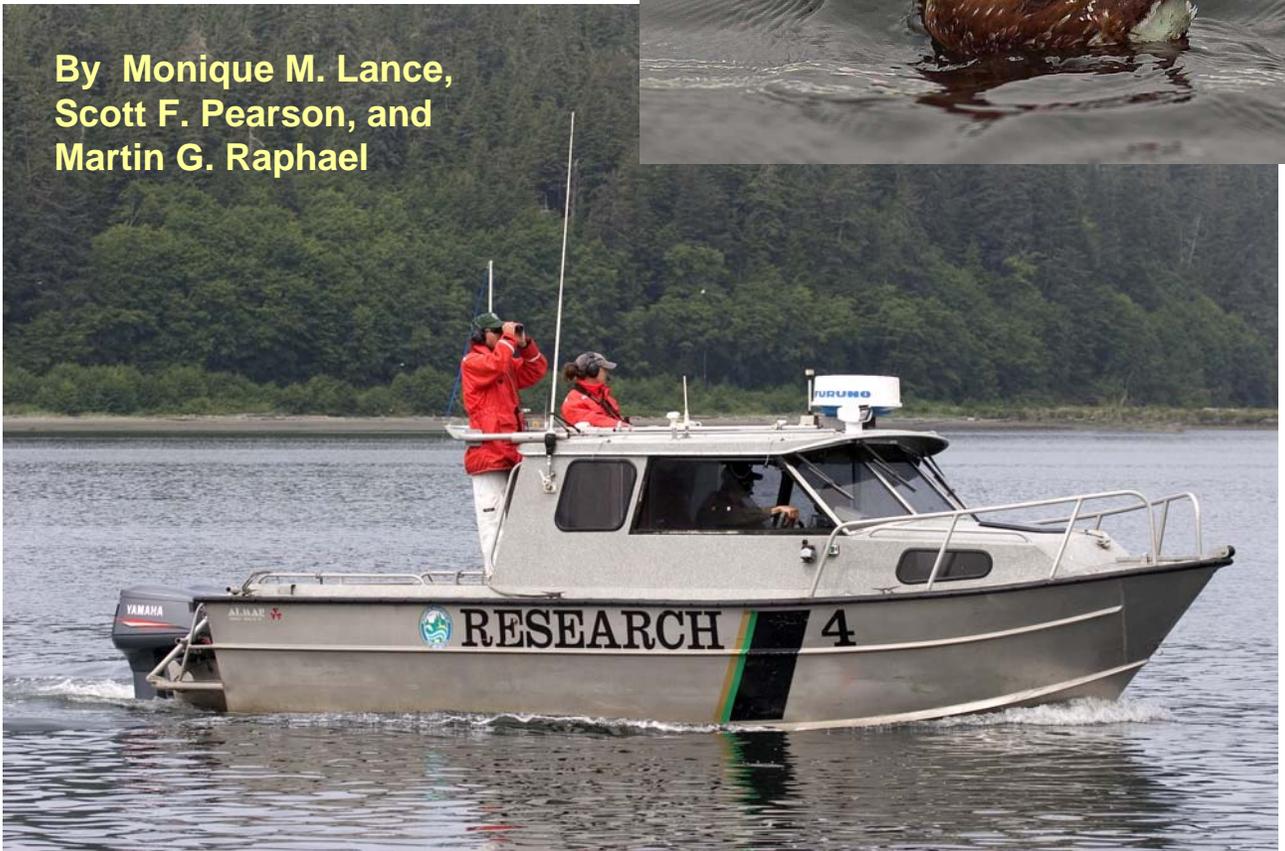


2007 AT-SEA MARBLED MURRELET POPULATION MONITORING

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Fish and Wildlife
Wildlife Program
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**2007 At-Sea Marbled Murrelet Population Monitoring:
Research Progress Report**

