Marbled Murrelet Effectiveness Monitoring
Northwest Forest Plan

2002 Annual Summary Report (Version 2)

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Mark Huff
Marbled Murrelet Module Lead
Northwest Forest Plan Interagency Regional Monitoring Program

Team Members for FY02

Population Monitoring
Patrick Jodice, Former Module Lead, US Fish and Wildlife Service
Jim Baldwin, Statistician, US Forest Service, Pacific Southwest Research Station
Sherri Miller, Researcher, US Forest Service, Pacific Southwest Research Station
Rich Young, GIS/Database Specialist, US Fish and Wildlife Service
Ken Ostrom, Former GIS/Database Specialist, US Fish and Wildlife Service
C.J. Ralph, Researcher, US Forest Service, Pacific Southwest Research Station
Martin G. Raphael, Researcher, US Forest Service, Pacific Northwest Research Station
Craig Strong, Researcher, Crescent Coastal Research
Chris Thompson, Researcher, Washington Department of Fish and Wildlife
Gary Falxa, Biologist, US Fish and Wildlife Service

Habitat Monitoring
Patrick Jodice, Former Module Lead, US Fish and Wildlife Service
Jim Baldwin, Statistician, US Forest Service, Pacific Southwest Research Station
Diane Evans Mack, Researcher, US Forest Service, Pacific Northwest Research Station
Sherri Miller, Researcher, US Forest Service, Pacific Southwest Research Station
Kim Nelson, Researcher, Oregon State University
Rich Young, GIS/Database Specialist, US Fish and Wildlife Service
Ken Ostrom, Former GIS/Database Specialist, US Fish and Wildlife Service

SUMMARY

This is the third annual report for marbled murrelet (*Brachyramphus marmoratus*) effectiveness monitoring in the area of the Northwest Forest Plan (NWFP). The purpose of this effectiveness monitoring is to assess status and trends of murrelet populations and nesting habitat. This report summarizes activities of the Marbled Murrelet Effectiveness Monitoring Program during fiscal year 2002 (FY02), including changes to monitoring methodologies, results of the annual at-sea population surveys, and updates on modeling nesting habitat. Also, a set of effectiveness monitoring questions are included that will be addressed in an upcoming 10-year NWFP effectiveness monitoring report.

The objectives of the murrelet population monitoring are to estimate (1) population trends and (2) population size during the breeding season within and across five murrelet conservation zones in coastal waters adjacent to the NWFP area. In 2002, murrelets were surveyed in all five conservation zones. The total population of marbled murrelets in 2002 for this area was ~23,700[*] +/- 5,300 birds at the 95% confidence interval. At this confidence level, the 2002 population estimate broadly overlaps estimates from the 2000 and 2001. Marbled murrelet density (per km^2) was highest in Zones 3 and 4 (entire coast of Oregon to just south of Cape Mendocino, California) and lowest in Zone 5 (California coast, just south of Cape Mendocino to just north of San Francisco Bay). Three years of surveys are insufficient to detect biologically statistically significant trends in density or population estimates.

For the habitat monitoring component of the Effectiveness Monitoring Program, predictive models, non-map and map, are being developed to estimate murrelet habitat. Field data for the non-map model has been collected from 198 sites, occupied and unoccupied by marbled murrelets, across the range of the species in the NWFP area. Fourteen site-level attributes were measured and assessed within more than 1,600 plots. The map models of murrelet habitat will be developed from spatial attributes of occupied sites based on variables that best predict known murrelet occupancy patterns. Results from the map and non-map models will be published in the 2003 annual report and in the 10-year interpretive report of the effectiveness monitoring program.

[*]The total number of birds in the population is ~23,700; this replaces the incorrect amount of ~18,400 provided in the Summary of the first version of this report.

PREFACE

In January 2003, Mark Huff replaced Patrick Jodice as the module lead for Marbled Murrelet Effectiveness Monitoring in the area of the Northwest Forest Plan. The 2002 reporting year for this annual report was guided under the leadership of Pat until his departure in early October 2002. The 2002 report was prepared by Mark Huff and the Marbled Murrelet Monitoring Team members. Also in 2002, Rich Young replaced Ken Ostrom for GIS support to the Marbled Murrelet monitoring module.

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Introduction

Mangers responsible for resolving natural resource issues need resource trend information to develop sound management plans. Evaluating population trends requires a commitment to long-term monitoring (multiple years) and consistent data collection from a network of target sites selected without biases (Urquhart et al. 1998). Regional-scale trend information can provide insights into broad-scale patterns and processes, as well as, help support management strategies to achieve desired goals and objectives and to formulate new strategies (i.e., adaptive process).

The Marbled Murrelet (*Brachyramphus marmoratus*) and Northern Spotted Owl (*Strix occidentalis*) are the only animal species selected as focal species to monitor and evaluate the effectiveness of the 1994 Northwest Forest Plan (NWFP). A two-pronged approached is used to monitor Marbled Murrelets (Madsen et al. 1999). First is to assess marbled murrelet population trends at sea. For Marbled Murrelets, at-sea surveys are the most accurate and direct means to monitor population trends across the range of the Northwest Forest Plan. Because Marbled Murrelets are secretive nesters, baseline reproductive information is difficult and expensive to collect at breeding locations. At-sea population surveys offer a cost-effective alternative for assessing the persistence and conservation status of this species. Status and trend information is used to assess the stability of murrelet populations, and whether land based management actions are providing for the recovery of the species that warrant delisting from threatened status. Second is to monitor the amount and trends of potential nesting habitat in the NWFP area. To accomplish this, murrelet habitat models need to be developed. Relations between environmental variables and murrelet site occupancy are being explored to establish the best set of parameters to predict nesting habitat. Two groups of murrelet habitat models are being developed: map and non-map. The non-map (regression) habitat model is developed from attributes measured in vegetation plots and remotely sensed data associated with these plots, and is used to estimate the amount of nesting habitat. To develop the map model, remotely-sensed data are being interpreted from known occupied sites and then used in prediction equations to estimate the distribution of murrelet habitat.

The objectives of this annual report are to provide updates on sampling and analytical methods, 2002 at-sea survey results, and habitat modeling. The organization of the report is as follows: Effectiveness Monitoring Questions, Methods, Results and Discussion, Effectiveness Monitoring Program Considerations, Marbled Murrelet Program Products, Literature Cited, and Contact Information. This report covers the third year of at-sea population monitoring using a standardized and unified protocol.

EFFECTIVENESS MONITORING QUESTIONS

The broad objectives and approach to effectiveness monitoring of status and trends for the NWFP are described in Mulder et al. (1999). Effectiveness monitoring questions examine the extent to which measures of interest (e.g., strategy or initiative) have achieved intended objectives by evaluating the observed outcomes or impacts against expectations. Status questions evaluate the conditions of an indicator resource at a given moment in time, whereas

trends follow how a condition of the indicator resource has changed over time at a given location.

The effectiveness monitoring goal for the marbled murrelet is to evaluate the success of the NWFP in maintaining and restoring murrelet populations and nesting habitat (Madsen et al. 1999). This is accomplished through addressing sets of questions on (1) the amount and (2) the distribution and size of nesting habitat estimated from quantitative habitat relationships models, and on (3) the population status and trends:

Predicted amount of marbled murrelet nesting habitat

   1. What is the amount of nesting habitat in the Northwest Forest Planning area?
   2. How has the predicted amount of nesting habitat changed within and outside Late-Successional Reserves (LSRs)?

Predicted distribution and size of marbled murrelet nesting habitat

   1. What is the spatial distribution of nesting habitat in the Northwest Forest Planning area?
   2. How has the fragmentation of nesting habitat changed within and outside LSRs?
   3. How has the patch size of nesting habitat, including the proportion and amount of interior late-successional forest, changed within and outside LSRs?
   4. How has the distribution of nesting habitat changed within and among LSRs and across federal land?

At-sea population status and trends during the breeding season

   1. What is the population status and trend among recovery zones 1-5 and for the entire Northwest Forest Plan area?
   2. What is the density status and trend among recovery zones 1-5 and for the entire Northwest Forest Plan area?

METHODS

Methods for data collection and analysis of population and habitat information are found in previous annual reports (Bentivoglio et al. 2002, Jodice 2002; available at http://www.reo.gov/monitoring/reports.htm#murrelet). Changes made to the methods in 2002 and further explanation of analysis techniques are featured below.

