Marbled Murrelet Effectiveness Monitoring
Northwest Forest Plan

2011 and 2012 Summary Report

Northwest Forest Plan Interagency Regional Monitoring Program

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[August 5, 2013 revision of earlier "July 2013" release, with correction to Table 4]

SUMMARY

This report updates previous versions of the Marbled Murrelet (*Brachyramphus marmoratus*) Effectiveness Monitoring Program for the Northwest Forest Plan (NWFP) with summaries from the 2011 and 2012 field seasons. The purpose of the effectiveness monitoring program is to assess status and trends of murrelet populations and nesting habitat. This report includes results of the annual at-sea population surveys including a trend analysis, and an update on modeling of nesting habitat.

The objectives of the murrelet population monitoring are to estimate population size and trend during the breeding season within and across five murrelet conservation zones in coastal waters adjacent to the NWFP area. The 2012 estimated population of murrelets in the NWFP target (sampling) area is 21,300 (95 percent confidence interval = 16,700 to 25,900), with the largest zone population estimates occurring in Conservation Zone 1 (Puget Sound and Straits of Juan de Fuca, about 8,400) and in Conservation Zone 3 (Columbia River to Coos Bay, Oregon , about 6,400). At the conservation zone scale, mean murrelet at-sea density estimates in 2012 ranged from 0.75/km^2 in Zone 2 (outer Washington coast) to 4.28 birds/km^2 in Zone 4. Conservation Zone 5, where densities are lowest, was surveyed in 2011 but not in 2012.

For the 5-zone area combined from 2001-2012, the trend analysis no longer shows a statistically significant population trend, where a decline was previously found. At the scale of individual conservation zones, we detected a significant decline during this same period only for Zone 2 (the outer coast of Washington), where the murrelet population declined at an estimated rate of 7.6 percent per year. Additional years of at-sea monitoring will be needed to reliably detect population declines in the other 4 zones that are surveyed. Continued monitoring is necessary to document long term and future changes in murrelet numbers.

In 2010 the team completed a map of baseline (1994/96) nesting habitat and estimated habitat changes since then through 2006/07, using maximum entropy (Maxent) models. The models provided habitat suitability scores for all forested lands in the 5 conservation zones in the NWFP area (Zones 1-5). We estimated 3.8 million acres of higher-suitability potential nesting habitat over all ownerships in this area at the start of the NWFP (1994/96); in this analysis suitability was based on relative likelihood of use for nesting, and did not evaluate quality in terms of nesting success. Most (89 percent) baseline habitat on federal lands occurred within reserved-land allocations, which include late-successional reserves established by the NWFP, wilderness areas, National Parks, and other areas not open to timber harvest. A substantial amount (36 percent) of baseline higher-suitability habitat occurred on non-federal lands. Focusing on losses of baseline habitat, we found a loss of about 13 percent of the baseline higher-suitability nesting habitat by 2006/07 over all lands, with losses greater on non-federal lands (about 30 percent of baseline) than on federal lands (about 3 percent). Fire has been the major cause of loss of nesting habitat on federal lands since the NWFP was implemented; timber harvest is the primary cause of loss on non-federal lands.

Publications that include recent population and habitat monitoring results in detail are Falxa *et al.* 2011; Raphael *et al.* 2011, and Miller *et al.* 2012.

PREFACE

This report was prepared by Martin Raphael, Gary Falxa, and the Marbled Murrelet Monitoring Team members.

ACKNOWLEDGMENTS

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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 http://www.reo.gov/monitoring.

SUGGESTED CITATION:

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INTRODUCTION

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). Evaluating population trends requires a commitment to long-term monitoring (multiple years) and consistent data collection from a target population sampled without biases (Urquhart *et al.* 1998).

The marbled murrelet (*Brachyramphus marmoratus*; hereafter murrelet) and northern spotted owl (*Strix occidentalis*) were the focal animal species selected to monitor and evaluate the effectiveness of the 1994 Northwest Forest Plan (NWFP). One NWFP goal is to maintain and restore murrelet nesting habitat and populations throughout the range of the species within the NWFP area. A two-pronged approach is used to monitor murrelets and evaluate the success of the NWFP (Madsen *et al.* 1999). The first approach uses annual at-sea surveys to assess murrelet population status and trends. Status and trend information is used to assess the stability of murrelet populations within the NWFP area, and to help inform whether land-based management actions are resulting in recovery of the species. For murrelets, at-sea surveys are an accurate and direct means to monitor population trends across the range of the NWFP. Because murrelets are secretive nesters, baseline reproductive information is difficult and expensive to collect at breeding locations. At-sea population surveys offer a cost-effective method for assessing the persistence and conservation status of this species. The methods used for the at-sea surveys were published in 2007 (Raphael *et al.* 2007). The second approach for evaluating murrelet status within the NWFP area is to monitor the amount and trends of potential nesting habitat in the planning area. To accomplish this objective, murrelet habitat models were developed and the initial results published in 2006 (Huff *et al.* 2006) and then updated in 2011 (Raphael *et al.* 2011).

The objectives of this report are to present the 2011 and 2012 at-sea survey results, to present results of population trend analyses using the population data collected through 2012, and to describe habitat modeling work.

EFFECTIVENESS MONITORING QUESTIONS

The effectiveness monitoring goal for the murrelet is to evaluate the success of the NWFP in maintaining and restoring murrelet populations and nesting habitat (Madsen *et al.* 1999). To meet that goal, the monitoring plan for murrelets identified questions to be addressed for the NWFP area, focused on (1) the predicted amount, distribution and spatial attributes of murrelet nesting habitat, and trends in those characteristics, and (2) murrelet population status and trends. These questions are detailed in the murrelet effectiveness monitoring plan (Madsen *et al.* 1999).

Subsequently, Northwest Forest Plan managers identified a list of key management questions for the NWFP monitoring program. This list contains two questions directly related to murrelets:

1. What is the status and trend of Marbled Murrelet habitat and populations?
    - Identified by managers as best answered by monitoring

2. What are the relationships between marbled murrelet status and stressors, how does this affect nesting distribution, and can habitat models effectively predict where murrelets nest?
    - Identified by managers as best answered by research

METHODS

Methods for data collection and analysis of population and habitat information can be found in Huff *et al.* (2006) and Raphael *et al.* (2007, 2011). Deviations from the population survey protocol during 2011 and 2012 are presented below.

Population Monitoring

We sample murrelets by conducting boat-based transects within 2 - 8 km of shore in Recovery Conservation Zones 1 through 5, adjacent to the NWFP area (U.S. Fish and Wildlife Service 1997; Figure 1). We conducted surveys from May 15 through the end of July, the peak activity period of the murrelet nesting season. We divided each conservation zone into two or three strata based on murrelet density patterns, and created contiguous Primary Sampling Units (PSU) of approximately 20 km coastline length throughout the NWFP area (Raphael *et al.* 2007). Our target sample size was 30 PSU surveys per zone in most zones (60 for the larger Zone 1, 15 for Zone 5). We used program DISTANCE (Buckland *et al.* 2001) to generate population density estimates at the conservation zone and NWF Plan scales. The confidence intervals for individual zone population estimates were constructed by using a bootstrap approach; this can result in asymmetric confidence intervals. For the population estimate for all zones combined, we constructed confidence intervals by first calculating the 5-zone standard error from the individual zone standard errors, weighting by zone area. We then constructed the 95 percent confidence intervals as plus/minus 1.96 times the 5-zone standard error; these are symmetric. See Raphael *et al.* (2007) for additional details on methods.

In most zones, most or all of the shoreline is sampled at least once each year. Zone 1 (Puget Sound, San Juan Islands, Straits of Juan de Fuca) has a long complex shoreline, with 98 Primary PSUs total. At the outset of the monitoring program, a one-time stratified random sample of 30 of the 98 PSUs was selected from Zone 1, with sampling effort distributed differentially among the zone's 3 geographic strata based on relative murrelet abundance. These 30 PSUs are sampled twice annually, for a total of 60 PSU samples from Zone 1 (Raphael *et al.* 2007). Stratum 3 of Zone 1 includes 47 PSUs and encompasses the Puget Sound, parts of Hood Canal and Whidbey Island, and the mainland between Puget Sound and the border with Canada. Historic data for this stratum indicated low murrelet densities; therefore the sampling design allocated relatively light effort where5 PSUs are sampled twice annually. This approach is robust with respect to detecting trends. While murrelet density and numbers are generally low within the stratum, they can be locally high at times, and density estimates for this stratum can be influenced by high murrelet density in a single PSU sample.

In 2010, we decided to exclude the 2000 results from Zones 1 and 2 from all population estimates and trend analysis. As discussed in a previous report (Falxa *et al.* 2009), inspection of

the data set suggested that the 2000 estimate may have been unusually low relative to later estimates. The cause for the low 2000 estimates is not known; it may represent the true abundance that year or it may represent natural or sampling variation. However, departures from the sampling protocol occurred in Zone 2 and in Stratum 1 of Zone 1 in 2000, the first year of implementing the protocol. These departures included use of a fixed-width transect rather than an unlimited-width transect, less sampling effort compared to subsequent years, and loss of distance data for many murrelet detections. Another consideration was that Stratum 1 of Zone 1 comprises a substantial portion of the Zone 1 murrelet population. After reviewing these facts at our January 2010 team meeting, we concluded that these departures from the protocol could potentially bias population estimates using the Zone 1 or Zone 2 data from 2000, sufficiently to be unreliable. Therefore, the team decided to exclude the 2000 survey results from the population estimates for Conservation Zones 1 and 2 and from the 5-zone trend analysis. The departures from protocol were corrected in subsequent years.