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Abstract

The Marbled Murrelet was listed as a Threatened species in California, Oregon and Washington in 1992. A recovery plan was published in 1997 that outlined recovery strategies including developing and conducting standardized at-sea surveys. Along with federal and state researchers, Washington Department of Fish and Wildlife has participated in a program to estimate marbled murrelet population size and trends since 2000. This monitoring program uses at-sea line transects within 8 km of the Washington, Oregon, and northern California coastline in the area of the Northwest Forest Plan. There are five monitoring zones throughout this range, two of which are in Washington. Zone 1 includes the Strait of Juan de Fuca, Hood Canal and the San Juan Islands and is monitored by U.S. Forest Service. Washington Department of Fish and Wildlife has been responsible for monitoring the outer Washington coast (Zone 2). Within Zone 2 there are two geographic strata based on marbled murrelet density: Stratum 1 (north of Pt. Grenville – high density) and Stratum 2 (south of Pt. Grenville – low density). Each stratum is divided into primary sampling units (PSUs), which is a roughly rectangular area along approximately 20 km of coastline. In 2007, at-sea surveys began 15 May and ended 26 July, and PSUs were accessed from four ports along the Washington coast. By design, all PSUs in Stratum 1 were sampled three times, except that PSU 8 was sampled twice. All PSUs in Stratum 2 were sampled once. Only half of PSU 12, which is located at the mouth of Willapa Bay, was sampled due to sustained adverse wind and tide conditions. Because of the difficulty associated with sampling this PSU, the sampling area was reduced to exclude the mouth of Willapa Bay from our 2007 estimate and all past population estimates were also adjusted to account for the reduced area sampled. A second survey of PSU 9 and 11 was conducted to investigate late season marbled murrelet distribution and abundance.

In Zone 2, highest concentrations of marbled murrelets were observed in PSU 7 on 14 June ($n = 145$), which spans the region between Kalaloch and the Raft River. In previous years, PSU 6 located to the north near Destruction Island contained high counts of marbled murrelets: 2004 ($n = 215$), 2005 ($n = 90$), and 2006 ($n = 72$). There were no juvenile (Hatch Year) marbled murrelets observed in 2007; however, this study was designed to monitor breeding birds and not to estimate juvenile recruitment, which would require extending the sampling period into August.

The marbled murrelet population estimate for all zones in the Northwest Forest Plan area 2007 was 17,400 (95% confidence interval 12,800 – 21,909). The population estimate has ranged from 17,400 – 23,700 over the 8 years of monitoring. Trend analyses indicate that for the 2000-2007 period, the estimated annual rate of population change over the entire sample area was -2.2%, with 95% confidence interval of -5.6% to +1.3% ($P = 0.19$ for a downward trend). When all zones are combined, we have a 95% percent power of detecting a 5 percent annual change within a 9-year sampling period (Miller et al. 2006), but only 8 years of monitoring have been completed. For the Washington outer coast (Zone 2), density and population size estimates for 2007 suggest overall marbled murrelet density was slightly higher in 2007 than in the previous two years, but lower than 2002 – 2004 estimates. The population estimate for the Washington coast for 2007 was 2,525 birds (95% confidence interval = 1,271 - 3,811 birds). For the inland Washington waters (Zone 1), population size estimates have fluctuated over the sampling period and do not exhibit an increasing or decreasing trend. The population estimate for inland Washington waters for 2007 was 6,985 birds (95% confidence interval = 4,105 - 10,382 birds).

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Introduction

In 1992, the marbled murrelet was listed under the federal Endangered Species Act of 1973 as a Threatened species in California, Oregon and Washington. A recovery plan was published (U.S. Fish and Wildlife Service 1997) that outlined recovery strategies including developing and conducting standardized at-sea surveys. These surveys were viewed as important because they allow researchers to model population trends and because detecting changes in populations are critical to the evaluation of recovery actions and ultimately to the determination of recovery success or failure. In response to this recovery goal, the U.S. Fish and Wildlife Service, U.S. Forest Service and state wildlife agencies initiated a marbled murrelet monitoring strategy in 2000 (Raphael et al. 1999, 2004, 2007; Miller et al. 2006). The goal of this monitoring strategy is to estimate marbled murrelet population size and to detect changes in population size for the area between San Francisco and the Washington – Canada border. Results will be used to evaluate any USFWS incidental take criteria and to facilitate the Recovery Plan development and evaluation. In addition to meeting the requirements of the Endangered Species Act, long-term marbled murrelet monitoring is required to evaluate the effectiveness of the Northwest Forest Plan (Madsen et al. 1999). This plan is a large-scale ecosystem management plan for federal lands in the Pacific Northwest. The marbled murrelet was identified as a conservation and monitoring target for evaluating the effectiveness of this plan. Finally, monitoring data are also being used to evaluate the effectiveness of the Habitat Conservation Plan for Washington State forested lands managed by the Department of Natural Resources.

