et al. (2006).

Role of the Northwest Forest Plan

The plan played a pivotal role in the fate of Marbled Murrelet habitat on federal lands. It has successfully conserved existing nesting habitat because relatively little habitat has been lost from timber harvest on federal lands. The plan has no direct control over the rate of harvest of nesting habitat on nonfederal lands. The greatest rate of habitat loss on federal lands, especially in reserves, was caused by fire. Loss of habitat from catastrophic events will always be a risk, and such losses were expected. The plan has little control over the loss of habitat from catastrophic events, except to the extent that active management in fire-prone areas might reduce risk by managing fuel. But, managing forest cover to reduce fire risk could also lead to better habitat for corvids (nest predators). Silvicultural practices may need to be fine-tuned to ensure that they do not inadvertently impair nesting success of murrelets by increasing the rate of nest depredation.

Sources of Uncertainty

Uncertainties in estimating the amount and distribution of nesting habitat of the Marbled Murrelet are similar to those cited for the Northern Spotted Owl (Noon & Blakesley 2006). One additional source is unique to the Marbled Murrelet. Because murrelet nesting behavior is so cryptic, biologists have found few nests. Habitat models for the Northern Spotted Owl were built based on attributes of a large sample of known owl nest sites. For the murrelet, biologists rely on locations of "occupied behaviors" to infer nesting activity. Occupied behaviors are observations of murrelets flying into the canopy or circling very close above the canopy. These behaviors are presumed to be associated with nesting, but nesting is rarely verified. Thus, sites in which occupied behaviors are observed may not be true nest sites, especially because non-nesting murrelets regularly fly inland (Peery et al. 2004*b*). Furthermore, occupied behaviors are not observed at every visit to a site. Thus the likelihood of failing to detect occupied behaviors even if the site is occupied is relatively high. The numbers of visits required to have a high likelihood (set at 0.95) of observing occupied behavior at an occupied site is nine visits in each of 2 years (Evans Mack et al. 2003). Under this protocol a

5% chance of failing to detect occupied behavior exists, so a small number of sites may be mistakenly classified as unoccupied and released for timber harvest. A more reliable modeling solution is to conduct more intensive searches to identify known nest sites and then to build models based on attributes of actual murrelet nests (e.g., Bradley et al. 2004).

Uncertainty also exists in the geographic distribution of the Marbled Murrelet. The FEMAT designated two zones as mentioned previously: zone 1 formed the area closer to the coast and zone 2 was an outer area along the eastern fringe of the species' range. Populations were assumed to be more abundant in zone 1. Results of more recent surveys provide evidence justifying substantial narrowing of zone 2 and possibly even zone 1, especially in northern California and southern Oregon (Hunter et al. 1998; Schmidt et al. 2000; Alegria et al. 2002). Federal agencies in those areas have redefined the eastern boundary, where surveys for murrelets are required prior to timber harvest, bringing it farther to the west to match survey results. This revised boundary has not been implemented formally in the plan databases and to date applies only to survey requirements. This strategy adds uncertainty to the calculation of habitat status to the extent that areas classified as habitat may actually fall outside the revised species range.

Population Trend

Expected Trend

Murrelet populations were thought to be declining at the start of the plan (Ralph 1994; Beissinger 1995; Ralph et al. 1995; Agler et al. 1999), and the FEMAT expected these declines to continue until habitat recovered from previous losses (FEMAT 1993). Furthermore, because murrelets have naturally low reproductive rates, population recovery was expected to be slow, a maximum of 3% per year (USFWS 1997). McShane et al. (2004) developed a population model to predict population change in each of five conservation zones that constitute the plan area. Their model, which used annual adult survival estimates obtained from detailed mark-recapture studies in British Columbia (Cam et al. 2003; Bradley et al. 2004) and fecundity estimates based on observations of juveniles at sea or from telemetry studies, predicted annual rates of decline varying from 3 to 5%/year over the first 20 years of their simulations in murrelet conservation zones 1 through 5. These models are strictly demographic, so population projections made under the model did not respond to changing amounts of nesting habitat.