Population Monitoring--Surveys

Marbled murrelets are sampled from boat-based transects within 2 - 8 km of shore in Recovery Conservation Zones 1 to 5, adjoining the Northwest Forest Plan (USDI Fish and Wildlife Service 1997; Fig. 1). At-sea surveys are done during the inland breeding season from mid-May through late-July. Each Zone has been divided into two or three strata based

on murrelet density patterns. A target number of sampling units is designated for each stratum, however density and population size are estimated at the Zone and Northwest Forest Plan scales only.
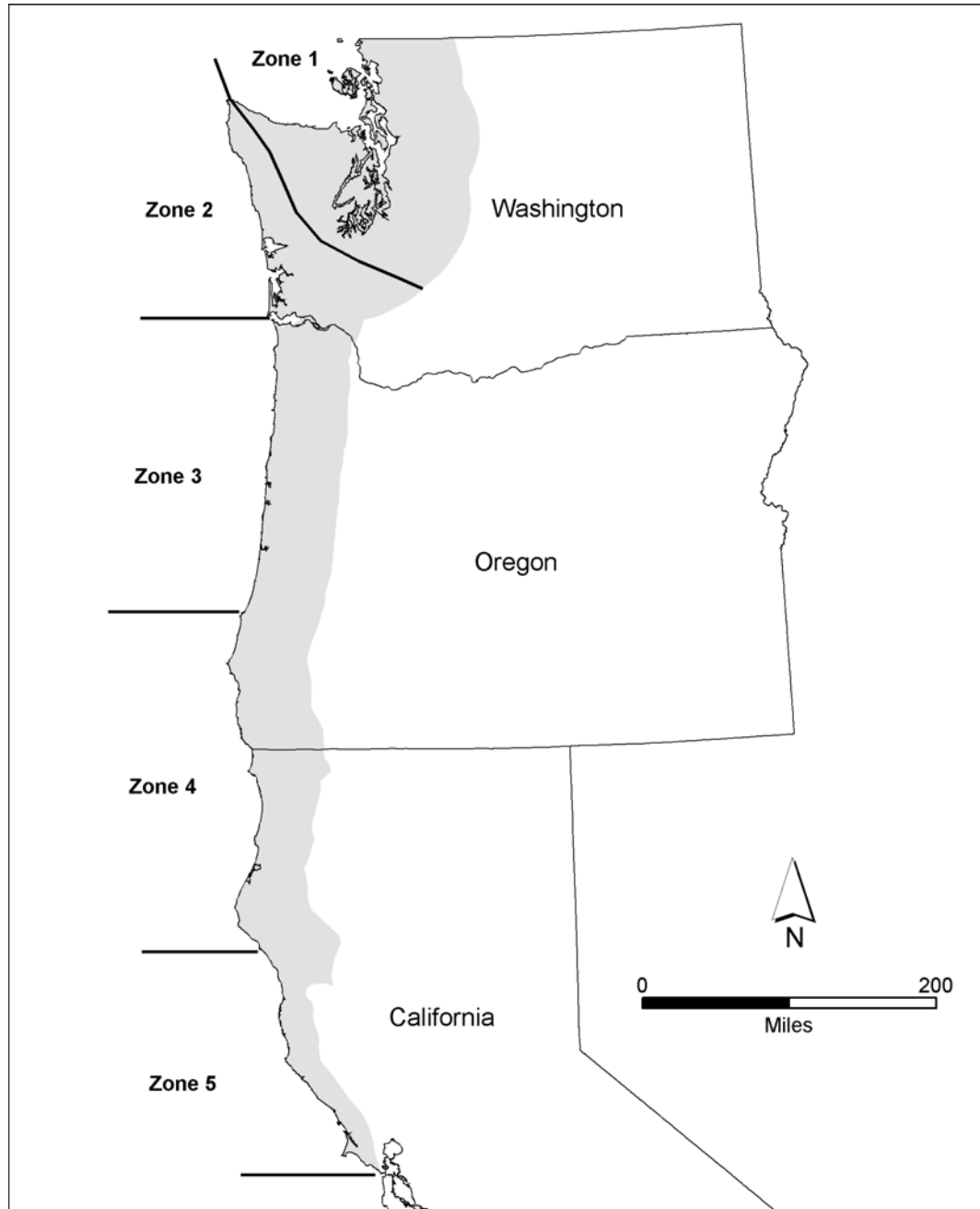

Figure 1. Five at-sea survey Zones for marbled murrelets. Inland breeding distribution is shaded (adapted from USDI Fish and Wildlife Service 1997).

Adjustments in survey methods

Before the 2002 field season, the annual randomization of at-sea transects were clarified further among zones. For the Inshore Subunit, all possible sets of parallel lines were determined before the 2000 field season; from this pool of parallel lines, a random selection is made each year without replacement. For the Offshore Subunit, new zigzag transect lines are to be selected randomly each year in Zones 2, 3, 4, and 5. Two sets of random zigzag transects had to be created in Zone 1, however, because the complex shoreline typical of this Zone hindered layout of zigzag transects offshore. In Zone 1, all Primary Sample Units (PSUs) are sampled twice, once in the first half of the sampling period and then again in the second half. For the first sample, a set of zigzag lines is randomly selected from the available pool of two sets. The remaining set is sampled for the second round. In subsequent years, these same sets of zigzag transects are sampled using this procedure. For the nearshore segment, transect lines are created randomly each round and each year in a manner identical to methods in other zones.

Population Monitoring--Data Analysis[1]

Examination of the estimation of the detection function

An important aspect of the line transect method is the estimation of the detection function. The detection function describes the probability of detecting an object in relation to distance from a random line or point. In analyzing of the data from 2000 through 2002, the DISTANCE program (Version 4, Release 1, Thomas, *et. al.*, 2002) was used to estimate the detection function. The individual perpendicular distances to an observed group of birds were used to fit the half-normal, hazard-rate, and uniform key functions with up to a 5-parameter cosine series multiplier. This provided additional flexibility but only allowed parameters that result in a strictly non-increasing detection probability with distance. The curve form was selected with the smallest Akaike's Information Criterion (AIC) value that was corrected for a finite sample size bias (AICc). AIC is a method for assessing the fitness of a model (i.e., a small deviation from observed data or large likelihood), taking into account the number and order of model parameters. This process is automated in DISTANCE.

Estimated detection functions for the 2002 Zones 4 and 5 surveys

Figure 2 shows the best AICc half-normal, hazard-rate, and uniform detection function estimates for the 2002 data from Zones 4 and 5. There are 730 observations (*i.e.,* 730 individual perpendicular distances to groups of birds), with a large relative frequency of counts near zero perpendicular distance. Histograms (using 25 equally spaced non-overlapping intervals) are superimposed over each detection function such that the area under the histogram equals the area under the detection function out to the maximum distance. For

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[1] Jim Baldwin prepared an update to the methods for analyzing the at-sea survey data that was amended for this report.

this example, the maximum distance is 175 m. The histogram plot in Figure 2 shows the number of observations for each histogram bar. The detection functions all have similar

Figure 2. Estimates of detection functions along with the display of the histogram of the counts in each of 25 categories for the observed data in the 2002 Zones 4 and 5 surveys.

curve forms estimated for effective strip half-widths ($\mu = 94.5$, 96.3, and 96.0 m for the half-normal, hazard-rate, and uniform detection functions, respectively) and similar estimates of the detection function probability, $f(0)$. The uniform key is chosen because of having the lowest AICc value.

Some problems estimating detection functions

Under the above settings for the estimation of a detection function, different estimates for the curve occur occasionally for some particular bootstrap samples. The estimated effective strip