Since 2000, Washington Department of Fish and Wildlife along with researchers from the US Forest Service, US Fish and Wildlife Service, Crescent Coastal Research, and the University of California Berkeley have been estimating marbled murrelet population size and trends using at-sea line transects within 8 km of the Washington, Oregon, and northern California coastline. These transects cover ~8,800 km². This area of coastline has been subdivided into the five Marbled Murrelet Conservation Zones identified in the Marbled Murrelet Recovery Plan (Figure 1; US Fish and Wildlife Service 1997). Washington Department of Fish and Wildlife has been responsible for monitoring the outer Washington coast (Zone 2 - from the northwest tip of the state to the mouth of the Columbia River; Figure 2).

At-sea monitoring from 2000-2003 observed the highest densities of marbled murrelets along the Oregon and northernmost California coasts and lowest along the California coast from the Humboldt-Mendocino County line to just south of San Francisco Bay (Miller et al. 2006). The total population estimate for the portion of the U.S. Pacific coast south of the Canadian border, as shown in Figure 1, ranged from 18,500 (95% Confidence Interval 13,400-23,700) birds on any single day in 2000 to 23,600 (95% Confidence Interval 18,300-28,900) birds on any single day in 2002 (Miller et al. 2006). As reported in the Northwest Forest Plan—the first 10 years (1994-2003): status and trends of populations and nesting habitat for the marbled murrelet (Miller et al. 2006), a decrease in the size of the target population over the first four years of monitoring at the 5 percent significance level was not detected. However, when all zones are combined, we have a 95% percent power of detecting a 5 percent annual decrease within a 9-year sampling period (Miller et al. 2006), but only 8 years of monitoring have been completed indicating that at least one more year of sampling is required to have a high probability of detecting trends.

Here we summarize the methodology, sampling and results for the 2007 at-sea monitoring on Washington's outer coast (Cape Flattery to the south jetty of the Columbia River).

Methods

Sampling Design.

Marbled murrelets were monitored from mid-May through the end of July when the birds detected on the water are most likely resident birds. Conservation Zone 2 on the outer coast of Washington (Cape Flattery to the south jetty of the Columbia River) is divided into two geographic strata (Figure 2). Stratum 1 (north coast) extends from the northwest tip of Washington south to Point Grenville and Stratum 2 (south coast) extends from Point Grenville south to the south jetty of the Columbia River. In an effort to reduce variability in the population estimates, more sampling effort is devoted to Stratum 1 because the density of marbled murrelets is higher than in Stratum 2 (Thompson 1999).

The following is a detailed summary of the methodology used in Conservation Zone 2 and is consistent with the population monitoring methods developed by the Marbled Murrelet Effectiveness Monitoring program used throughout the Northwest Forest Plan area since 2000 (Raphael et al. 1999, 2004, 2007; Miller et al. 2006). Each stratum is divided into primary sampling units (PSUs), which is a roughly rectangular area of coastline about 20 km in length (Figure 3). The PSUs meet end to end without any gaps along shore. There are 8 PSUs in Stratum 1 and 6 PSUs in Stratum 2 (Figure 2). The width of the PSU (the distance between the nearshore and offshore boundaries) varies by stratum. Each PSU consists of two subunits, the nearshore and the offshore units (Figure 3). For Conservation Zone 2, the nearshore subunit starts at 350 m from shore and extends 1,500 m offshore to the “centerline”. The offshore subunit extends 3,500 m offshore from the “centerline” in Stratum 1 and 6,500 m offshore from the “centerline” in Stratum 2 (Figure 3). These widths for the nearshore and offshore units were used because most marbled murrelets occur within 1,500 meters from shore and at least 95% of marbled murrelets occur within 5,000 and 8,000 m from shore in Strata 1 and 2, respectively (Thompson 1997a, 1997b, 1999).