We calculated a population estimate for the entire 5-zone area by summing the estimates of population size from each zone, for a given year. Because Zone 5 was not surveyed in 2006, 2009, 2010, or 2012, we used estimates for the missing data to allow 5-zone population estimates and trend analyses for all years. We estimated the 2006 Zone 5 density and population as the mean of the 2005 and 2007 Zone 5 estimates, and similarly used the mean of 2008 and 2011 data to estimate the 2009 and 2010 values for Zone 5. For 2012, we used the 2011 Zone 5 density and population estimates. Because the counts from Zone 5 are so low with respect to the other zones, these estimations had little effect on the overall estimated number of birds, or on the trend analyses.

Adjustments and other notes on 2011 surveys

Zone 1: Surveys were conducted by the Forest Service's Pacific Northwest Research Station, using 2 crews of 3. Five of the 6 crew were experienced. One crew had a boat accident on the first day of survey: the engine stalled and the boat was swamped in turbulent water and capsized, off Cattle Pass (thankfully everyone was safe). The crew had an extra boat so the accident resulted in minimal down time, about 1 week. Both rounds of replicates were completed on time. The crew collected actual track line (transect route) to compare with projected track line: on average actual track for a PSU sample was longer by about 100m than projected for that PSU, or <0.5 percent difference on average.

Zone 2: The Washington Department of Fish and Wildlife again conducted the surveys. Their crew had the same boat operator as the previous year, and 2 of 3 observers were experienced. Surveys could not be completed on 10 weather days; this was fewer than in past years. In Stratum 1 many birds were observed near Destruction Island, particularly in the off-shore subunit, and high numbers were observed in mid-to-late July. In Stratum 2, most murrelets were observed in PSU 9, and none in PSUs 10 and 11.

Zones 3, 4, and 5: Crescent Coastal Research conducted these surveys, and the crews had 4 very experienced observers and 2 new observers. Crews operated 2 boats most of the time. The distribution of survey effort was more clumped than random due to foul weather and frequent closure of harbor exit channels by the Coast Guard which forced switching of ports. Crews

obtained 31 samples in Zone 3 (2 additional samples were discarded due to poor conditions). The crews switched to digital data recorders, increasing recorder reliability. Zone 5 surveys were completed mostly in July due to weather constraints. Sampling included 10-day gaps in both Zones 3 and 4. Almost all murrelets in Zone 5 were within 1 PSU, which was sampled twice.

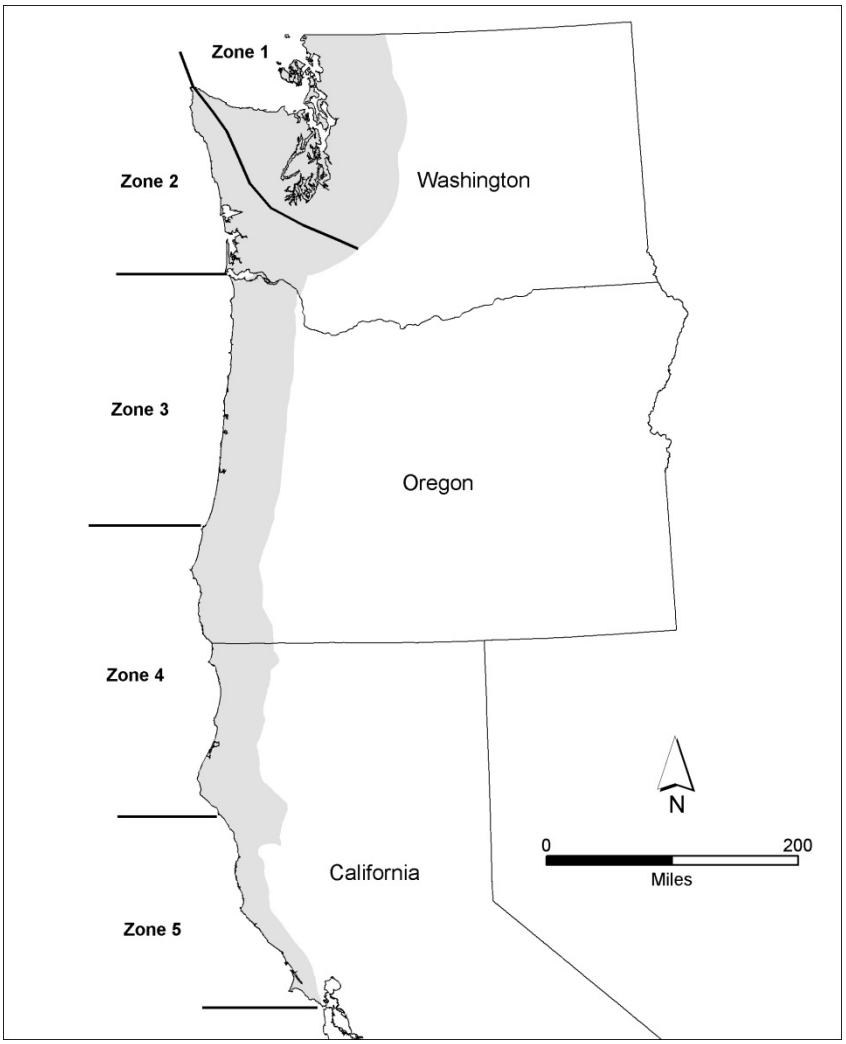

Figure 1. The five at-sea marbled murrelet survey zones adjacent to the NWFP area. Inland breeding distribution is shaded (adapted from U.S. Fish and Wildlife Service 1997).

In 2011, the module lead accompanied the California survey team from Crescent Coastal Research on a murrelet survey in Zone 4, as part of an ongoing program to check for consistency among crews and zones in implementing the survey protocol. No major inconsistencies were identified. We did identify inconsistencies with the daily distance calibration procedure which the crew used to maintain accuracy in estimating distances to observed birds. The crew did the

distance calibration, but did not determine on the spot whether observer estimates were within the criteria (each of 5 estimates within 15 percent of actual distance to target), and feedback was not consistently provided to observers on how their distance estimates compared to the actual distance. Starting in 2012, the Zone 3 and Zone 4 crews began using the standard protocol for distance calibration.

Adjustments and other notes on 2012 surveys

Zone 1: Surveyed by 2 crews from the U.S. Forest Service's Pacific Northwest Research Station (PNW). No significant issues in 2012. Both crews had experienced crew leaders, and each crew had one observer without previous seabird experience. One survey was affected by weather, but the survey met criteria for inclusion, as 96 percent of the survey was completed and our analyses accounted for the reduced survey distance. Surveys in Stratum 1 (Strait of Juan de Fuca) had notably high counts. Twenty juveniles (hatch-year birds) were observed between July 3 and 25, which is a relatively large number; half of these were observed on a single survey in PSU 3 (Clallam Bay, Stratum 1), with 5 near Lopez, 2 near Port Angeles, 2 near Port Townsend, and 1 near Port Ludlow. In preparation for 2013, when Washington Department of Fish and Wildlife (WDFW) will be assuming survey responsibilities in Zone 1, Monique Lance and Scott Pearson from WDFW accompanied the PNW crew on a Zone 1 survey.

Zone 2: Surveyed by WDFW. No significant issues in 2012. The same boat was used as in previous years. The crew had a new boat captain who was very capable, and 1 experienced plus 2 new murrelet observers. Weather conditions prevented surveys on 10 days. Quality assurance distance estimation/calibration tests were conducted weekly (every 3 survey days). Notably, 3 hatch-year murrelets were observed in July—2 in PSU 4 and 1 in PSU 13; these are the first hatch-year birds observed in Zone 2 since at least 2004.

Zones 3 and 4: Both zones were again surveyed by crews from Crescent Coastal Research. Bad weather caused some temporal gaps in survey effort; on some days bar closures prevented the boat from leaving port, even when acceptable survey conditions existed outside. One PSU in Zone 4 (PSU 4, Cape Blanco) was not sampled in 2012 due to poor weather. In 2012, some surveys had to be excluded; five surveys were conducted in poor weather conditions, outside the range of acceptable conditions, and had to be removed from the sample. The zone lead did not learn of this until processing the data at the end of the season. This served as a reminder that even experienced observers need refreshers at the start of every season. With the 5 surveys omitted, the sample size was 29 PSU samples in Zone 3 and 30 in Zone 4 (see below for additional adjustments to the Zone 4 sample).

After reviewing the 2012 data from Zone 4, we also excluded several samples that had been collected for a separate study. Although these samples used the program's sampling protocol, the timing of these samples was non-random, as they were conducted late in the sample period, particularly during the last 3 weeks of July. The sampling protocol assumes relatively even sampling effort across the May 15 - July 31 sample period. The location of these samples was also non-random, as they targeted areas of higher murrelet density. These samples represented 3rd samples from individual PSUs which normally would be sampled once or twice. Upon reviewing the sampling effort, and in order to avoid potential biases in the data, we decided to

exclude the third samples, which represented the extra effort late in the season for the separate study. We also reviewed the sampling effort from 2011, when additional effort for the separate study had been collected. Based on our criteria, we excluded 3 PSU samples from Zone 4 for 2012, and 2 PSU samples for 2011. The resulting sample sizes for 2011 and 2012 were 32 and 27 respectively. All results presented here for 2011- 2012 are based on those sample sizes.