half-widths ($\mu = 92.5$, 14.4, and 90.1 m for the half-normal, hazard-rate, and uniform detection functions, respectively) vary considerably for the bootstrap sample shown in Figure 3. (The bootstrap is a method for estimating the distribution of an estimator by simulated re-sampling data with replacement). The estimate for the hazard-rate key has an extremely small estimate of the effective strip half-width which corresponds to a very large estimate of $f(0)$. The problem arises when certain predictors produce unreasonable outcomes for individual bootstrap samples. The effects of this are seen, for example, at 20 m for the hazard-rate estimate which predicted a probability of less than 0.20 to observe a group of murrelets for this distance. This type of lack of fit for the hazard-rate function occurred in about 10 to 20 of the 1,000 bootstrap samples of the 2002 Zones 4 and 5 surveys, resulting in very large estimates of $f(0)$ and density estimates with large standard errors. While data
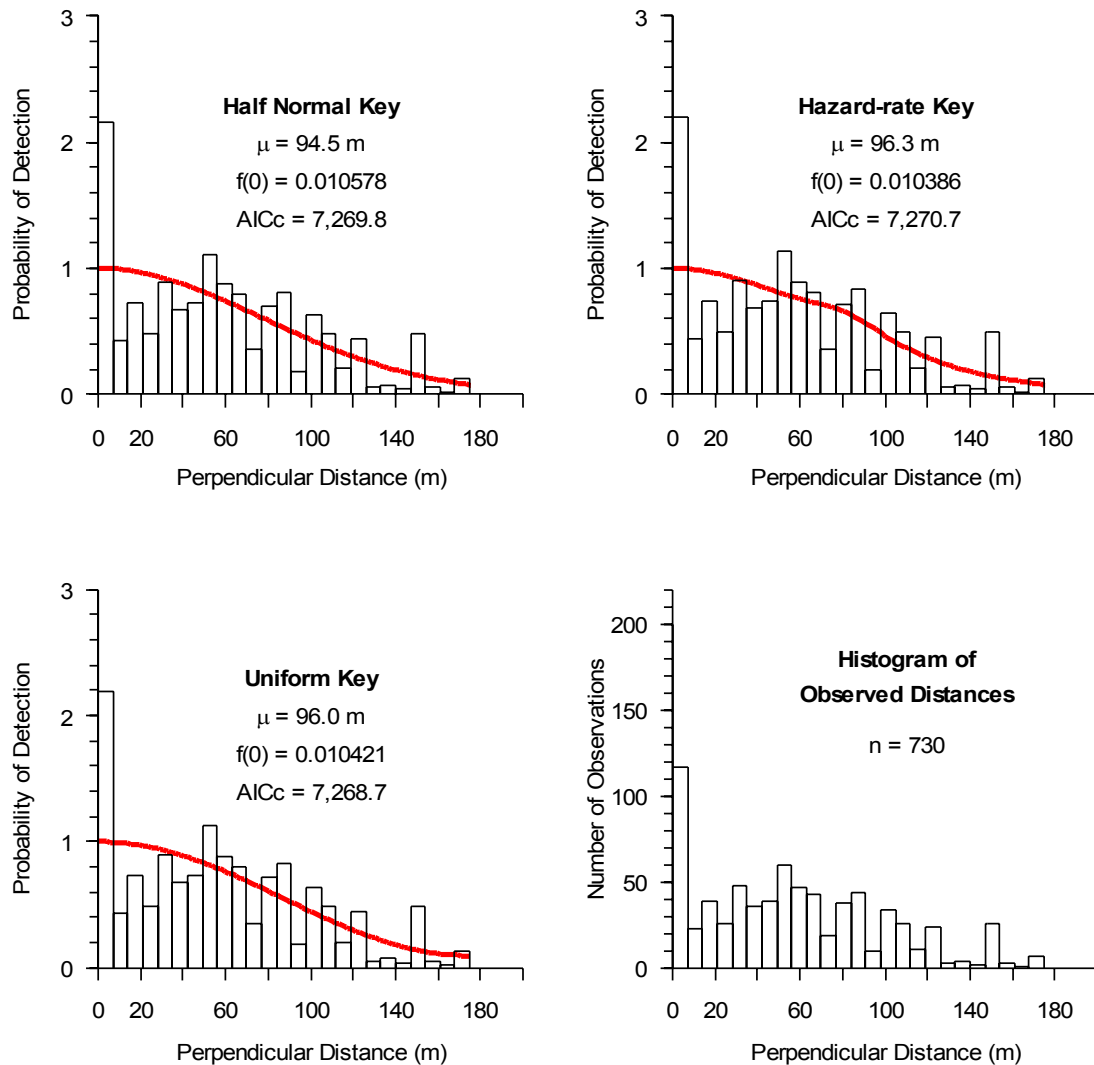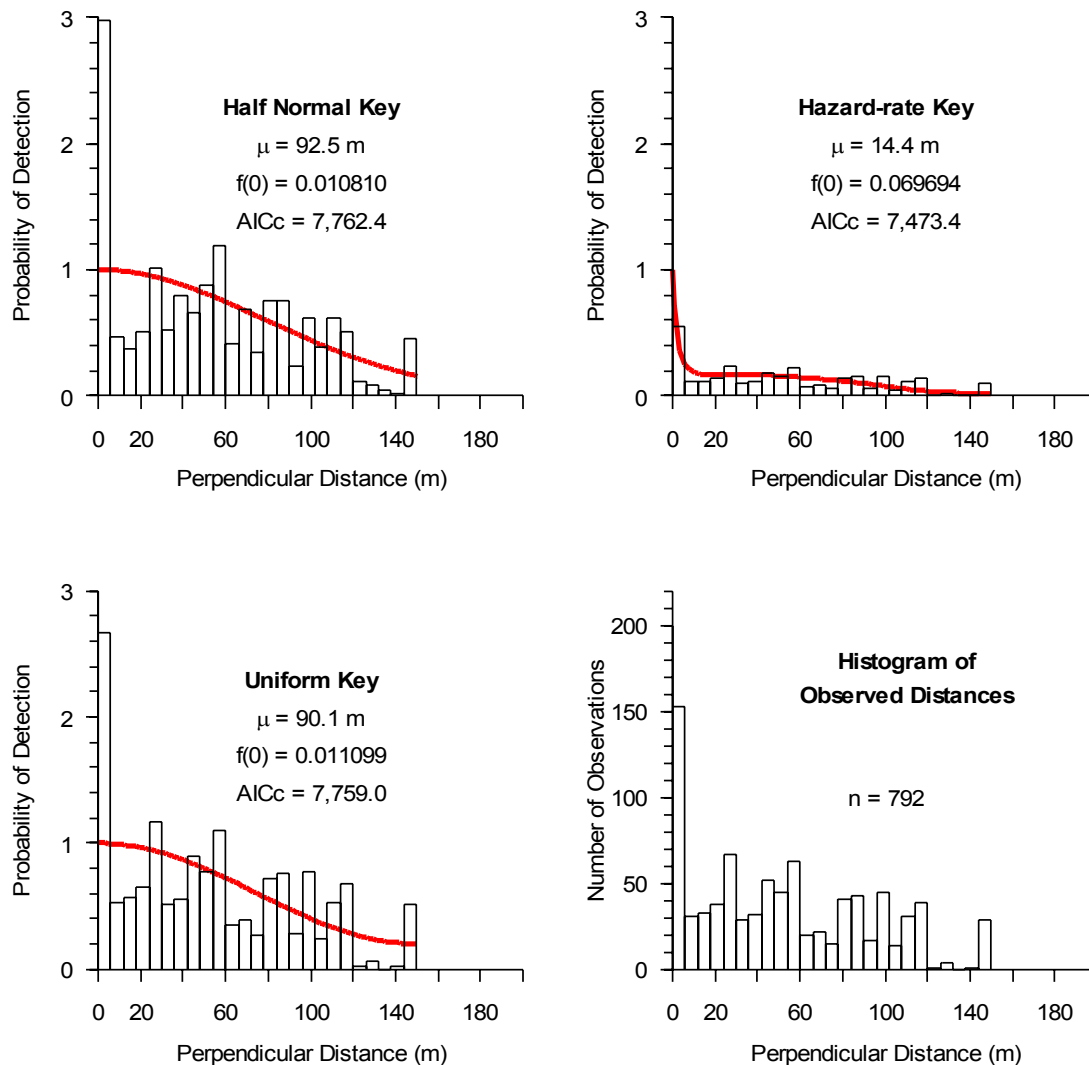

Figure 3. Estimates of detection functions along with the display of the histogram of the counts in each of 25 categories for a particular bootstrap sample from 2002 Zones 4 and 5 surveys.

with large standard errors are plausible, the ones observed with the standard hazard-rate key are spurious because of the unjustifiable estimates of $f(0)$. Though removal of the hazard-rate key function is defensible, unfortunately none of the key functions fit the histograms very well as shown by the large number of observations (for more that just Zones 4 and 5) near zero meters.

The estimates of the detection functions for the 2002 at-sea surveys and the scaled histogram of the observations for each zone are shown in Figure 4. Scaling has the effect of making area under the histogram equivalent and the area under the detection function ≤ 1.0. Zone 1 shows a "spike" of observations near zero meters, as does Zone 4 and 5. This is characteristic of the condition called "guarding the centerline". One approach to reduce this effect after the fact is to group data into intervals and then use the grouped data to estimate the detection functions. Using the 2002 Zones 4 and 5 survey data as an example, the estimated detection functions for all three key functions in Figure 5 appears to fit better than that of the ungrouped data shown in Figure 2; and, the estimates of $f(0)$ differ little between the grouped and ungrouped data. Re-fitting of the extreme bootstrap of ungrouped data shown in Figure 4 with the distances grouped at every 20 m shown in Figure 6 gives a much more reasonable estimate of the effective half-strip width for the hazard-rate key function. However, even after grouping the data, up to10 bootstrap samples from the 2002 Zone 4 and 5 surveys result in extreme estimates of $f(0)$ and associated detection function that are unsuitable.