Parallel transects are used in the nearshore subunit and zigzag transects are used in the offshore subunit. Within the nearshore subunit, the length of the PSU (approximately 20 km) was divided into four segments that were approximately 5-km long and parallel to shore (Figure 3). The width of each subunit was divided into four bins parallel to shore and of equal size. One transect was randomly placed within each bin (without replacement) ensuring that transects were distributed spatially at different distances from shore (Figure 3). Within the bins, transect segments were selected in increments of 100-m distances from shore. Within the offshore subunit, a zigzag transect traversed the entire width of the subunit and a portion of the length of the PSU; in some cases the entire length of the PSU. The zigzag configuration sampled across the density gradient associated with distance from shore, while allowing less effort per area in this low marbled murrelet density subunit. The transect trajectory was determined from a random starting point. The length of the zigzag transect in each area was roughly calculated from a formula based on strata area and marbled murrelet densities (from previous data). See Miller et al. (2006) and Raphael et al. (2007) for further details.

Observer Training.

In 2007, two of three observers were new to the program. New observers had prior at-sea seabird identification experience. This was the fifth season for the boat operator. The crew consisted of one dedicated boat operator and three observers/data recorders. The data recorder and two observers (one responsible for each side of the boat) switched duties at the beginning of each PSU. Observers had one week of training that consisted of office and on-water training. Office training included a presentation of

background information, survey design and protocols, sampling methodology, line transect distance sampling methodology, and measurement quality objectives. On-water training included boat safety orientation, seabird identification, in particular training on correctly assigning marbled murrelet plumages (Strong 1998), practice transects, and distance estimation testing using laser rangefinders. Boat safety training included instructions and reminders for weather and sea condition assessment, use of the radio, boat handling, proper boat maintenance, safety gear, rescue techniques, and emergency procedures. Washington Department of Fish and Wildlife observer training was designed to be consistent with training conducted by USFWS and other groups within the Marbled Murrelet Effectiveness Monitoring program (Raphael et al. 2007, Huff et al. 2003, Mack et al. 2003).

During practice transects, observers were taught how to scan, where to focus their eyes, and which portions of the scan area are most critical. Distance estimates from the transect line are a critical part of the data collected and substantial time was spent practicing and visually 'calibrating' before surveys began, followed by quality assurance tests. During distance trials, each individual's direct estimate of perpendicular distance was compared to a perpendicular distance recorded with a laser rangefinder. These trials were conducted using stationary buoys as targets, which were selected at a range of distances from the transect line and in locations in front of as well as to the sides of the boat where marbled murrelets would be encountered on real surveys (see Raphael et al. 2007 for details). Each Washington Department of Fish and Wildlife observer completed 100 distance estimates during pre-survey training.

Quality assurance tests were repeated weekly throughout the entire survey period where each observer was tested on their ability to accurately estimate distances. Observers made a set of five estimates of perpendicular distance to five targets and the actual perpendicular distance was measured with a laser rangefinder. After the first set of five, the observer's results were assessed. If all five estimates were within 15% of the actual distance, the trial was complete for that observer. If any of the five estimates were not within 15% of actual, the observer continued to conduct estimates in sets of five until all five distances were within 15% of the actual distance. In addition, one of the project leads accompanied the survey crew and observed their overall performance and ability to detect marbled murrelets three times during the survey season and completed an audit form created by the Murrelet Monitoring Program (Raphael et al. 2007, Huff et al. 2003). The results of the audit were shared with the observers after the survey day was completed for feedback and discussion.

Observer Methods.

Two observers scanned from 0° off the bow to 90° abeam of the vessel. More effort was expended watching for marbled murrelets close to the transect line ahead of the boat (within 45° of line). Observers scanned continuously, not staring in one direction, with a complete scan taking about 4-8 seconds. Observers were instructed to scan far ahead of the boat for birds that flush in response to the boat and communicate between observers to minimize missed detections. Binoculars were used for species verification, but not for sighting birds. Observers relayed data via headsets to a person in the boat cabin who entered data directly onto a laptop computer with software that is interfaced with a GPS unit, which collects real time location data (detailed below). Consistent with previous years, survey speed was maintained at 8-12 knots, and survey effort was ended if glare obstructed the view of the observers, or if Beaufort wind scale was 3 or greater. Beaufort 3 is described as a gentle breeze, 7-10 knot winds, creating large wavelets, crests beginning to break, and scattered whitecaps.