Observed Trend

The Marbled Murrelet effectiveness monitoring group designed a coordinated sampling protocol and obtained empirical population estimates starting in 2000. Yearly estimates have continued and are reported up to 2003 (Miller et al. 2006). The total estimated population offshore of the plan area has averaged about 21,700 birds over these 4 years of surveys. Estimates vary by conservation zone, with the largest population in zone 1 (Puget Sound) and the smallest in zone 5 (northern California). Population size did not show a downward trend during the 4 years of study; the estimated at-sea population was relatively stationary among years, yet highly variable within years. Given an estimate of the combination of sampling error and annual variation from fitting a linear trend to the annual population estimates, Miller et al. (2006) computed that 7 years of survey would be required to detect a 5% annual decline with a power of 80% and 9 years to detect a 5% decline with 95% power. After 4 years of surveys, data suggest that the rapid declines predicted based on demographic models have not occurred; more years of survey will be needed, however, to confirm this conclusion with greater confidence. Similar population surveys have been conducted in zone 6 in central California, and those surveys have also shown a relatively stationary population (Peery et al. 2006). I conclude that little evidence exists of the expected decline in murrelet numbers, but I recognize that more years of surveying will be needed to provide greater confidence.

Role of the Northwest Forest Plan

Marbled Murrelet populations are affected by a variety of factors, only some of which are under the plan's direct influence. The plan has no influence on marine conditions (including marine food sources) or sources of mortality at sea, such as oil spills and gill netting. Therefore it will be more difficult to relate changes in Marbled Murrelet populations to land management under the plan. With the plan conserving habitat exactly as expected, murrelet populations could still fall because of adverse marine conditions, habitat loss on nonfederal lands, or low nest success due to high rates of nest depredation. Despite this uncertainty, some evidence suggests that inland habitat conditions are the major driver setting murrelet population size. Studies of the relationship between counts of murrelets observed flying into large drainages (estimated from radar surveys) in British Columbia (Burger 2001) and Washington (Raphael et al. 2002*a*) show strong linear and positive correlations of counts with the amounts of nesting habitat at the drainage scale. On a larger scale there is also a strong correlation between the total amount of habitat and the size of adjacent murrelet populations for large segments of the murrelet range in the plan area (Fig. 3). Although this relationship seems valid for the plan area as a whole, evidence from studies in central California suggests that murrelet populations in that area are limited by food availability in some years and nest predation in other

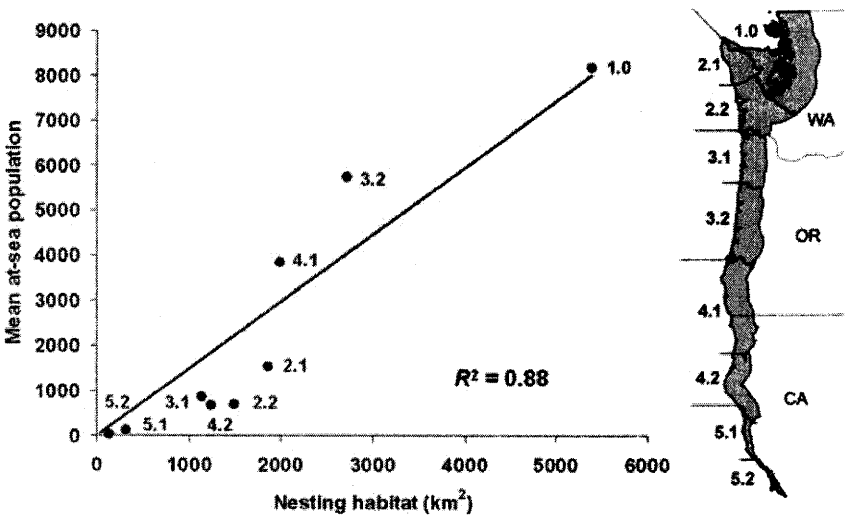

Figure 3. Relationship of estimated mean at-sea Marbled Murrelet population size (averaged from 2000 to 2003) with adjacent potential murrelet nesting habitat (defined based on habitat suitability scores >60) by latitudinal segments within conservation zones in the area of the Northwest Forest Plan in Washington (WA), Oregon (OR), and California (CA). Shaded area on the map is the inland range of the Marbled Murrelet. Segment numbers denote conservation zones and segments within zones. See Miller et al. (2006) for a description of methods used to estimate at-sea murrelet population size and Raphael et al. (2006) for methods used to estimate amounts of nesting habitat in each segment.

years, but enough nesting habitat exists for most of the population to breed (Peery et al. 2004*a*).