Adjustments to analysis methods

To eliminate the inappropriate estimates of $f(0)$ and the associated detection functions, data was grouped into 7 intervals after truncating 5 percent of the most extreme distances from all observations in a Zone. An alternative method where the grouping is selected from a data-driven process, as recommended by Barabesi *et al*. (2002) will be investigated as this is not yet a feature of DISTANCE. Based on the current data about a 20-meter interval seems appropriate. As more data are gathered with the future monitoring, additional investigation will be done selecting the appropriate intervals.

The hazard-rate key function has been dropped from the marbled murrelet population analyses because of the unrealistic $f(0)$ estimates encountered from Zones 4 and 5. Similar problems have occurred with this function in other studies with somewhat spiked data. Buckland et al. 2001 reported that the hazard-rate function can give density estimates with large positive bias, especially when the data spikes are an artifact of data rounding.
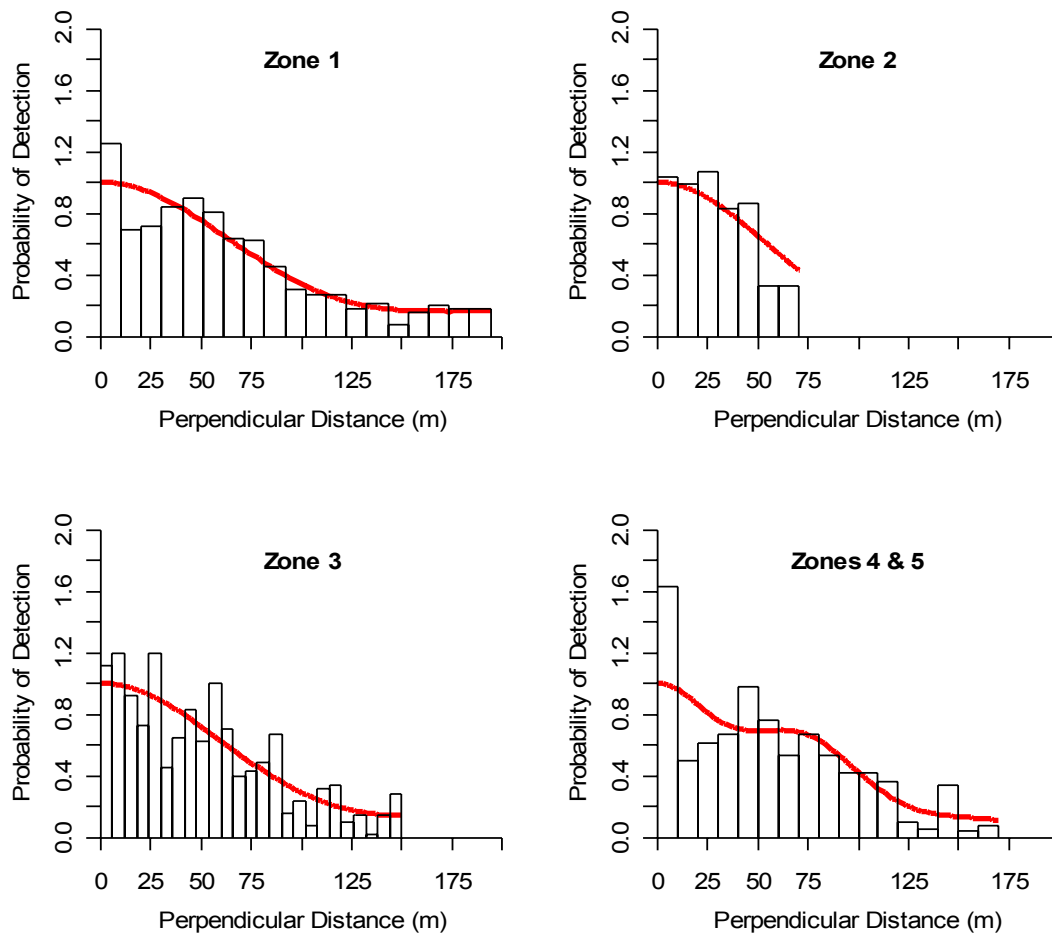
Figure 4. Estimated detection functions for at-sea surveys taken 2002 for each Zone along with the scaled histograms.
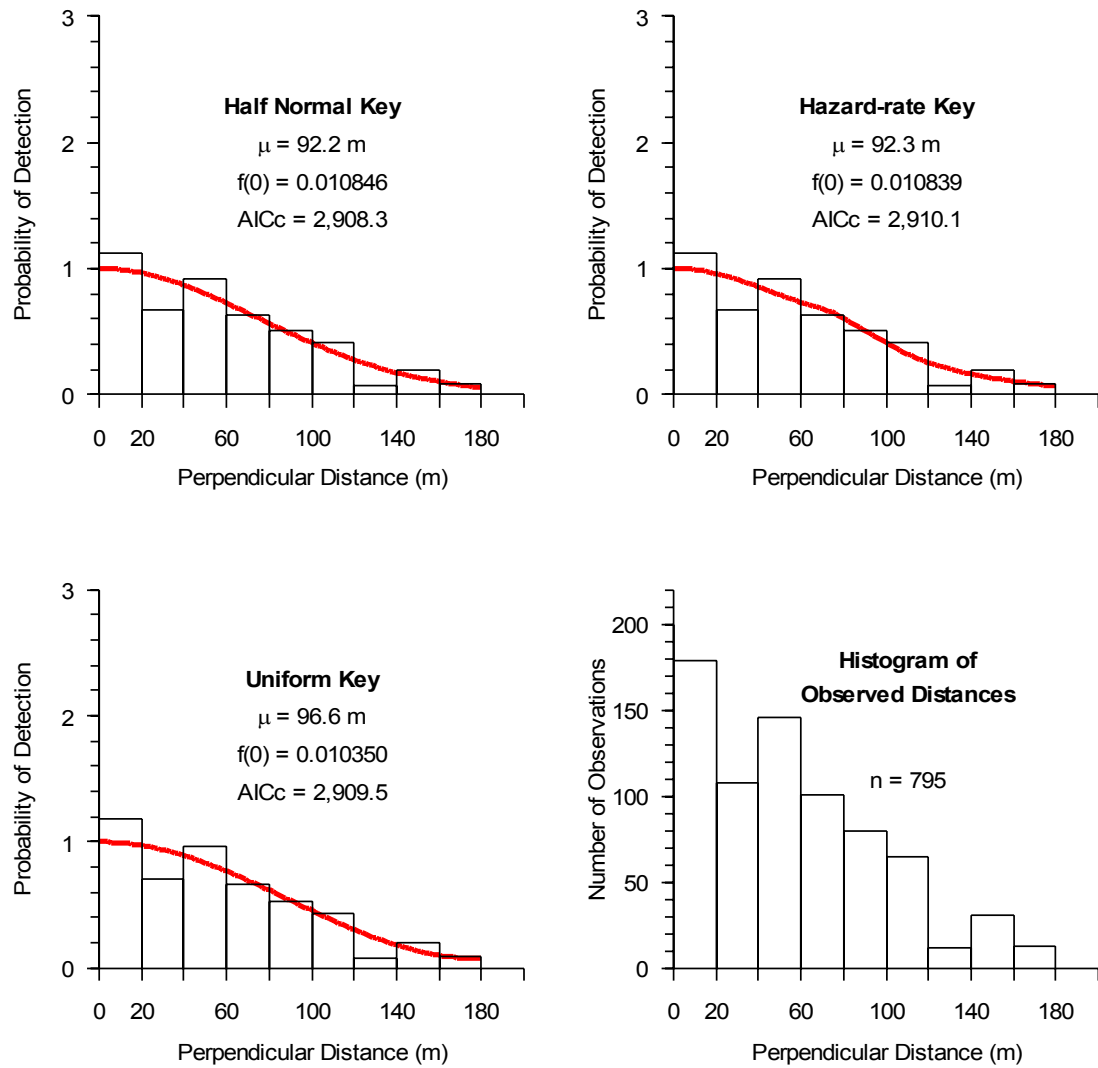
Figure 5. Detection functions for the observed 2002 Zones 4 and 5 data fit with distances grouped at every 20 m.
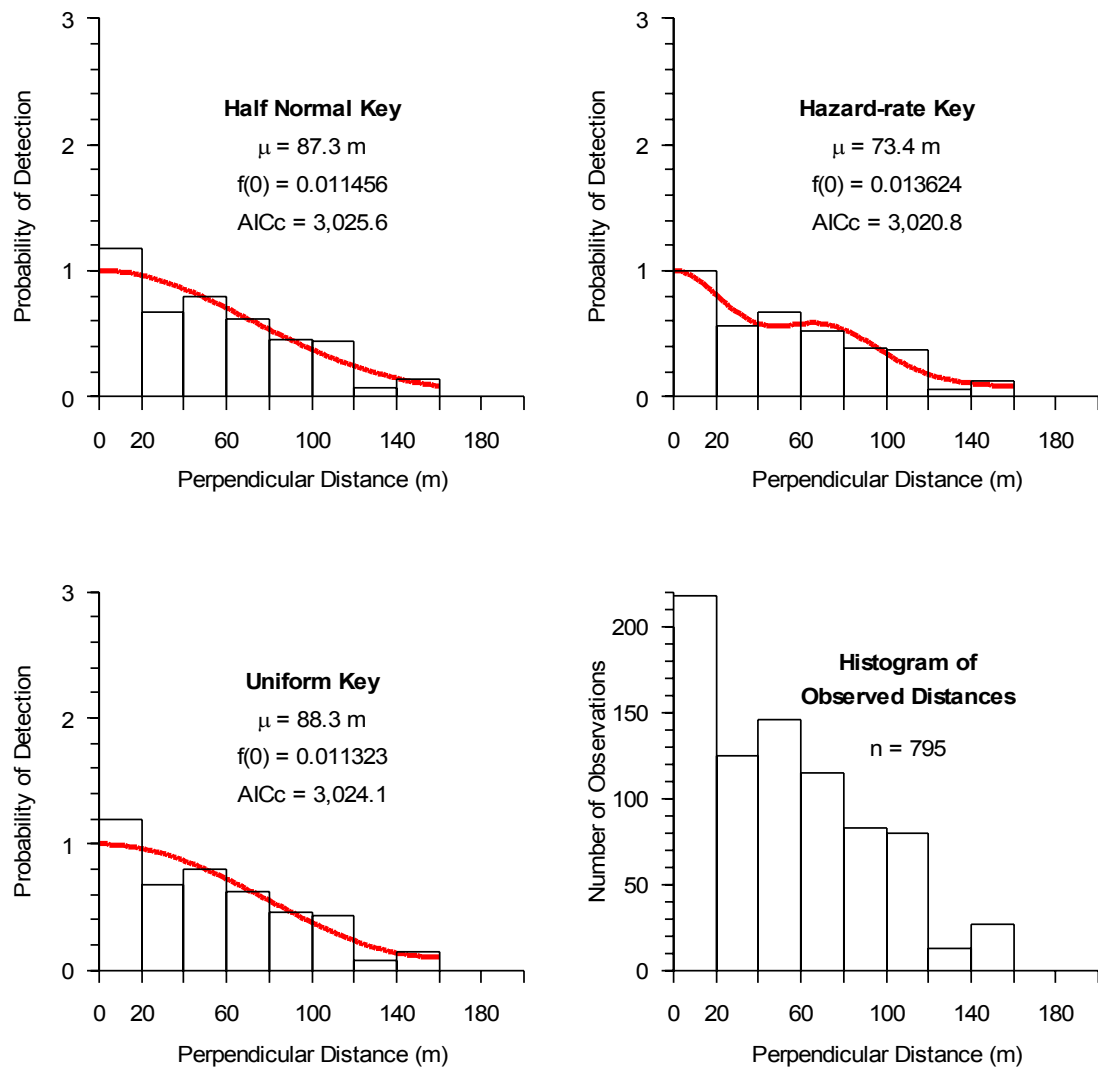
Figure 6. Detection functions for an "extreme" bootstrap sample from the 2002 Zones 4 and 5 data fit with distances grouped at every 20 m.