Zone 5: Was not surveyed in 2012.

Trend Analysis

The statistical test for trends was conducted by fitting a regression line to the logarithm (ln) of the annual population density estimates for each of the five individual zones within the NWFP area, and for the 5-zone area combined. Because the population estimates are computed by multiplying murrelet density by the area sampled within each zone (which is constant from year to year), the rate of change will be identical using either the densities or the population numbers in the regression. Starting in 2010, we conducted the regression on the log of densities rather than on the simple densities (Miller *et al.* 2012). This better fits and tests the predictions of demographic models (USFWS 1997; McShane *et al.* 2004) which predict a population that is declining by a constant *percent* of the population size for a given year (consistent with the basic model of exponential population growth or decline; Begon *et al.* 2006), rather than declining by a fixed *number* of birds per year.

The statistical tests for trends were conducted as one-tailed tests for declines; significance was tested at the level of alpha (α) = 0.05. Thus, we tested the null hypothesis that the slope equals zero or greater (no change or an increase in murrelet numbers) against the alternative hypothesis of the slope being less than zero (murrelet numbers decreasing, Miller *et al.* 2006: 46). Estimates for annual rates of decline were calculated by dividing the estimated annual decline for the period of analysis (the slope from the regression equation, in numbers of birds) by the mean population for the period of analysis (the average of the annual population estimates). The trend analyses are based on the period of 2001-2012 for the all-zone trend analyses. For the single-zone trend analyses data from 2001-2012 were used for Zones 1 and 2 and data from 2000-2010 were used for the other 3 zones.

Habitat Modeling

In 2010 the team completed work initiated in 2007 to map baseline nesting habitat conditions (at the start of the NWFP in 1994), and to estimate habitat changes since then, using maximum entropy (Maxent) models. We based our nesting habitat estimates on habitat suitability models that used vegetation mapping from GNN (Gradient Nearest Neighbor; Ohmann and Gregory 2002). We used a recent modeling platform, Maxent habitat suitability software (Phillips *et al.* 2006), which we found to perform best based on a test of several current habitat modeling methods. Using Maxent models, we estimated the amount and distribution of potential murrelet nesting habitat during two periods: (1) baseline (1994 for California, 1996 for Oregon and Washington) and (2) 2006 (Oregon and Washington) or 2007 (California) to estimate change since the baseline. As input to the models, we used maps of the distribution of various environmental characteristics, including GNN vegetation data and climate and topographic

conditions at the 30-meter pixel scale. We trained the Maxent model by using environmental conditions at 342 known murrelet nest locations and sites classified as occupied by audiovisual surveys. Model output is a map of habitat suitability, which we summarized into four classes ranging from low (class 1) to high (class 4) suitability, based on relative likelihood of murrelet presence. We used the higher two of these (classes 3 and 4) to denote potential higher suitability nesting habitat. This modeling approach does not address the larger question of how habitat and landscape characteristics affect nesting success within suitable habitat, and is intended to portray habitat at larger scales such as watershed, ecoregions or larger, and not for individual stands or sites.

We used two methods to assess change in the amount and distribution of higher suitability nesting habitat: The "bookend" approach used the Maxent model to estimate habitat suitability in two periods, the baseline year and in 2006/2007; by comparing mapped habitat suitability for the two periods, we estimated net change as the balance between losses and gains of higher suitability habitat during the analysis period. This method cannot identify causes of habitat losses. Our second approach used forest disturbance data provided by LandTrendr (Landsat-based detection of Trends in Disturbance and Recovery; see Raphael *et al.* [2011] for details) to refine the estimates of habitat loss as determined by the bookend approach. Using LandTrendr data allowed us to identify likely causes of habitat loss, focusing on areas where bookend losses were also mapped as disturbed by LandTrendr. This second approach did not provide information on potential habitat gains.

New vegetation data and Maxent models provided more powerful and consistent results across the monitoring area than those available from the 10-year report (Huff *et al.* 2006). The new baseline maps and estimates replace those from the 10-year report.

In late 2013, we will begin a new habitat status and trend analysis for the period of the first 20 years of the Northwest Forest Plan, based on a comparison of 1993 as the baseline year the entire area, with forest conditions in 2012. Methods will be similar to those used habitat modeling effort completed in 2010 and reported by Raphael *et al.* (2011).

RESULTS AND DISCUSSION

Population Monitoring

The area of coastal waters sampled by the NWFP at-sea surveys is approximately 8,800 km^2; sampled areas vary by zone, as indicated in Tables 3 and 4. In 2012, when Zone 5 was not sampled, the area actually sampled was about 7,900 km^2.

Table 1 summarizes the 2011 and 2012 sampling efforts and Table 2 the 2001-2012 results. The 2011 estimated murrelet population size in Conservation Zones 1 through 5 was 22,700 birds and in 2012 was 21,300 murrelets (Table 2). Among conservation zones, Zones 1 and 3 had the highest population estimates in both years and Zone 4 the highest average density in 2011 (5.74 birds/km^2) and 2012 (4.28 birds/km^2). As in past years, Zone 5 had the lowest murrelet density. A summary of results for Conservation Zones 1 through 5 combined is provided in Table 2 and Figure 2. Tables 3 and 4 provide the 2011 and 2012 density and population estimates for each conservation zone and include related estimation parameters generated by the program DISTANCE. Figure 3 provides murrelet density (birds/km^2) by zone.

The relative precision for density estimates can be measured and compared by using the coefficient of variation (CV; the standard error divided by the mean, and then multiplied by 100). Larger CVs indicate less precise estimates of density or population size. The CV for the combined 5-zone density estimate has ranged from ~8 to 13 percent since 2001, and was 11.8 in 2011 and 11.0 percent in 2012 (Table 2). At the scale of individual zones, CVs are typically larger, and ranged from ~16 to 44 percent in 2011 (Table 3) and from ~16 to 30 percent in 2012 (Table 4); these CVs are comparable to previous years (Falxa *et al.* 2009, Falxa *et al.* 2011). In general, estimate precision tended to be lower in zones and strata with low densities. Consistent with this, the highest CV at the zone scale was 44 percent for Zone 5 in 2011 (Table 3).

Maps that display the average estimated population density of murrelets from 2000/2001 through 2012 by primary sampling unit for each of the three States are provided in the Appendix. The information presented in the Appendix is provided only to illustrate general patterns of murrelet distribution within the areas sampled. The figures should not be used for other analyses because the sampling program was designed to monitor densities at the conservation zone scale and larger, and the primary sampling unit density estimates have large confidence intervals, which are not shown in the figures.

Table 1. The number of marbled murrelet population monitoring primary sampling unit (PSU) surveys completed for the Northwest Forest Plan in 2009 and 2010 by zone and the kilometers of survey transect sampled.

Zone	2011 Number of PSU Surveys	2011 Survey Effort (km)	2012 Number of PSU Surveys	2012 Survey Effort (km)
All	169	6,061	150	5,668
1	60	2,222	60	2,231
2	30	1,356	34	1,567
3	31	1,201	29	1,168
4	32	813	27	702
5	16	469	No surveys	No surveys

Table 2. Summary of 2001-2012 murrelet density and population size estimates (rounded to nearest 100 birds) in all conservation zones combined.

Year	**Density (birds/km^2)**	**Bootstrap Standard Error (birds/km^2)**	**Coefficient of Variation of Density (%)**	**Birds**	**Birds Lower 95% CL**	**Birds Upper 95% CL**
2001	2.52	0.27	10.5	22,200	17,600	26,800
2002	2.69	0.31	11.5	23,700	18,300	29,000
2003	2.53	0.24	9.5	22,200	18,100	26,400
2004	2.43	0.25	10.5	21,400	17,000	25,700
2005	2.30	0.25	10.8	20,200	16,000	24,500
2006	2.14	0.17	8.0	18,800	15,900	21,700
2007	1.98	0.26	13.4	17,400	12,800	21,900
2008	2.03	0.18	9.1	17,800	14,600	21,000
2009	2.03	0.21	10.2	17,800	14,300	21,400
2010	1.91	0.21	11.0	16,800	13,200	20,400
2011	2.59	0.30	11.8	22,700	17,500	28,000
2012	2.42	0.27	11.0	21,300	16,700	25,900