Sources of Uncertainty

A major source of uncertainty is the degree to which the murrelet population is open. That is, existing population models assume that there is little or no recruitment of either adults or juveniles from outside the study population. The local population may be declining, but populations may be subsidized by immigrants, perhaps from Alaska or British Columbia, where the birds are more numerous. Recruitment of new, breeding birds from outside the local range has been proposed as the most likely explanation for observed stationary murrelet population trends in central California, despite models that suggest a decline (Peery et al. 2006). An alternative explanation is that only a fraction of the population is breeding and the remainder of birds observed offshore are nonbreeders from farther north; thus the apparent low productivity could be, in fact, stable productivity for a much smaller, resident population. If the discrepancy between at-sea counts and demographic models is due to visitors rather than true migrants, immigration will just mask population declines rather than result in stable breeding populations.

Future population trends are also difficult to predict because of uncertainties in the timing and extent of risk factors. Catastrophic loss of habitat from uncharacteristically severe wildfire is an ever-present risk in drier portions of the range. Populations at sea are subject to risk from even modest oil spills if they occur during seasons of concentration. Changes in ocean currents can have profound effects on forage fish leading to starvation or breeding inhibition, as has been observed in other seabird populations (e.g., Montevecchi & Myers 1997; Becker 2001). Emerging threats exist from West Nile virus, which could cause direct mortality to nesting birds, but the virus could also have indirect beneficial effects. The virus kills jays, crows, and ravens (Mclean et al. 2001; Caffrey et al. 2003), and mortality of these birds may increase nest success of murrelets by reducing nest depredation.

Validity of Plan Assumptions

Habitat Loss and Recovery

Two fundamental assumptions of the plan were that the rate of loss of murrelet habitat in reserves would slow or stop and that unsuitable habitat would recover. Available data support this assumption (on federal lands) and show that rates of loss are low and that forest stands in reserves are on a trajectory toward higher habitat suitability. Conservation and restoration of murrelet nesting habitat are essential to survival of the species.

The plan also assumes that surveys prior to timber harvest would prevent the loss of occupied sites. I was unable to test this assumption because I had no way to assess whether sites were classified as unoccupied when they might actually have been occupied. I can say that sites classified as occupied on federal lands were, in fact, set aside and managed as reserves.

Effects of Past Timber Harvest

The plan assumes that past timber harvest will have lingering effects on murrelet carrying capacity and nesting success. I am aware of no new data to challenge this assumption. Murrelet population size is reduced as habitat

is lost, and birds do not pack into remaining suitable habitat (Burger 2001; Raphael et al. 2002*a*). In Oregon Luginbuhl et al. (2001) found that predator densities and rates of nest depredation are higher in areas with a variety of tree ages, so nest success is reduced in areas intermixed with young tree or brush habitats.

Role of Large Reserves

A major premise of the plan is that large reserves will support more murrelets, eventually leading to stationary or increasing populations. Nest depredation seems to be a major limiting factor on Marbled Murrelet populations. Over half of the known murrelet nests whose fate has been determined failed because eggs or chicks were lost to predators, primarily jays, crows, and ravens (Nelson & Hamer 1995; Manley & Nelson 1999; Peery et al. 2004*a*), which have been thought to primarily occupy second-growth and fragmented forests. Predator numbers are, in fact, fairly high in old-growth forests such as those expected to develop in plan reserves (Marzluff et al. 2000; Raphael et al. 2002*b*). Planners assumed habitat fragmentation would decline as young patches within reserves matured, creating more contiguous canopy cover. The decrease in fragmentation would lower rates of nest predation. More recent evidence suggests that rates of nest depredation may be just as high in contiguous forest as in fragmented stands (Marzluff & Restani 1999). Murrelet populations may not grow at the rate predicted from recovery of nesting habitat in reserves because nest depredation could suppress successful reproduction. Understanding of the full suite of factors that affect nest success is lacking, which increases uncertainty about the relations between amounts of habitat and murrelet populations.