Non-Map Habitat Modeling

To determine the amount of marbled murrelet habitat in the area of the NWFP, vegetation sampling was planned for each of the six NWFP physiographic provinces where murrelets are distributed: in Washington: Olympic Peninsula, Cascades, and Western Lowlands; in Oregon: Coast Range and Klamath Mountains; and in California: Coastal (see Jodice 2002). Sites were selected randomly in each province, 20 "occupied" (met marbled murrelet occupancy protocol standards) and 20 unoccupied sites, hereafter 20/20 sites. In California, too few known unoccupied sites were available from which to make a random selection; consequently, unoccupied sites were selected randomly from old-growth, mature and young

with old-growth legacy forests on state and federal lands. All selections were made from state-maintained databases that tracked inland sites where murrelets have been surveyed since1994 using established protocols (see review of protocols in Evans et al. 2003).

Habitat variables that were collected on the 20/20 vegetation plots during 2001 and 2002 are shown in Table 1 and reviewed in previous annual reports. The remotely sensed variables also shown in Table 1 identify additional information collected about the 20/20 sites using spatial databases. Non-map modeling methods to estimate the amount of marbled murrelet habitat in the area of the NWFP are being developed and reviewed. Full documentation of the analysis methods will accompany the 2003 annual report. Included in this report are methods for gathering the remotely sensed attributes, changes to the data collection, and a brief sketch of the analysis approach.

Table 1. Habitat variables for habitat modeling collected on vegetation plots and interpreted from remotely sensed data layers.

Ground-Plot Variables	Remotely Sensed Variables
Tree species (number of >25 cm diameter at breast height (dbh) by species)	Slope
Tree dbh	Solar radiation index
Number platforms/tree (branch like structure ≥10 cm basal diameter and ≥10 above ground)	Elevation
Basal diameter and height above ground of each platform (in 3 diameter and 2 height classes)	Distance to marine water (coastline)
Percentage of tree with platform covered by moss	Distance to nearest stream[a]
Amount of mistletoe on tree with platform (index)	Distance to nearest forest opening[b]
Crown diameter of tree with platform	
Single or multiple canopy layers	

[a] Stream data layer currently not available
[b] Methods to be developed later.

Remotely sensed variables[2]

Mean and standard deviation values for slope and elevation variables were derived from 30-meter Digital Elevation Models (DEMs) using the Zonal Statistics function of the Spatial Analyst module of ArcMap 8.3. These values were stored in the SLOPE_MEAN, SLOPE_STDEV, ELEV_MEAN and ELEV_STDEV attribute fields of the Polygon Attribute Table (PAT) for the 20/20 site GIS layer. The measure of solar radiation for each 20/20 site was calculated from a raster grid of cells containing solar radiation values. Three different raster grids, one each for western Washington, western Oregon, and northwestern California, were created using an established Arc AML (i.e.,. programming language to customize GIS processing commands) written by Lalit Kumar and Niklaus Zimmermann (shortwavc.aml in public domain), and that was further developed for the Pacific Northwest by Jan Henderson and Greg Dillon of the USFS, Mt Baker-Snoqualmie NF. The AML calculates the maximum amount of shortwave radiation received at the surface of the earth for a given period of time accounting for slope, aspect, elevation, solar angle, length of daylight and shading from nearby landforms. The input grids used are the 30-meter DEMs from the National Elevation Dataset (NED). For each of the three state grids, a specific date was selected as input for the AML to represent the mid-point of the murrelet breeding season: June 19th, 26th, and 9th for Washington, Oregon and California, respectively (Hamer and Nelson, 1995). Mean and standard deviation values were derived for the each of the 20/20 sites again by using zonal statistics. These values were stored in the SOLAR_MEAN and SOLAR_STDEV attributes fields of the PAT. In all cases for 20/20 sites that consisted of multiple, disjunct polygons, the mean and standard deviation values for measures of solar radiation, slope, and elevation were calculated based upon an aggregate of the grid pixels from each of the individual parts.

The distance to coastline (marine water) attribute was measured from the geographic center of each 20/20 site polygon to the nearest intersection along the coast. This was measured as a straight line from each site rather than the shortest path of waterways which probably emulates the true distance traveled by murrelets. A comprehensive streams GIS layer is not yet available for the NWFP area in which to measure waterway distances accurately. The geographic center of each vegetation site was determined using the Arc command CENTROIDLABELS with the INSIDE argument on the Arc polygon coverage. Using the Arcedit environment, the label points for the vegetation site polygons were SELECTed and PUT into a new (empty) point coverage. ArcInfo coverages of the coastlines of California and Oregon were compiled from existing 1:24,000 scale source data, and for Washington from existing 1:100,000 scale source data. These coverages were modified using Arc edit tools to close off major bays and rivers along the California, Oregon and outer Washington coasts. A straight line was digitized between the two outermost points across the mouth of each bay or river. The exception to this was the Columbia River, which was closed off with a line due north from Clatsop spit to a point midway between East and West Sand Islands, then due west to intersect with the spit of land coming south off of Cape Disappointment. Bays and rivers were excluded because marbled murrelet are rarely detected feeding in these areas during the breeding season. The three separate coastline coverages then were merged

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[2] Provided by Rich Young

into a single one for the entire region. The Arc command NEAR was used to determine the shortest distance (in meters) from center of each site to the arcs of the coastline coverage. These distances were then related back, using RELATE, to the 20/20 site polygon coverage and placed in the attribute DIST_TO_COAST in the PAT. For vegetation sites that consisted of multiple, disjunct polygons, the final distance coded in the PAT was the average of the distances for each of the individual parts. Distances to coast were determined independently for each state; however, coastlines from adjacent states were taken into consideration to cover situations where a site in one state was actually closest to the coastline of a neighboring state.