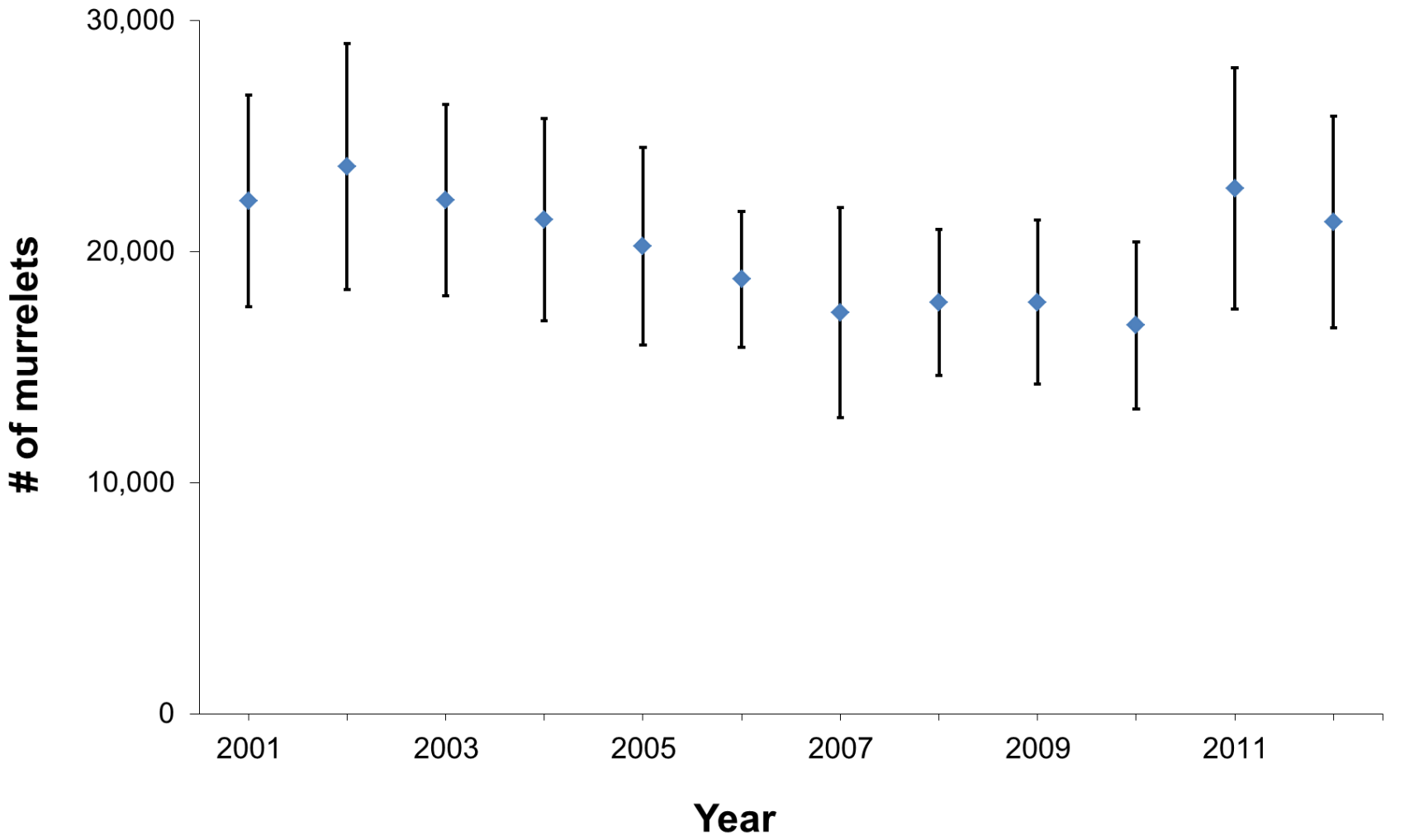

Figure 2. Annual marbled murrelet population estimates and 95 percent confidence intervals, for Conservation Zones 1 - 5 combined.

Table 3. Estimates of murrelet density and population size during the 2011 breeding season in the area of the Northwest Forest Plan. E(s), f(0), and truncation distance are parameters used by the program DISTANCE; see Raphael *et al.* (2007) for details.

Zone	Stratum	Density (birds/km^2)	Bootstrap Standard Error (birds/km^2)	Coefficient of Variation of Density (%)	Birds	Birds Lower 95% CL	Birds Upper 95% CL	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	5.5805	1.1836	21.2%	4,717	2,570	6,630	845.200						
1	2	1.2435	0.2985	24.0%	1,484	821	2,186	1,193.690						
1	3	0.6761	0.4309	63.7%	986	216	2,242	1,458.240						
1	**All**	**2.0551**	**0.3701**	**18.0%**	**7,187**	**4,512**	**9,745**	**3,497.130**	**0.0089**	**0.0006**	**1.6662**	**0.0573**	**289**	**11.0**
2	1	1.3144	0.4046	30.8%	952	426	1,639	724.470						
2	2	0.2561	0.2543	99.3%	237	40	751	925.934						
2	**All**	**0.7206**	**0.2318**	**32.2%**	**1,189**	**597**	**2,060**	**1,650.404**	**0.0110**	**0.0021**	**1.4964**	**0.1313**	**161**	**19.4**
3	1	0.9418	0.3706	39.4%	622	316	1,441	660.888						
3	2	7.2700	1.2828	17.6%	6,794	4,499	9,332	934.546						
3	**All**	**4.6486**	**0.7636**	**16.4%**	**7,417**	**5,200**	**10,078**	**1,595.434**	**0.0126**	**0.0008**	**1.6800**	**0.0420**	**120**	**8.4**
4	1	7.7137	2.5482	34.5%	5,660	2,363	9,063	733.735						
4	2	2.3353	1.1006	47.9%	993	426	2,318	425.415						
4	**All**	**5.7398**	**1.6324**	**29.9%**	**6,653**	**3,505**	**10,444**	**1,159.150**	**0.0123**	**0.0012**	**1.6277**	**0.0624**	**150**	**13.7**
5	1	0.5093	0.2784	52.4%	225	31	487	441.179						
5	2	0.1308	0.1013	77.7%	58	--	138	441.396						
5	**All**	**0.3200**	**0.1518**	**44.2%**	**282**	**49**	**582**	**882.576**	**0.0123**	**0.0012**	**1.6277**	**0.0624**	**150**	**13.7**
All		**2.5873**	**0.2991**	**11.8%**	**22,729**	**17,499**	**27,958**	**8,784.693**						

Table 4. Estimates of murrelet density and population size during the 2012 breeding season in the area of the Northwest Forest Plan. E(s), f(0), and truncation distance are parameters used by the program DISTANCE; see Raphael *et al.* (2007) for details. Because Zone 5 was not sampled in 2012, the "All Zone" population results use an estimated density for Zone 5 (see text for details). [Note: correction made on 5 August, 2013 for 95% CLs for Zone 2 "All"; lower and upper CL values were reversed in original July report]

Zone	Stratum	Density (birds/km^2)	Bootstrap Standard Error (birds/km^2)	Coefficient of Variation of Density (%)	Birds	Birds Lower 95% CL	Birds Upper 95% CL	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	7.1656	1.7317	24.2%	6,056	3,388	8,976	845.200						
1	2	1.5073	0.4455	29.6%	1,799	851	2,917	1,193.690						
1	3	0.4024	0.1910	47.5%	587	162	1,201	1,458.240						
1	**All**	**2.4141**	**0.4827**	**20.0%**	**8,442**	**5,276**	**12,030**	**3,497.130**	**0.0109**	**0.0011**	**1.8474**	**0.0920**	**164**	**10.3**
2	1	1.1508	0.3447	30.0%	834	626	976	724.470						
2	2	0.4386	0.2960	67.5%	406	207	528	925.934						
2	**All**	**0.7512**	**0.2270**	**30.2%**	**1,240**	**833**	**1,504**	**1,650.404**	**0.0126**	**0.0012**	**1.4944**	**0.0612**	**107**	**10.7**
3	1	0.8950	0.3138	35.1%	591	252	1,065	660.888						
3	2	6.1717	1.0099	16.4%	5,768	3,623	7,234	934.546						
3	**All**	**3.9859**	**0.6318**	**15.9%**	**6,359**	**4,120**	**8,022**	**1,595.434**	**0.0112**	**0.0011**	**1.7653**	**0.0633**	**186**	**20.6**
4	1	6.0501	1.6232	29.7%	4,439	2,909	7,313	733.735						
4	2	1.2254	0.4738	49.9%	521	158	944	425.415						
4	**All**	**4.2794**	**1.0379**	**26.7%**	**4,960**	**3,404**	**7,818**	**1,159.150**	**0.0107**	**0.0007**	**1.6522**	**0.0502**	**140**	**11.7**
5	**All**	***Not sampled in 2012***												
All		**2.4228**	**0.2662**	**11.0%**	**21,284**	**16,700**	**25,867**	**8,784.693**						