The Work of Federal Agencies

One of the principal assumptions of the plan was that the federal land management agencies would work together to achieve the plan's objectives (FEMAT 1993). To date, these agencies (notably the Bureau of Land Management, Forest Service, and National Park Service) have all participated in implementing the plan, including designating late-successional reserves. As a result of a recent lawsuit, however, the Bureau of Land Management is revising management plans for those lands covered under requirements of the Oregon and California Lands Act of 1937 (an area covering about a third of the federal lands in Oregon). At least one alternative will consider elimination of reserves on Oregon and California lands, except as needed to avoid jeopardy to species listed as threatened or endangered (e.g., the murrelet). This possibility raises uncertainty about whether the current reserve system on these lands in Oregon will be maintained long enough to achieve the plan's objective for habitat recovery (Strittholt et al. 2006 [this issue]).

Legal Status of the Murrelet

The Marbled Murrelet provisions within the plan are predicated on the bird's status as a listed species under the Endangered Species Act. As this paper goes to press, the U.S. Fish and Wildlife Service has announced its intent to reconsider the listing status of the Marbled Murrelet. One outcome of this process could be delisting. If the bird is delisted, then it is likely that current levels of protection of murrelet habitat on nonfederal and federal lands will be reduced, and I would expect a more rapid rate of loss of nesting habitat. Although the magnitude of additional loss of nesting habitat is difficult to predict, delisting the murrelet will certainly add further uncertainty to future habitat conservation and restoration.

Conclusions

Marbled Murrelet population trends reflect the cumulative effects of multiple interacting factors. Habitat conditions on federal lands are but one of those factors, albeit the one over which the Northwest Forest Plan has the most direct influence. Although federal habitat protection is essential to murrelet viability, it may not be sufficient given the cumulative effects of other influences on population viability. Habitat loss on nonfederal lands, marine conditions, threats from disease, oil spills, and bycatch from gill net fishing in Washington could reduce the likelihood of survival, despite the habitat protections built into the plan.

Monitoring both habitat trends and population trends is of value (Madsen et al. 1999). Monitoring habitat trends tells managers how well the plan is meeting its primary objectives and whether the plan is having the desired effects. Ideally, population trends will track habitat trends, but the trends may not coincide, as has occurred for Northern Spotted Owls (Noon & Blakesley 2006). In such cases, one can dig deeper to discover whether understanding of habitat relationships is mistaken or whether other, perhaps unmeasured, factors are driving population trends.

What can be said with confidence is that the amount of habitat will set the carrying capacity for wildlife populations. Carrying capacity is a measure of the potential population size that can be supported by a given amount and distribution of suitable habitat (Ricklefs 1979). The actual population may be lower than the carrying capacity because of a variety of other factors such as hostile weather, interactions with other species, habitat conditions outside the plan area, disease, or other factors. Observing a declining population in the face of habitat conservation does not mean habitat or its conservation is unimportant. It could merely mean that the decline would be even more precipitous were it not for the habitat conservation; all options must be examined to manage some of the other

factors that might be driving the population trend. As more robust models of wildlife habitat relationships are developed, including these other factors, it will be essential to continue monitoring both population and habitat trends to evaluate how well the Northwest Forest Plan is meeting its intended objectives.

The Northwest Forest Plan remains the boldest effort ever undertaken by federal agencies to meet large-scale biodiversity objectives. The plan has been quite successful in meeting its short-term objective of conserving the best remaining Marbled Murrelet habitat. The plan's long-term objective of creating a system of reserves containing desired sizes and distributions of large blocks of suitable habitat on federal lands is on course, but many more decades will be needed to judge the plan's success. Long-term persistence of the murrelet in the area of the plan is by no means certain: recruitment of young birds is low throughout Washington, Oregon, and especially California. If high rates of nest depredation continue and marine conditions do not support adequate prey resources to support nesting activities, then murrelet populations will fall despite the habitat protections built into the plan. Furthermore, changes in legal status of the murrelet or changes in land-management plans by responsible agencies may further erode land manager's motivation to conserve and restore murrelet nesting habitat. Time will tell.

Acknowledgments

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