Changes in data collection

The Western Washington Lowlands Province was omitted from the original sample design because of funding issues; this province was selected because it has the least amount of federal land in a province where murrelets breed. Initially, the field data collection protocol called for installing 10 nested plots of 13 and 25 m at each 20/20 site, however this was reduced to a minimum of 8 plots due to budget constraints. The number of 20/20 sites sampled in the Olympic Peninsula and Washington Cascades Provinces was 43 and 36, respectively.

Interpreting attributes associated with levels of fragmentation at the 20/20 sites derived using program FRAGSTATS (McGarigal and Marks 1995) were proposed for the '04 Interpretive Report, however this work has been postponed until after the report. Updates on use of fragmentation indices for modeling murrelet habitat will be provided in future annual reports.

Analysis methods of non-map data

The non-map habitat prediction model will be developed in two stages. For the first stage, a logistic regression model is used to determine which independent variables, derived from the 20/20 site variables shown in Table 1 best explain site occupancy by marbled murrelet while controlling for province effects. (Logistic regression is a type of regression model used to predict the probability of occurrence for just two outcomes, such as sites occupied and unoccupied, as a function of the independent variables). AIC will be used to evaluate model fitness among the independent variable combinations. The predictive ability of the logistic regression model will be assessed by using a procedure (jackknife) where the model will be fitted from repeatedly drawn samples of the original data set. In the second stage, the logistic regression model is used to make probability predictions of potential murrelet breeding habitat within the NWFP area. Using the variables in the logistic regression model and variable data from sites within a randomly-place grid (Current Vegetation Survey (CVS) and Forest Inventory Analysis (FIA) plots), the probability of occupancy is projected for each site along the grid. The grid points represent an area proportional the entire grid across the NWFP, which collectively can be used to make area-based projections (i.e., amount of marbled murrelet potential habitat) based on occupancy probabilities.

Field methods for the variables used to characterize tree platforms on the 20/20 plot (variables in Table1) were added to the FIA and CVS field protocol in 1999. So far, only

about ½ of the grid points where marbled murrelets are distributed have been sampled for platform information, thus the number of plots from which the amount of habitat projections can be made based platform information is limited. Hence, separate logistic regression, with and without platform data, will be investigated. Also, the tree platform data has been sampled for only one time period, and therefore can not be used for detecting change until re-sampling is done.

Map Habitat Modeling

A method to map potential habitat that will provide estimates of the distribution and relative size of habitat patches for murrelets is being developed in collaboration with the Northern Spotted Owl and with the Late-Successional and Old-Growth Effectiveness Monitoring modules. These methods will be included in the 2003 annual report.

RESULTS AND DISCUSSION

Population Monitoring

2002 Season

The total coastal waters within the NWFP area that is sampled by the at-sea surveys each year is (fixed at) 8,811 km^2, of which Zones 1 to 5 cover 40, 19, 18, 13, and10 percent of the total area surveyed (i.e., 40 percent of the 8,811 km^2 are sampled in Zone1). The total length of transect sampled in 2002 was 6,507 km. The number of PSU surveys completed in Zones 1 to 5 was 60, 25, 31, 56, and 26, respectively. During the 2002 surveys, 4,616 murrelets were detected from 2,555 groups of observations. The 2002 density and population estimates and related estimation parameters for each Zone are shown in Table 2.

Mean at-sea density of marbled murrelets within the entire NWFP area during the breeding season was 2.69 birds/km^2. Density estimates of marbled murrelets varied among zones: highest in Zones 3 and 4, 3.97 and 4.17 birds/km^2, lowest in Zones 2 and 5, 1.56 and 0.28 birds/km^2, and intermediate in Zone 1, 2.77 birds/km^2, and varied among strata in each Zone. This suggests that murrelet distribution and use of the coastal environment is inequitable within the effective area of the NWFP. The relative variation in density estimates as measured by coefficient of variation (i.e., proportion of standard error to mean multiplied by 100) ranged from ~15 to 42 percent. The highest variation in density estimates occurred in the Zones with the fewest samples and lowest densities of murrelets (Figure 7). Variation (as measured by the coefficient of variation) in density estimates was negatively correlated with bird density among Zones (Spearman's r_s [1-tailed]=-0.90, *p*=0.019).

The 2002 population estimate for the entire NWFP area was ~23,700 murrelets, with a 95 percent confidence interval of +/- ~5,300 birds (+/- ~22.4 percent of the population estimate). The highest population resided in the largest zone (Zone 1~9700 birds), and lowest in the smallest zone (Zone 5, ~300 birds).

Table 2. Estimates of density and population size of marbled murrelets during the 2002 breeding season in the area of the Northwest Forest Plan.

| Zone	Stratum	Density (birds/km^2)	Bootstrap Standard Error (birds/km^2)	Coefficient of Variation of Density (%)	Birds[a]	Birds Lower 95% CL[a]	Birds Upper 95% CL[a]	Survey Area (km^2)	f(0)	std. err. of f(0)	E(s)	std. err. of E(s)	Truncation Distance (m)	std. err. of Truncation Distance
1	1	7.19	2.32	32.2	6,000	2,800	9,700	840						
1	2	1.86	0.47	25.3	2,200	1,000	3,200	1,196						
1	3	0.97	0.30	31.2	1,400	600	2,500	1,459						
1	**All**	**2.77**	**0.57**	**20.7**	**9,700**	**6,000**	**13,800**	**3,494**	**0.010**	**0.001**	**1.76**	**0.07**	**194**	**7.9**
2	1	3.13	1.03	32.7	2,300	500	3,500	727						
2	2	0.38	0.15	40.2	400	0	600	961						
2	**All**	**1.56**	**0.47**	**30.1**	**2,600**	**800**	**3,800**	**1,688**	**0.021**	**0.004**	**1.44**	**0.08**	**70**	**5.7**
3	1	0.79	0.27	34.6	500	300	900	645						
3	2	6.17	1.45	23.5	5,800	3,600	9,200	934						
3	**All**	**3.97**	**0.91**	**23.0**	**6,300**	**4,000**	**10,000**	**1,579**	**0.013**	**0.002**	**1.93**	**0.12**	**150**	**11.5**
4	1	5.24	0.82	15.6	3,900	2,600	5,100	739						
4	2	2.31	0.74	32.0	1,000	500	1,700	427						
4	**All**	**4.17**	**0.62**	**14.9**	**4,900**	**3,500**	**6,400**	**1,165**	**0.011**	**0.001**	**1.72**	**0.04**	**175**	**12.8**
5	1	0.51	0.23	45.5	200	(14)	400	443						
5	2	0.05	0.04	71.4	(24)	0	100	442						
5	**All**	**0.28**	**0.12**	**41.5**	**300**	**(30)**	**400**	**885**	**0.011**	**0.001**	**1.72**	**0.04**	**175**	**12.8**
All	**All**	**2.69**	**0.31**	**11.4**	**23,700**	**18,400**	**28,900**	**8,811**						