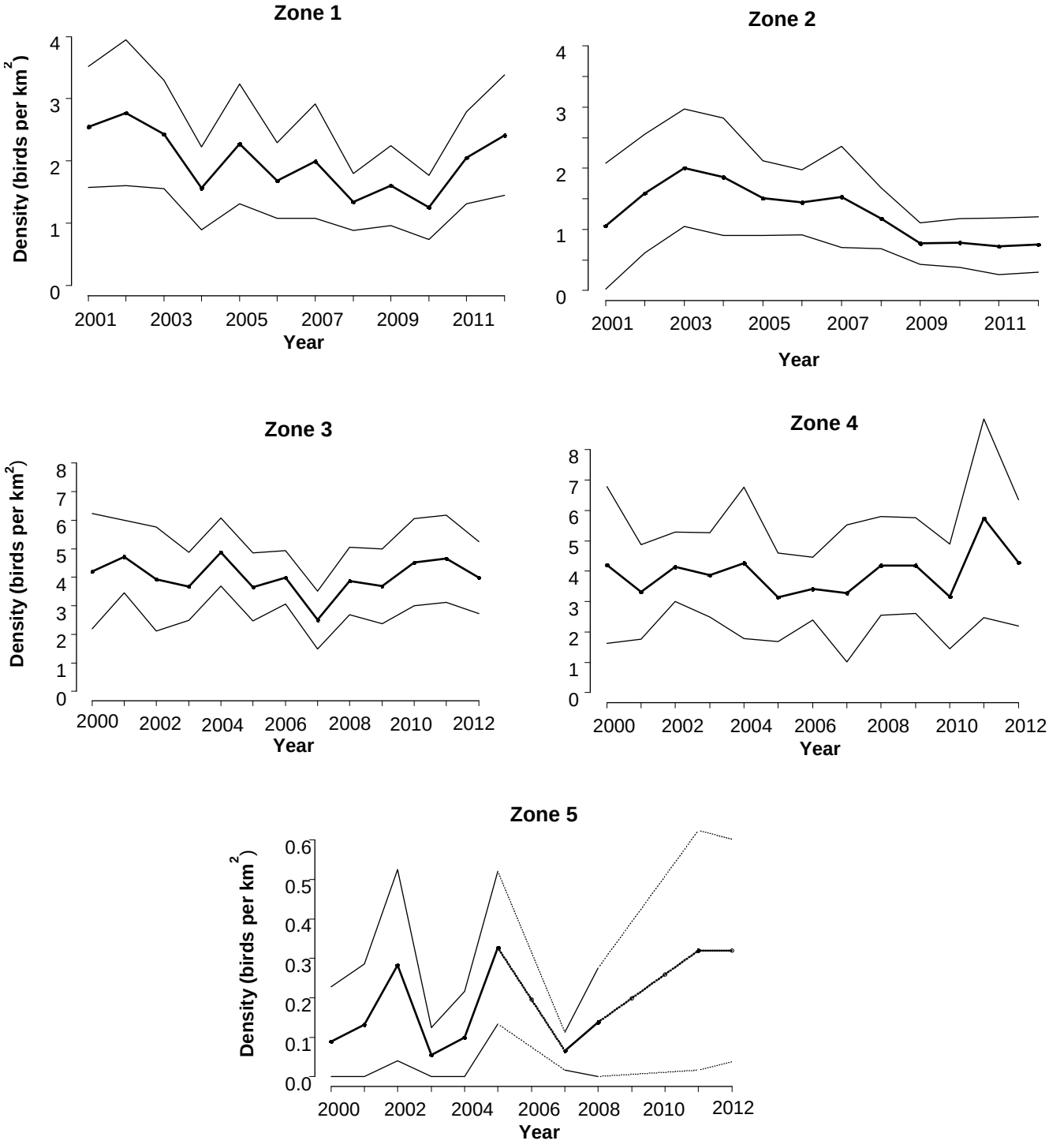

Figure 3. Estimated marbled murrelet densities (birds per km^2) for each conservation zone along with approximate 95 percent confidence intervals for years 2001 through 2012 (includes year 2000 for Zones 3, 4, and 5).

Trend Analysis

In early 2010, we conducted an analysis of the statistical power of the sampling design to detect population changes at the single and all-zone spatial scales; this power analysis used the population data for 2001 to 2009, and updated the previous analysis published in Miller *et al.* (2006) which used the 2000 to 2003 data. For the population of the 5 conservation zones combined, the new power analysis estimated that with 9 years of annual sampling (the current sampling effort), an annual decrease of 3 percent could be detected with 95 percent power or greater, and that an annual decrease of 2 percent could be detected with lower (80 percent) power (Tables 5a and 5b). More years of sampling are required to detect smaller rates of decline, or to achieve greater certainty (power) of detecting an actual decline of any given magnitude given the observed variability in annual estimates. For individual zones, power to detect trends is always less. For example, 9 years of sampling would be adequate to detect an annual decline of 7 percent or more with high confidence in Zone 4 (Table 5b, 95 percent power); more years would be needed to detect smaller annual rates of decline. The power values here and in Table 5 should be interpreted as approximate values; power estimates based on other data sets, such 2001 to 2012, could differ.

Population demographic models predicted population declines of 3 to 7 percent per year for the listed range, which includes Zone 6 (U.S. Fish and Wildlife Service 1997; McShane *et al.* 2004). Miller *et al.* (2012) reported a statistically significant decline of 3.7 percent per year for the combined population of Conservation Zones 1 through 5 for the 2001-2010 period. For the new analysis based on 2001-2012 data, no trend was detected at the 5 percent level ($p = 0.154$; Table 6). While the trend line slope for this period is slightly negative (Table 6), the 95 percent confidence interval for the trend slope includes zero (Table 6 and Figure 4), which also indicates no statistically significant trend. The reason for finding no significant population trend through 2012, when Miller *et al.* (2012) found a declining trend through 2010, is the increased estimates of murrelet abundance for both 2011 and 2012. In 2011, estimates of murrelet population size increased in all conservation zones except Zone 2, compared to estimates from recent years. In 2012, population estimates remained higher in some zones, most notably Stratum 1 of Zone 1 (Strait of Juan de Fuca, Washington), and the 2012 population estimate for all conservation zones combined (Washington south to San Francisco Bay) also remained above that of recent years, in large part an effect of the increase in Zone 1 (Figures 2 and 3; Tables 3 and 4).

The sampling error associated with population estimates for such a mobile and patchily distributed species could have contributed to the increased estimates, as could other factors. Results of murrelet population monitoring in 2013 and beyond will help further clarify population status and trend, as will data explorations underway. For the latter, we have identified several topics to explore as potential causes for the increased population estimates in 2011-2012:

- Has the distribution of birds relative to distance from shore changed? Specifically, did bird distribution shift closer to shore in 2011-2012, such that birds previously too far offshore to be within our sampling areas moved closer in those years, to put them within the sampled area?
    - Initial data explorations, based on the distribution of murrelets in the offshore versus inshore subunits of the PSUs, do not indicate a change in murrelet distribution with respect to distance from shore.

- Do any of the parameters used to estimate density differ in 2011-2012 from previous years? Parameters of interest include the probability density function of detection distances [f(0) in

DISTANCE], the mean number of birds per murrelet group detected [E(s) in DISTANCE], and the encounter rate of murrelets during surveys.
    - Initial data inspections indicate that f(0) and E(s) did not differ markedly, but encounter rates increased in 2011-2012.

- Did the detection function models used by DISTANCE change between years in a way that could affect density estimates in 2011 or 2012?

- Could the distribution of murrelets within Zone 1 have shifted from unsampled PSUs to sampled PSUs? Changes in density estimates in Stratum 1 of Zone 1 contributed heavily to the 2011-2012 increases in Zone 1 estimates (Tables 3 and 4), and not all PSUs are surveyed in this stratum, thus a movement of birds between PSUs could contribute to an increase in estimates. For example, did the dam removals on the Elwah River, which generated large sediment plumes within Stratum 1 of Zone 1 during the survey season, create a foraging opportunity that attracted murrelets from other PSUs or strata?

- Our murrelet density estimates from Zones 3 and 4 increased or were stable in 2011compared to the previous several years, which is not consistent with movement of birds from these zones into Zone 1. However, could birds have moved from the north into our sample area, such as across the Strait of Juan de Fuca from British Columbia to northern Washington?
    - Comparable regional results are not available from British Columbia. However, limited data are available from one long-term at-sea sampling effort from about 100 km of transects on the southwest coast of Vancouver Island during May to July. This effort observed a marked increase in murrelet numbers during the 2006 to 2012 period, especially during the years 2010-2012 (Y. Zharikov, pers. comm.). The data from this small area, which is in part on the Strait of Juan de Fuca, are not consistent with a marked emigration of birds out of their study area.

- Did the temporal or spatial distribution of survey effort (timing and location of surveys) differ in a way that could contribute to the observed population estimate increases?

- Were fewer murrelets breeding in 2011 and 2012, thus more birds were on the water versus at nest sites?
    - Numbers of hatch-year birds counted around the San Juan Islands in 2011-2012 were comparable to numbers in other years (M. Raphael and T. Bloxton, unpublished data), suggesting similar rates of nesting for the murrelet population associated with the waters around the San Juan Islands.
    - As noted above under *Adjustments and other notes on 2012 surveys*, the number of hatch-year birds observed in the Strait of Juan de Fuca suggests that for the murrelets using this area, reproductive effort was not markedly low in 2012. This, however, might not be the case in other areas such as Zones 3 and 4.

We also conducted trend analyses for each individual zone (Table 6). The analysis only showed a significant decline in Zone 2, with an estimated annual rate of decline of 7.6 percent (95 percent confidence interval of -12.2 to -2.7 percent). As noted earlier, the variability in population estimates generally increases at smaller spatial scales, such as zone. As a result, more years of sampling are typically required to detect a trend for a single zone (Tables 5a, 5b).