Equipment.

As in previous years, the survey platform was the 26' Almar with a twin-outboard engines, *Research 4*. Data were collected during at-sea surveys using a windows based software program called DLOG2 (for 'datalog', developed by R.G. Ford, Inc., Portland, OR.) loaded onto a laptop computer. DLOG2 interfaces with a GPS and GIS overlays of the Washington shoreline and adjacent bathymetry, and uses these data to record GPS coordinates and perpendicular distance to shore at operator-defined time intervals (e.g. every 30 seconds). Transect survey length was calculated from the GPS trackline recorded in DLOG2. Additional data such as weather and sea conditions, on/off effort, and names of observers were recorded manually in DLOG2. One of the survey crew manually entered bird observation data including: species, number of birds, estimated perpendicular distance of the bird(s) from the trackline of the boat at first detection regardless of distance from the line, and behavior (flying, on water, flushed, etc.) in real time into the laptop as relayed from both the port and starboard observers through audio-headphones. In addition to these data, for each marbled murrelet sighting the following data were collected: group size (a collection of birds separated by less than or equal to 2 m at first detection and moving together, or if greater than 2 m the birds are exhibiting behavior reflective of birds together), plumage class (Strong 1998), and water depth (from boat depth finder). The DLOG2 program interfaces with a thermosalinograph, which was installed on *Research 4* to collect water parameter data (temperature and conductivity). Unfortunately, we were unable to collect these data during the 2007 season because of software incompatibility issues.

Survey Effort

At-sea surveys began 15 May and ended 26 July. PSUs were accessed from four ports along the Washington coast: Neah Bay (PSUs 1-3), La Push (PSUs 4-7), Westport (PSUs 8-11), and Ilwaco (PSUs 12-14). The survey schedule was established prior to the start of the season in the following manner: the sampling period was divided into three 18-day periods (excluding weekends and 2 holidays) to avoid clustered sampling and to ensure that PSUs were selected randomly without replacement and distributed evenly over the field season.

PSUs in Stratum 1 were sampled three times. To sample Stratum 1 (PSUs 1-8), a port (Neah Bay or LaPush) was randomly selected during each 18-day period. From the selected port, the PSU to be completed each day was randomly selected. Within each PSU, a coin flip determined whether to conduct the nearshore or offshore segment of the PSU first. After all PSUs were completed from that port, the same protocol of random selection of PSUs was completed from the other port.

PSUs in Stratum 2 were sampled once. To sample Stratum 2 (PSUs 9-14), a port (Westport or Ilwaco) was randomly selected and two PSUs were surveyed during each 18-day period. Within each PSU, a coin flip determined whether to conduct the nearshore or offshore segment of the PSU first.

Results

In 2007, three replicates of all PSUs in Stratum 1 were sampled, except only two replicates were completed in PSU 8. All PSUs in Stratum 2 were sampled once and two replicates were made of PSU 9 and 11. Weather (wind and swell) and tide precluded a complete survey of PSU 12 located along the mouth of Willapa Bay as a result, only segments C and D were surveyed. This has been a problematic PSU for the past three years. The monitoring program decided to reduce the PSU area by removing segments A and B to account for the area that is difficult to navigate at the mouth of Willapa Bay and requires nearly perfect conditions (high tide, Beaufort 0-1 and low swell). All past population estimates were also adjusted to remove this area, which had very little effect on the overall population estimate for the zone. Elsewhere, throughout the 11-week season, poor weather and rough seas precluded surveying on only three days.