[a]Numbers rounded to the nearest 100 birds.
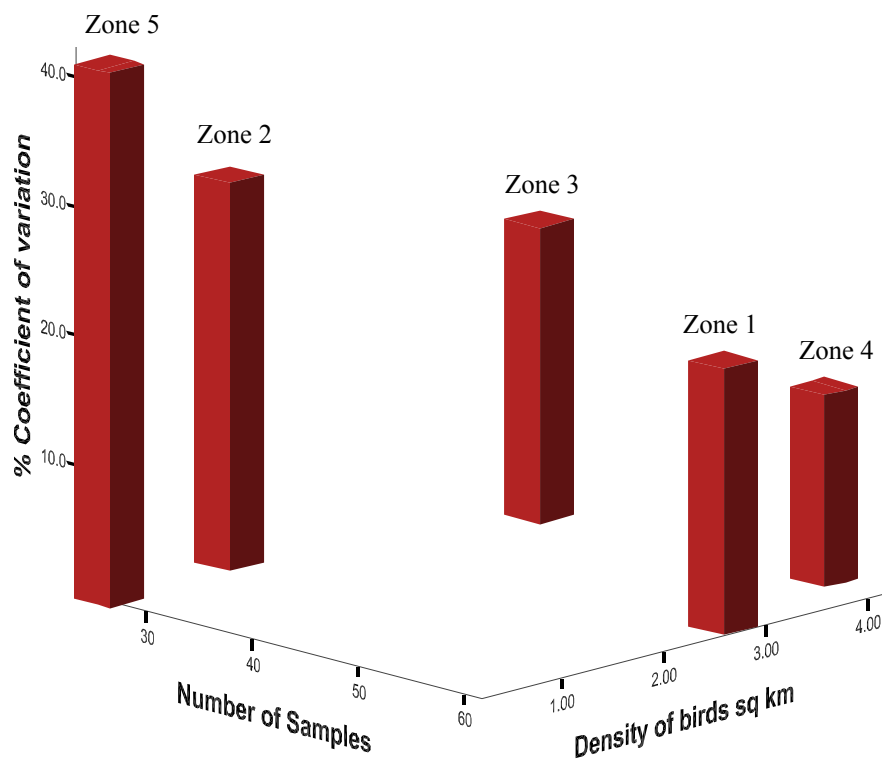
Figure 7. The relationship of three parameters from the 2002 breeding season: density of marbled murrelets, coefficient of variation of density, and number of primary sample units completed.

Revised 2001 and 2000 results

The 2000 and 2001 density and population estimates were re-analyzed grouping the data into 7 equal-sized intervals and without using the hazard-rate key function and using grouped perpendicular distances as explained above in Methods. The revised results are shown in Tables 3 and 4, thus replacing results produced for the 2000 and 2001 annual reports (Bentivoglio et al. 2002, Jodice 2002). The new analysis had little effect on density and population estimates, but reduced the standard errors of most estimates, especially in Zones 4 and 5.

Table 3. Estimates of density and population size of marbled murrelets during the 2001 breeding season in the area of the Northwest Forest Plan that were re-analyzed without using the hazard-rate function and using grouped perpendicular distances.

Zone	Stratum	Density (birds/km^2)	Bootstrap Standard Error (birds/km^2)	Coefficient of Variation of Density (%)	Birds[a]	Birds Lower 95% CL[a]	Birds Upper 95% CL[a]	Survey Area (km^2)	f(0)	std. err. of f(0)	E(s)	std. err. of E(s)	Truncation Distance (m)	std. err. of Truncation Distance
1	1	4.51	1.08	23.9	3,800	2,400	5,900	840						
1	2	1.76	0.38	21.4	2,100	1,000	2,800	1,196						
1	3	2.07	0.74	36.0	3,000	500	4,900	1,459						
1	**All**	**2.55**	**0.46**	**18.0**	**8,900**	**5,800**	**11,900**	**3,494**	**0.013**	**0.001**	**1.59**	**0.04**	**142**	**12.6**
2	1	1.51	0.76	50.6	1,100	200	2,300	727						
2	2	0.67	0.70	104.4	600	100	2,300	961						
2	**All**	**1.03**	**0.51**	**49.2**	**1,700**	**500**	**3,800**	**1,688**	**0.013**	**0.004**	**1.47**	**0.21**	**80**	**5.8**
3	1	1.78	0.43	23.8	1,200	600	1,700	645						
3	2	6.84	0.96	14.0	6,400	4,400	7,900	934						
3	**All**	**4.77**	**0.63**	**13.1**	**7,500**	**5,500**	**9,300**	**1,579**	**0.017**	**0.002**	**1.74**	**0.05**	**140**	**18.6**
4	1	4.65	1.29	27.7	3,400	2,500	6,100	739						
4	2	1.06	0.30	28.6	500	300	800	427						
4	**All**	**3.33**	**0.83**	**24.8**	**3,900**	**3,000**	**6,700**	**1,165**	**0.010**	**0.001**	**1.75**	**0.07**	**170**	**7.0**
5	1	0.17	0.07	40.3	100	(7)	100	443						
5	2	0.10	0.13	130.2	(44)	0	200	442						
5	**All**	**0.13**	**0.07**	**54.5**	**100**	**(18)**	**300**	**885**	**0.010**	**0.001**	**1.75**	**0.07**	**170**	**7.0**
All	**-**	**2.52**	**0.26**	**10.3**	**22,200**	**17,700**	**26,700**	**8,811**						

[a]Numbers rounded to the nearest 100 birds.

Table 4. Estimates of density and population size of marbled murrelets during the 2000 breeding season in the area of the Northwest Forest Plan that were re-analyzed without using the hazard-rate function and using grouped perpendicular distances. Zone 2 was sampled using a fixed width transect; detection functions were not estimated for this Zone.

Zone	Stratum	Density (birds/km^2)	Bootstrap Standard Error (birds/km^2)	Coefficient of Variation of Density (%)	Birds [a]	Birds Lower 95% CL [a]	Birds Upper 95% CL [a]	Survey Area (km^2)	f(0)	std. err. of f(0)	E(s)	std. err. of E(s)	Truncation Distance (m)	std. err. of Truncation Distance
1	1	3.37	1.03	30.7	2,800	1,000	4,500	840						
1	2	1.12	0.50	44.6	1,300	500	2,600	1,196						
1	3	1.01	0.58	57.9	1,500	100	3,100	1,459						
1	**All**	**1.61**	**0.46**	**28.3**	**5,600**	**2,700**	**8,900**	**3,494**	**0.012**	**0.002**	**1.53**	**0.09**	**179**	**11.6**
2	1	0.72	0.20	27.8	500	300	900	727						
2	2	0.25	0.07	25.8	200	100	400	961						
2	**All**	**0.46**	**0.09**	**20.6**	**800**	**500**	**1,200**	**1,688**	**-**		**-**		**-**	
3	1	1.53	0.40	26.4	1,000	500	1,500	645						
3	2	6.14	1.53	25.0	5,700	3,200	8,900	934						
3	**All**	**4.25**	**1.01**	**23.8**	**6,700**	**4,000**	**10,100**	**1,579**	**0.019**	**1.640**	**1.64**	**0.11**	**85**	**6.9**
4	1	6.02	2.03	33.8	4,400	3,300	9,000	739						
4	2	1.10	0.34	31.0	500	300	900	427						
4	**All**	**4.22**	**1.30**	**30.8**	**4,900**	**3,800**	**9,500**	**1,165**	**0.010**	**0.001**	**1.73**	**0.05**	**180**	**9.8**
5	1	0.18	0.14	78.2	100	-	300	443						
5	2	0.00	0.00	-	-	-	-	442						
5	**All**	**0.09**	**0.07**	**78.2**	**100**	**-**	**300**	**885**	**0.010**	**0.001**	**1.73**	**0.05**	**180**	**9.8**
All	**-**	**2.06**	**0.31**	**15.0**	**18,100**	**12,800**	**23,500**	**8,811**						

[a]Numbers rounded to the nearest 100 birds.

Comparisons Among Years

In 2002, the estimated total population of marbled murrelets for the NWFP area was higher than the previous two years surveyed (Figure 8, Tables 2-4). Confidence intervals are wide for all three survey years and overlap broadly among years, indicating that precision of estimating the true population of murrelets is relatively low and there is little evidence for differences in the yearly estimates.

Estimated populations of marbled murrelets were higher in 2002 than 2001 in all Zones except Zone 3 (Figure 9, Tables 2-4). Estimates in Zones 1, 2, and 5 increased each year

from 2000 to 2002. Again the broad confidence interval display that there is little evidence for differences among years within zones.