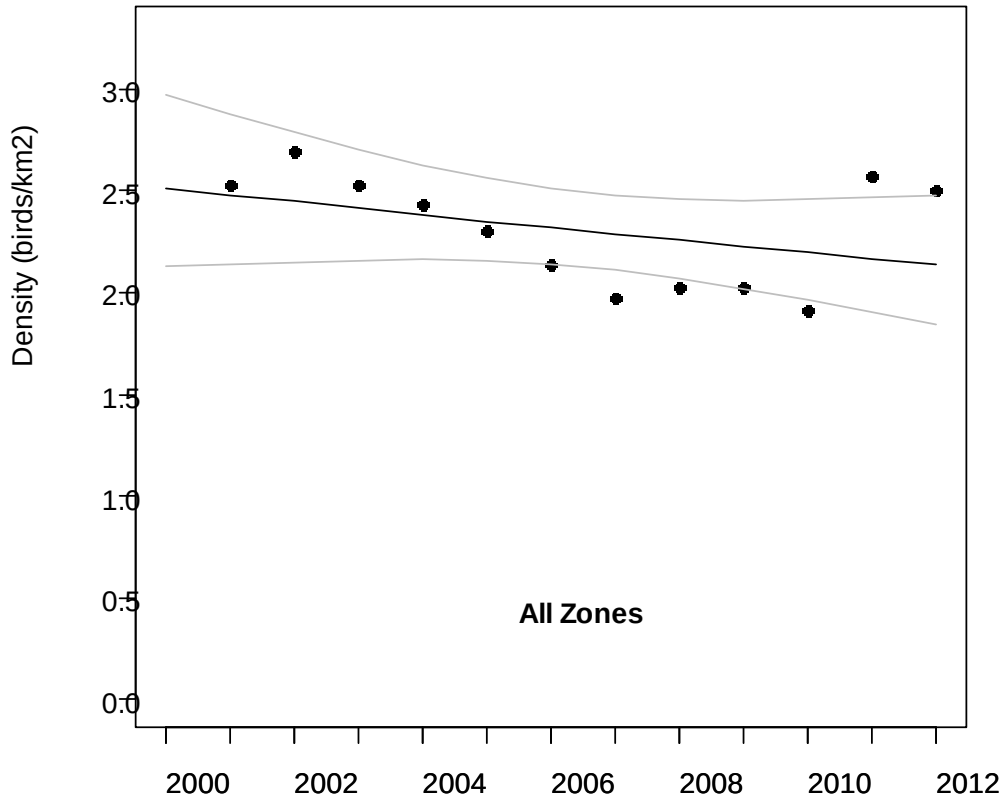

Figure 4. Results of trend analysis for Conservation Zones 1 through 5 combined for 2001-2012. Graph shows annual point estimates, the regression line and associated 95 percent confidence limits for line. Overall slope is -0.014, adjusted $R^2 = 0.11$, $P = 0.154$.

Table 5a. Estimate of the number of years of survey needed to detect various percentages of annual decrease in the NWFP murrelet population with 80 percent power or greater, in all conservation zones combined or by individual zone. Based on a power analysis conducted using 2001-2009 population results, using methods described in Huff *et al.* (2006; Chapter 3).

Annual Decrease Rate (%)	**Zone**					
	All	**1**	**2**	**3**	**4**	**5**
2	8	18	26	18	16	45
3	7	14	20	14	12	35
4	6	12	16	12	10	29
5	5	10	14	10	9	25
6	5	9	13	9	8	22
7	5	9	12	9	7	20
8	4	8	11	8	7	18

9	4	7	10	7	7	17
10	4	7	9	7	6	16

Table 5b. Estimate of the number of years of survey needed to detect various percentages of annual decrease in the NWFP murrelet population with 95 percent power or greater, in all conservation zones combined or by individual zone. Based on a power analysis conducted using 2001-2009 population results, using methods described in Huff *et al.* (2006; Chapter 3).

Annual Decrease Rate (%)	**Zone**					
	All	**1**	**2**	**3**	**4**	**5**
2	10	22	31	22	19	54
3	8	17	23	17	14	42
4	7	14	20	14	12	34
5	6	12	17	12	11	30
6	5	11	15	11	10	26
7	5	10	14	10	9	24
8	5	9	13	9	8	22
9	5	9	12	9	8	20
10	5	8	11	8	7	19

Table 6. Estimates of average annual rate of change based on the at-sea population surveys conducted from 2000 through 2012. For "All Zones" and Zones 1 and 2, 2001-2012 was the basis for the trend analyses, while other analyses used the full data set; see text for details. Standard errors are for the estimates of percent annual change. The *P*-value is for testing whether the annual change is zero or a negative value less than zero.

Zone	**Annual Rate of Change (%)**		**95% Conf. Limits**		**Adjusted R^2**	***P*-value**
	Estimate	**Std. Err**	**Lower**	**Upper**		
All Zones	-1.4	0.9	-3.6	0.8	0.11	0.15
1	-3.2	2.0	-7.8	1.7	0.12	0.15
2	-7.6	2.0	-12.2	-2.7	0.53	<0.01
3	-0.4	1.3	-3.4	2.8	0.00	0.78
4	1.1	1.3	-1.9	4.2	0.00	0.42
5	7.9	5.8	-5.9	23.7	0.10	0.19

Habitat Monitoring

In 2010 the team completed a map of baseline (1994/96) nesting habitat and estimated habitat changes since then through 2006/07, using maximum entropy (Maxent) models. We selected Maxent models based on their performance against several other modeling platforms. Maxent provided habitat suitability scores for all forested lands in the 5 conservation zones within the NWFP area (Zones 1-5). We estimated 3.8 million acres of higher-suitability potential nesting habitat over all ownerships in this area at the start of the NWFP (1994/96). Most (89 percent) baseline habitat on federal lands occurred within reserved-land allocations, which include late-successional reserves established by the NWF Plan, wilderness areas, National Parks, and other areas not open to timber harvest. A substantial amount (36 percent) of baseline higher-suitability habitat occurred on non-federal lands. Focusing on losses of baseline habitat using the LandTrendr-informed approach, we found a loss of about 13 percent of the baseline higher-suitability nesting habitat by 2006/07 over all lands, with losses greater on non-federal lands (about 30 percent of baseline) than on federal lands (about 3 percent). Fire has been the major cause of loss of higher-suitability nesting habitat on federal lands since the NWFP was implemented; timber harvest is the primary cause of loss on non-federal lands. We also found that murrelet population size is strongly and positively correlated with the amount of nesting habitat, suggesting that conservation of remaining nesting habitat and restoration of currently unsuitable habitat is key to murrelet recovery. Raphael *et al.* (2011) provides the full results of this modeling effort.

MONITORING PROGRAM CONSIDERATIONS

Funding continues to be a challenge for the at-sea surveys, exacerbated by reduced agency budgets. Surveys will be conducted in 2013. Funding surveys remains difficult for Zone 5, and has become a greater challenge in Zone 1, where the primary funding responsibility shifted in 2010 from the U.S. Forest Service PNW to the U.S. Fish and Wildlife Service.

In the near term, the Habitat and Population teams have brought their data together to investigate the relationships between nesting habitat distribution and trends, oceanographic conditions, and murrelet population distribution and trends. One question is the roles of various factors on the temporal and spatial distribution of murrelets. Terrestrial factors include the amount and distribution of suitable nesting habitat, and indices of human influence (human footprint), and past and ongoing losses of suitable nesting habitat. Oceanographic conditions include sea surface temperature, chlorophyll concentration (as an index to productivity), bathymetry, marine human influences (marine footprint), and shoreline substrate. We are exploring various models to better understand the strength of influence of these attributes on the observed abundance of murrelets along the coast and over time.

RECENT PROGRAM PRODUCTS

Earlier program products are listed in previous reports, which are available at: http://www.reo.gov/monitoring/reports/marbled-murrelet-reports-publications.shtml. The following recent publications and reports were published in association or collaboration with the Marbled Murrelet Effectiveness Monitoring Program in the last 3 years:

Falxa, G.; J. Baldwin, D. Lynch; S.K. Nelson; S.L. Miller; S.F. Pearson; C.J. Ralph; M.G. Raphael; C. Strong; T. Bloxton; B. Galleher; B. Hogoboom; M. Lance; R. Young; and M.H. Huff. 2009. Marbled murrelet effectiveness monitoring, Northwest Forest Plan: 2008 summary report. 19 pp. Available at: http://www.reo.gov/monitoring/reports/marbled-murrelet-reports-publications.shtml

Falxa, G.; J. Baldwin, D. Lynch; S.K. Nelson; S.L. Miller; S.F. Pearson; C.J. Ralph; M.G. Raphael; C. Strong; T. Bloxton; B. Galleher; B. Hogoboom; M. Lance; R.D. Young; and M.H. Huff. 2011. Marbled murrelet effectiveness monitoring, Northwest Forest Plan: 2010 summary report. 19 pp. Available at: http://www.reo.gov/monitoring/reports/marbled-murrelet-reports-publications.shtml

Falxa, G; M. Raphael; S.L. Miller; J. Baldwin; T.D. Bloxton, Jr.; K. Dugger; B. Galleher; M.M. Lance; D. Lynch; S.K. Nelson; S.F. Pearson; C.J. Ralph; C.S. Strong; and R. Young. 2011. Status and Trends of Populations and Nesting Habitat for the Marbled Murrelet. Chapter 3 *in*: Davis, R.; Falxa, G.; Grinspoon, E.; Harris, G.; Lanigan, S.H.; Moeur, M.; Mohoric, S. Northwest Forest Plan—The First 15 Years [1994-2008]: Monitoring the Northwest Forest Plan - Fifteen Year Summary of Key Findings. Tech. Paper R6-RPM-TP-03-2011. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. Available at: http://www.reo.gov/monitoring/reports/15yr-report/summary/index.shtml

Miller, S.L.; M.G. Raphael; G.A. Falxa; C. Strong; J. Baldwin; T. Bloxton; B.M. Galleher; M. Lance; D. Lynch; S.F. Pearson; C.J. Ralph; and R.D. Young. 2012. Recent population decline of the marbled murrelet in the Pacific Northwest. Condor 114:771-781.