Along the outer coast of Washington, physical features of the shoreline influenced navigation. In some instances, these physical features were permanent obstructions such as submerged groups of rocks or larger rocky islands (e.g. Cape Alava, Tatoosh Island). In other cases, these features were less permanent such as kelp beds. Tidal fluctuations and swell height causing waves to break also affected navigation. For Conservation Zone 2, the nearshore boundary was 350 m. In 2007, the innermost subunit (e.g. 350 or 450 m) had to be moved further from shore in order to be completed for seven subunits in Stratum 1 and five subunits in Stratum 2. In these cases, the subunit was moved out from shore in 100 m increments until 75% or greater of the transect line could be surveyed. The reason for moving the subunit and the new distance from shore was documented. The crew made every effort to follow the predetermined random schedule of nearshore and offshore surveys, but there were five instances where the survey order had to be switched due to tide or swell height.

Data Analysis

Group size and perpendicular distance data were compiled for each marbled murrelet (or group of murrelets) observation and were sent to US Forest Service statistician Jim Baldwin for analysis. Jim Baldwin used the program DISTANCE and SAS to calculate densities and 95% confidence intervals (CI) as described in Miller et al. 2006 and Raphael et al. 2007 (Table 1, Figure 4).

Population Estimates and Trends – Washington Coast (Zone 2)

Overall, marbled murrelet density was slightly lower in 2007 than in the previous two years (Table 1, Figure 4). In 2007, marbled murrelet density was higher in Stratum 1 and lower in Stratum 2 than 2006 and similar to 2005 estimates. Results from 2000-2007 do not indicate that the at-sea breeding murrelet population in Zone 2 is decreasing, but additional years of sampling are needed before we will have adequate power to detect a decline should one occur (Miller et al. 2006, Tables 3-9 a, b) (Zone 2; Figure 4). The 2007 population estimate for the Washington coast was 2,525 birds (95% confidence interval = 1,271 - 3,811 birds, Table 1).

As in all previous years, higher densities of marbled murrelets were observed in Stratum 1 than Stratum 2 (Tables 1 and 2). The highest concentrations of marbled murrelets were observed in PSU 7, which is located just south of Destruction Island and spans the coastline from Kalaloch south to the Raft River. PSU 6 and PSU 7 have contained the highest counts of marbled murrelets (2004-2007) with numbers as high as 215 in PSU 6 during a single survey in 2004 (Table 3). The high count from 2007 was 145 birds in PSU 7 (Tables 2-3).

In general, higher numbers of marbled murrelets were observed in nearshore segments in Stratum 1 (PSU 1-8), although offshore observations are higher in PSU 6 and 8 (Figure 5, Table 2). In Stratum 2, numbers of marbled murrelets are lower and distribution between nearshore and offshore are more variable. Transect lengths in nearshore segments are shorter (approximately 19 km) than the offshore segments (approximately 27 km). Although we discuss trends at the PSU level here, it should be noted that this monitoring scheme was designed to detect changes in murrelet population density at the zone level and not at the PSU level.

Murrelets were observed in all PSU surveys (Table 2). There were no juvenile (Hatch Year) marbled murrelets observed in any PSU during the season, but this monitoring scheme was not designed to track juvenile recruitment.

Population Estimates and Trends – Puget Sound and Strait of Juan de Fuca (Zone 1)

In Zone 1, there was no detectable decrease in the at-sea breeding murrelet population over 8 years of monitoring (2000-2007; Figure 6), but additional years of sampling are required before we will have high power to detect a trend should one occur (Tables 3-9a & b in Miller et al. 2006). The population estimate for Zone 1 for 2007 was 6,985 birds (95% confidence interval = 4,105 - 10,382 birds).

Population Estimates and Trends – All zones combined

Trend analyses indicate that for the 2000-2007 period, the estimated annual rate of population change over the entire sample area was -2.2%, with 95% confidence interval of -5.6% to +1.3% ($P = 0.19$ for a downward trend) (Figure 7). When all zones are combined, we have 95% percent power of detecting a 5 percent annual decrease within a 9-year sampling period (Miller et al. 2006), but only 8 years of monitoring have been completed. Consequently, power analyses indicate that an additional year of monitoring is needed to detect a population change with high confidence. However, there appears to be a significant population decline over the last six years of the study indicating a need to continue to monitor population trends.