At this point in the monitoring, after three years, these data are insufficient to estimate statistically valid population trends of interest. Using murrelet population data from the 2003 surveys (year 4), estimates of minimum of years needed to detect valid trends will be projected as part of the 2003 report. These three years of data do, however, provide a useful baseline estimate of the marbled murrelet population.
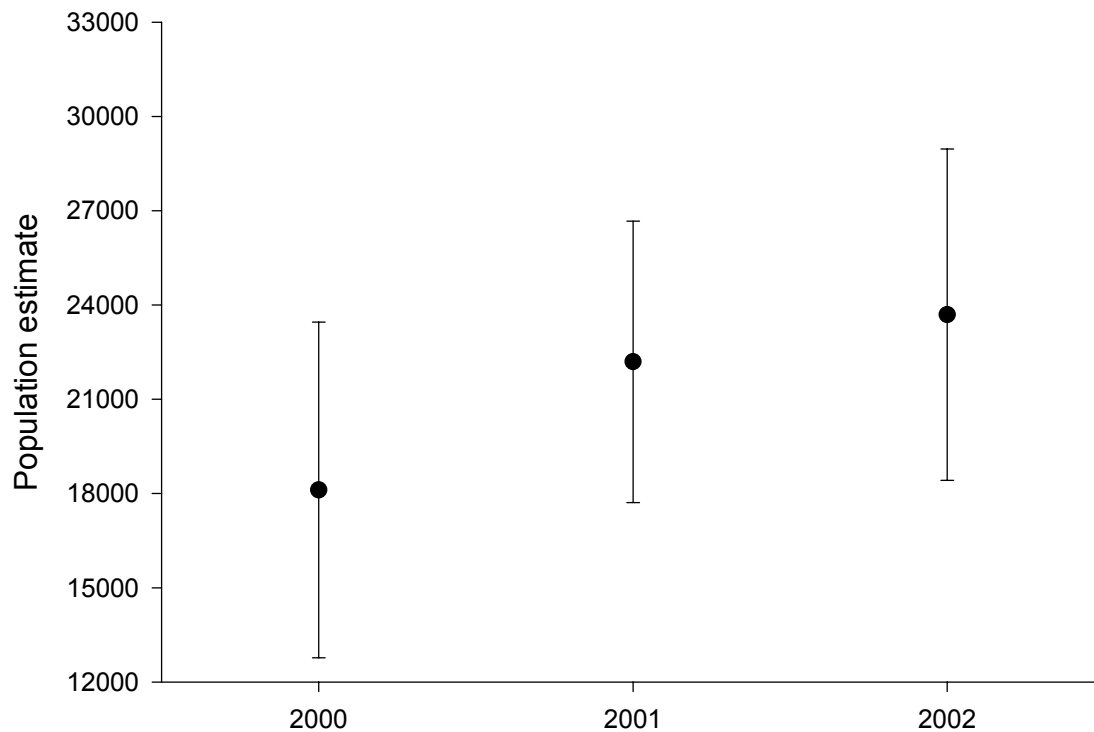

Figure 8. Marbled murrelet population estimates and 95 percent confidence intervals for the entire Northwest Forest Plan area by year.
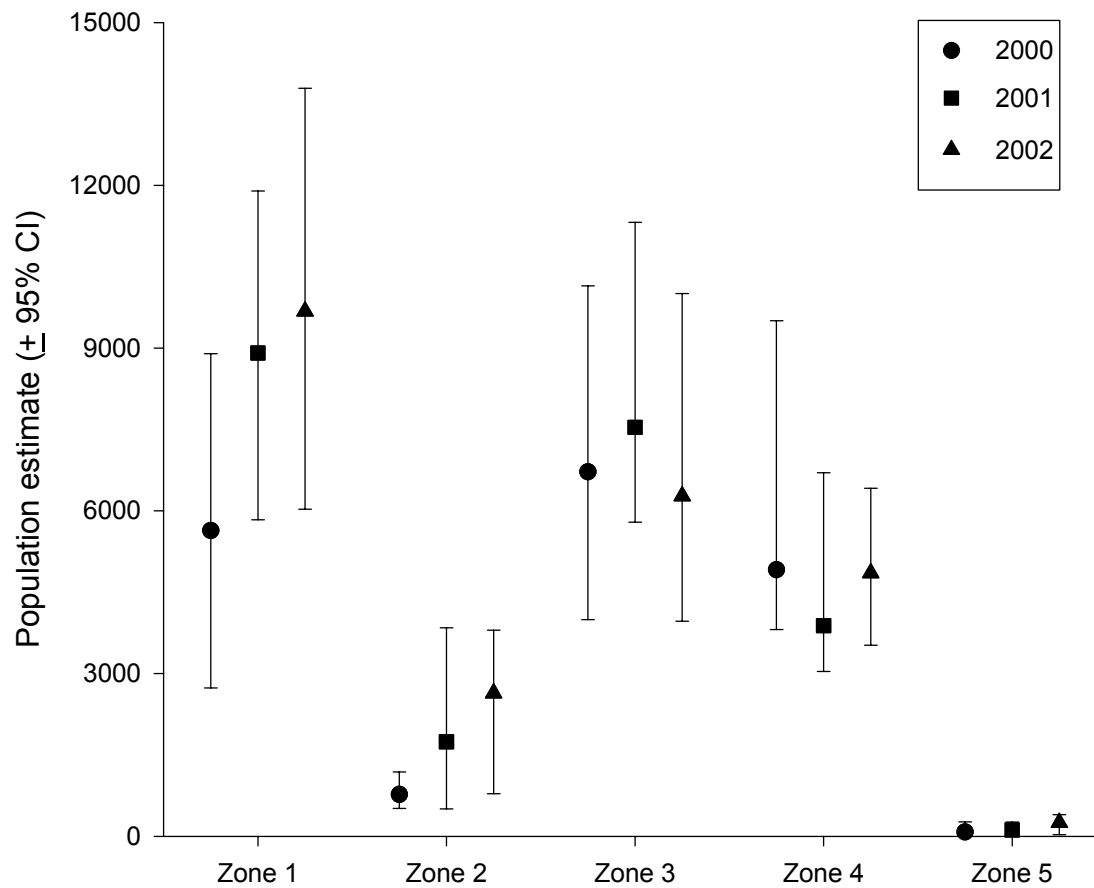
Figure 9. Marbled murrelet population estimates and 95 percent confidence intervals by zone and year in the area of the Northwest Forest Plan. In 2000, Zone 2 was sampled using a fixed width transect; detection functions were not estimated for this Zone, which resulted in a narrow estimate for the confidence interval.

Habitat Monitoring

Vegetation and habitat data collection and data entry was completed for the 20/20 sites, 79 each in Oregon and Washington and 40 in California (one more Oregon site may be sampled in 2003). Analytical results using these data will be provided in the 2003 annual report.

MONITORING PROGRAM CONSIDERATIONS

Funding to maintain annual at-sea surveys continues to be problematic. Budget shortfalls occur annually. Refining analysis plans for the map and non-map models and implementation of the related analyses will be conducted in 2003.

PROGRAM PRODUCTS

The following publications and reports were published in 2002 or early 2003 in association or collaboration with or functionally linked to the Marbled Murrelet Effectiveness Monitoring Program:

Evans Mack, D., W.P. Ritchie, S.K. Nelson, E. Kuo-Harrison, and T.E. Hamer. 2003. Methods for surveying marbled murrelets in forests: a revised protocol for land management and research. 76 p. Pacific Seabird Group unpublished document available at http://www.pacificseabirdgroup.org.

Meyer, C.B.; Miller, S.L.; Ralph, C.J. 2002. Multi-scale landscape and seascape patterns associated with marbled murrelet nesting areas on the U.S. west coast. Landscape Ecology 17: 95-115.

Miller, S.L.; Meyer, C.B.; and Ralph, C.J. 2002. Land and seascape patterns associated with marbled murrelet abundance offshore. Waterbirds 25(1): 100-108.

Nelson, S.K. and A.K. Wilson. 2002. Marbled murrelet habitat characteristics on state lands in western Oregon. Final Report to OR Dept. of Forestry, OR Dept. Fish and Wildlife, U.S. Fish and Wildlife Service, and National Council fir Air and Stream Improvement. 154 p.

Raphael, M.G.; Mack, D.E.; Marzluff, J.M.; Luginbuhl, J.M. 2002. Effects of forest fragmentation on populations of the marbled murrelet. Studies in Avian Biology No. 22: 221-235.

Strong, C.S. 2003. Status of marbled murrelets at sea in conservation zone 5: Mendocino, Sonoma, and Marin counties. Final Report to U.S. Fish and Wildlife Service and California Department of Fish and Game. 23 p.

Strong, C.S. 2003. Marbled murrelet abundance and reproductive indices in Oregon during 2002. Annual Report to the Oregon Department of Fish and Wildlife, and U.S. Fish and Wildlife Service. 14 p.

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Madsen, S., D. Evans, T. Hamer, P. Henson, S. Miller, S.K. Nelson, D. Roby, and M. Stapanian. 1999. Marbled murrelet effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-439. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 51 p.

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CONTACT INFORMATION

For more information on the Marbled Murrelet Module, contact

Mark Huff (Marbled Murrelet Module Lead)
Phone: 503-231-2042
Email: mark_huff@r1.fws.gov

For more information on the Interagency Regional Monitoring Program, contact

Jon Martin (Monitoring Program Manager)
Phone: 503-808-2269
Email: jrmartin@fs.fed.us

Web Site

Additional information, reports, publications, and program updates relevant to the Marbled Murrelet Effectiveness Monitoring Program (as well all other modules from the Interagency Regional Monitoring Program) can be found at www.reo.gov/monitoring.