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Raphael, M.G.; G.A. Falxa; K.M. Dugger; B.M. Galleher; D. Lynch; S.L. Miller; S.K. Nelson and R.D. Young. 2011. Northwest Forest Plan—the first 15 years (1994-2008): Status and trend of nesting habitat for the Marbled Murrelet. Gen. Tech. Rep. PNW-GTR-848. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Available at: http://www.reo.gov/monitoring/reports/15yr-report/marbled-murrelet/index.shtml

Strong, C.S. 2013. Marbled murrelet population monitoring in Oregon and California during 2012. Report to the U.S. Fish and Wildlife Service, Oregon State Office, Portland, OR, and Arcata Office, Arcata, CA. Crescent Coastal Research, Crescent City, CA. 15 p.

Strong, C.S. 2013. Marbled murrelet productivity measures as sea in northern California during 2011 and 2012, an assessment relative to Redwood National and State Park lands. Report to the U.S. Fish and Wildlife Service, Arcata, CA. Crescent Coastal Research. Crescent City, CA. 17 p.

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Raphael, M.G.; J. Baldwin; G.A. Falxa; M.H. Huff; M. Lance; S.L. Miller; S.F. Pearson; C.J. Ralph; C. Strong; and C. Thompson. 2007. Regional population monitoring of the marbled murrelet: field and analytical methods. Gen. Tech. Rep. PNW-GTR-716. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 70 p.

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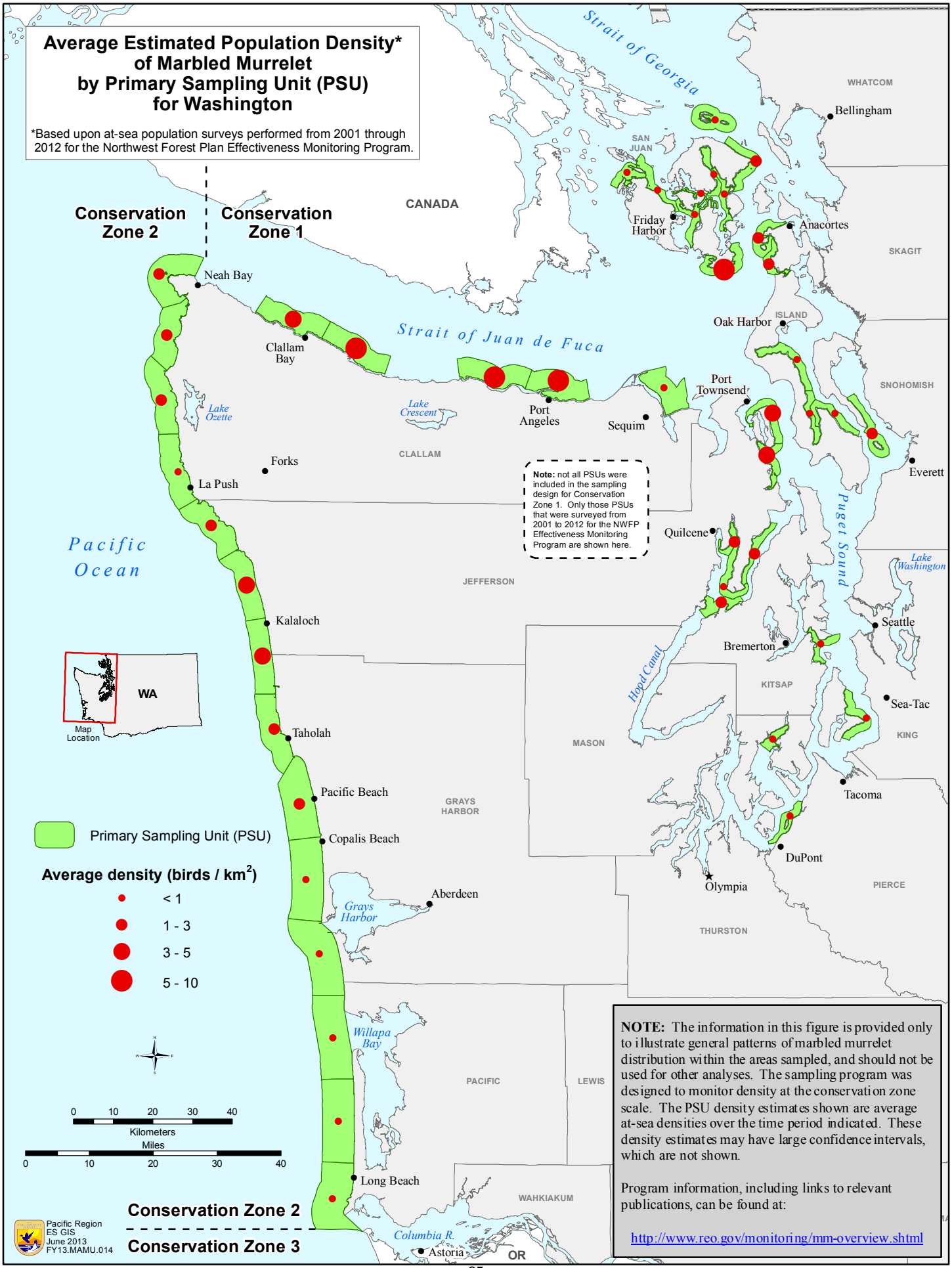
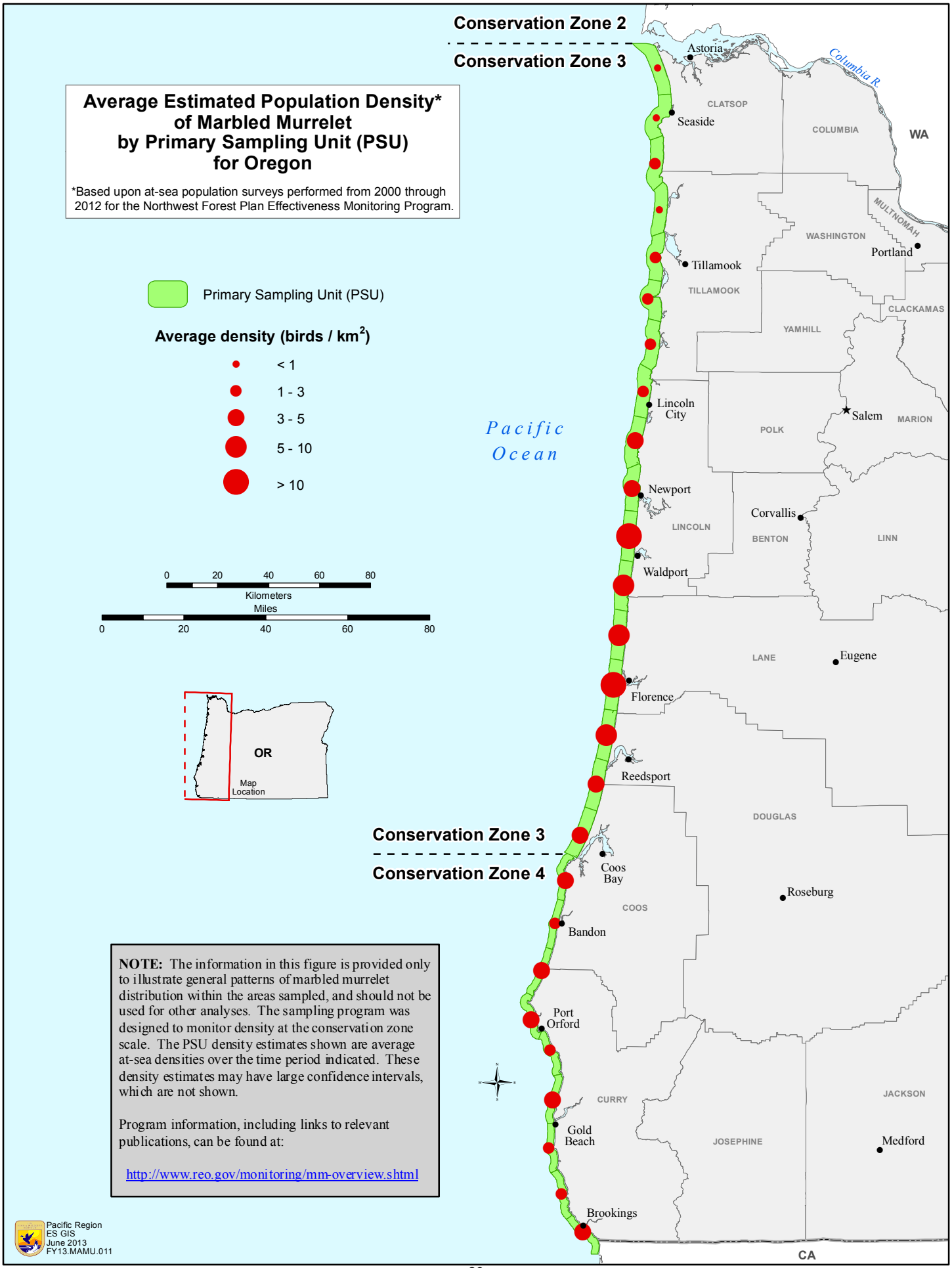
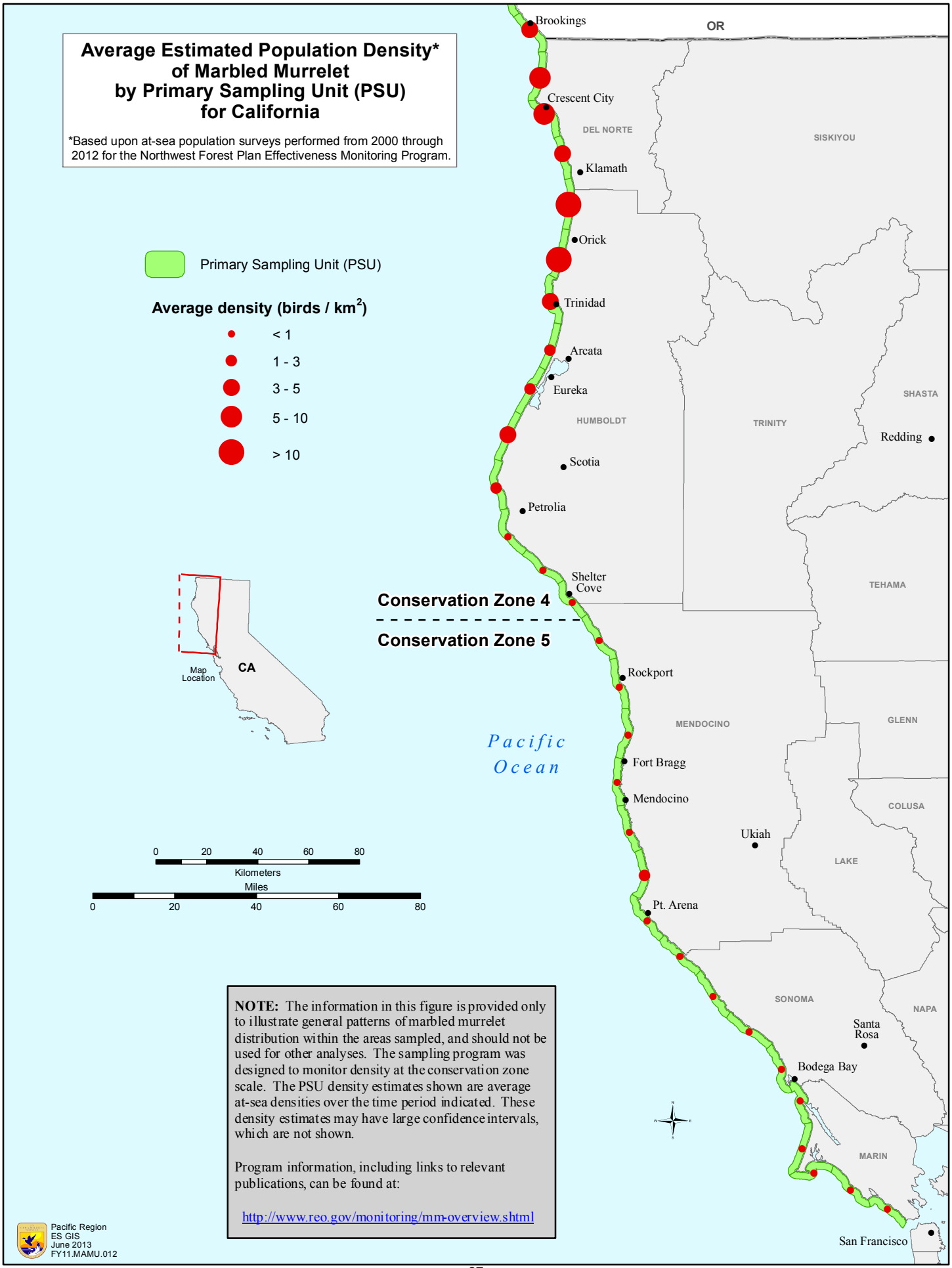
APPENDIX