Figure 1. Marbled Murrelet Recovery Plan Conservation Zones (from Raphael et al. 2007).

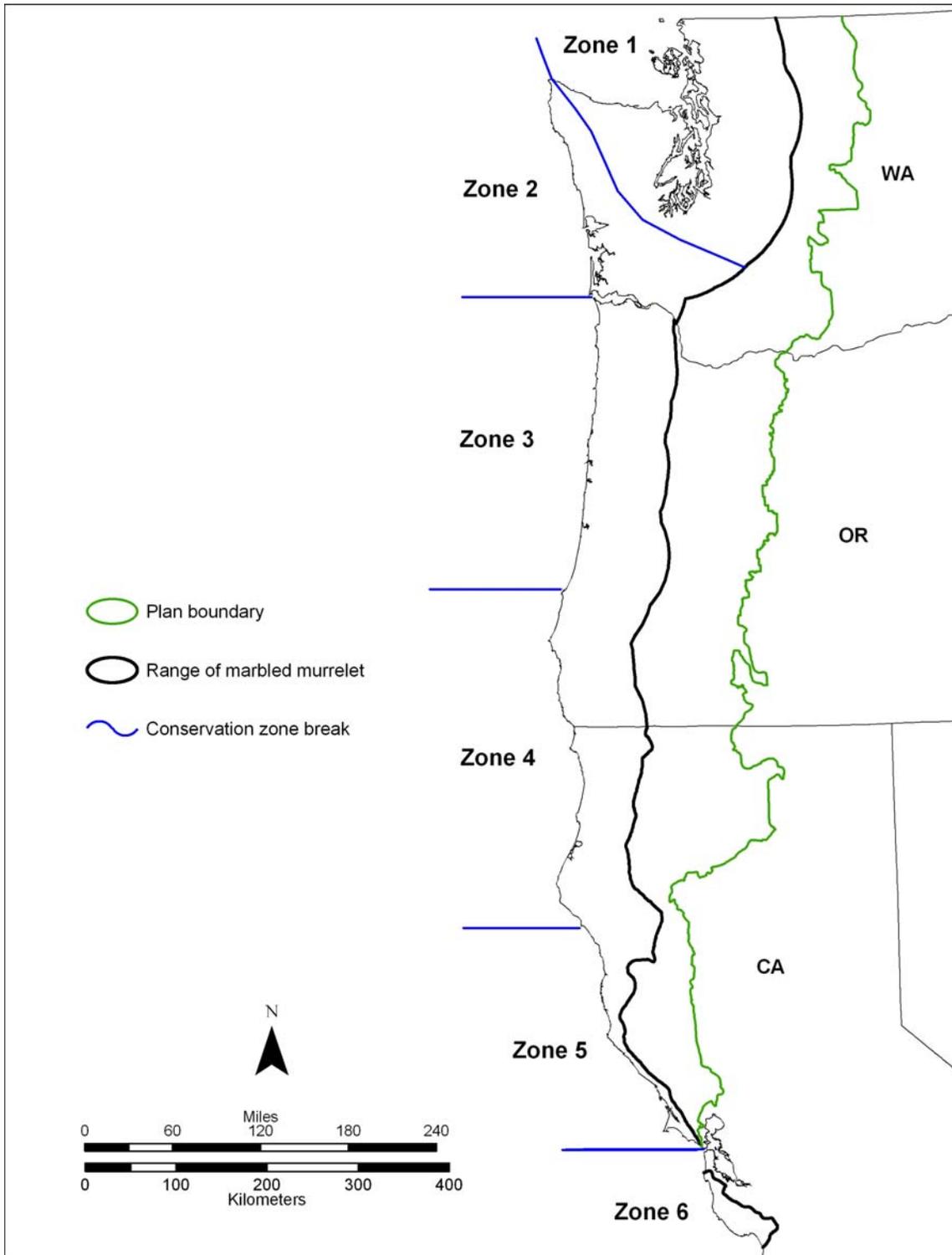


Figure 2. Stratum 1 and 2 along the outer coast of Washington and 14 PSUs in Conservation Zone 2 (from Huff 2006).