MAPS OF AVERAGE MARBLED MURRELET DENSITIES AT SEA AT THE SCALE OF PRIMARY SAMPLING UNIT, FOR WASHINGTON, OREGON, AND CALIFORNIA, BASED ON 2000/2001-2012 DATA


Average Estimated Population Density* of Marbled Murrelet by Primary Sampling Unit (PSU) for Washington
*Based upon at-sea population surveys performed from 2001 through 2012 for the Northwest Forest Plan Effectiveness Monitoring Program.
Conservation Zone 2
Conservation Zone 1
CANADA
Strait of Georgia
Strait of Juan de Fuca
Pacific Ocean
WHATCOM
Bellingham
SAN JUAN
Friday Harbor
Anacortes
SKAGIT
ISLAND
Oak Harbor
SNOHOMISH
Everett
Port Townsend
Sequim
Port Angeles
Lake Crescent
Lake Ozette
Neah Bay
Clallam Bay
CLALLAM
Forks
La Push
Note: not all PSUs were included in the sampling design for Conservation Zone 1. Only those PSUs that were surveyed from 2001 to 2012 for the NWFP Effectiveness Monitoring Program are shown here.
Quilcene
Puget Sound
Lake Washington
JEFFERSON
Kalaloch
Seattle
Bremerton
Hood Canal
KITSAP
Sea-Tac
KING
Tacoma
MASON
Taholah
Pacific Beach
GRAYS HARBOR
Copalis Beach
DuPont
Olympia
PIERCE
Aberdeen
Grays Harbor
THURSTON
Willapa Bay
PACIFIC
LEWIS
Long Beach
WAHKIAKUM
Columbia R.
Astoria
OR
WA
Map Location
Primary Sampling Unit (PSU)
Average density (birds / km2)
< 1
1 - 3
3 - 5
5 - 10
0 10 20 30 40
Kilometers
Miles
0 10 20 30 40
Conservation Zone 2
Conservation Zone 3
Pacific Region ES GIS June 2013 FY13.MAMU.014
NOTE: The information in this figure is provided only to illustrate general patterns of marbled murrelet distribution within the areas sampled, and should not be used for other analyses. The sampling program was designed to monitor density at the conservation zone scale. The PSU density estimates shown are average at-sea densities over the time period indicated. These density estimates may have large confidence intervals, which are not shown.
Program information, including links to relevant publications, can be found at:
http://www.reo.gov/monitoring/mm-overview.shtml


Conservation Zone 2
Conservation Zone 3
Average Estimated Population Density* of Marbled Murrelet by Primary Sampling Unit (PSU) for Oregon
*Based upon at-sea population surveys performed from 2000 through 2012 for the Northwest Forest Plan Effectiveness Monitoring Program.
Primary Sampling Unit (PSU)
Average density (birds / km2)
< 1
1 - 3
3 - 5
5 - 10
> 10
0 20 40 60 80
Kilometers
Miles
0 20 40 60 80
OR
Map Location
Conservation Zone 3
Conservation Zone 4
NOTE: The information in this figure is provided only to illustrate general patterns of marbled murrelet distribution within the areas sampled, and should not be used for other analyses. The sampling program was designed to monitor density at the conservation zone scale. The PSU density estimates shown are average at-sea densities over the time period indicated. These density estimates may have large confidence intervals, which are not shown.
Program information, including links to relevant publications, can be found at:
http://www.reo.gov/monitoring/mm-overview.shtml
Pacific Ocean
Columbia R
Astoria
Seaside
Tillamook
Lincoln City
Newport
Waldport
Florence
Reedsport
Coos Bay
Bandon
Port Orford
Gold Beach
Brookings
Portland
Salem
Corvallis
Eugene
Roseburg
Medford
CLATSOP
COLUMBIA
WASHINGTON
MULTNOMAH
TILLAMOOK
CLACKAMAS
YAMHILL
POLK
MARION
LINCOLN
BENTON
LINN
LANE
DOUGLAS
COOS
CURRY
JOSEPHINE
JACKSON
WA
CA
Pacific Region
ES GIS
June 2013
FY13.MAMU.011


Average Estimated Population Density* of Marbled Murrelet by Primary Sampling Unit (PSU) for California
*Based upon at-sea population surveys performed from 2000 through 2012 for the Northwest Forest Plan Effectiveness Monitoring Program.
Primary Sampling Unit (PSU)
Average density (birds / km2)
< 1
1 - 3
3 - 5
5 - 10
> 10
Map Location
CA
Conservation Zone 4
Conservation Zone 5
Pacific Ocean
0 20 40 60 80
Kilometers
Miles
0 20 40 60 80
Brookings
OR
Crescent City
DEL NORTE
SISKIYOU
Klamath
Orick
Trinidad
Arcata
Eureka
HUMBOLDT
TRINITY
SHASTA
Redding
Scotia
Petrolia
Shelter Cove
TEHAMA
Rockport
MENDOCINO
GLENN
Fort Bragg
Mendocino
COLUSA
Ukiah
LAKE
Pt. Arena
SONOMA
NAPA
Santa Rosa
Bodega Bay
MARIN
San Francisco
NOTE: The information in this figure is provided only to illustrate general patterns of marbled murrelet distribution within the areas sampled, and should not be used for other analyses. The sampling program was designed to monitor density at the conservation zone scale. The PSU density estimates shown are average at-sea densities over the time period indicated. These density estimates may have large confidence intervals, which are not shown.
Program information, including links to relevant publications, can be found at:
http://www.reo.gov/monitoring/mm-overview.shtml
Pacific Region
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