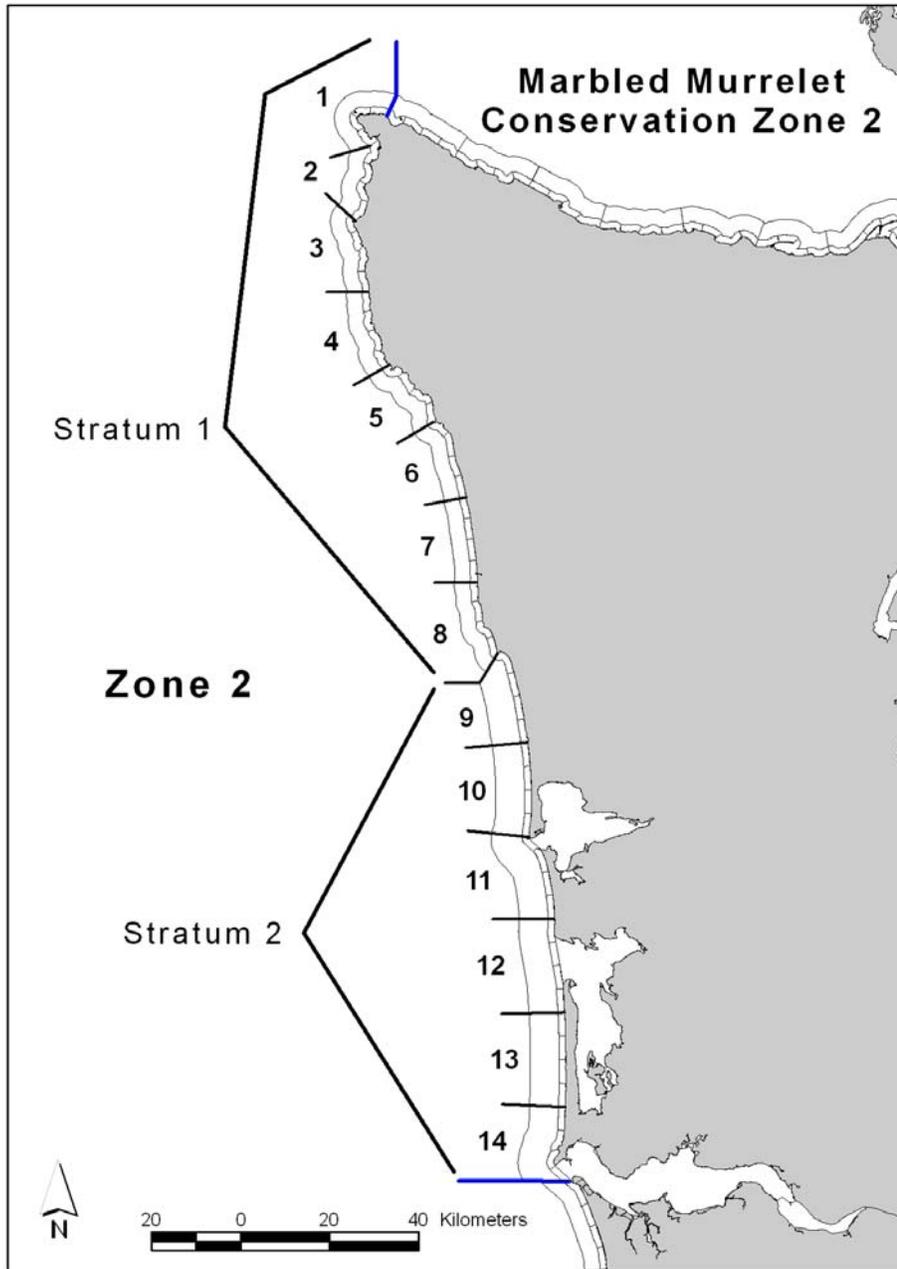


Figure 3. Marbled Murrelet monitoring primary sampling unit (PSU) illustrating nearshore and offshore subunits and 1500 m centerline. The nearshore unit is divided into four equal-length segments (about 5 km each) and four equal-width bins (bands parallel to and at increasing distances from the shore). One bin is selected (without replacement) for each segment of transect (from Raphael et al. 2007).

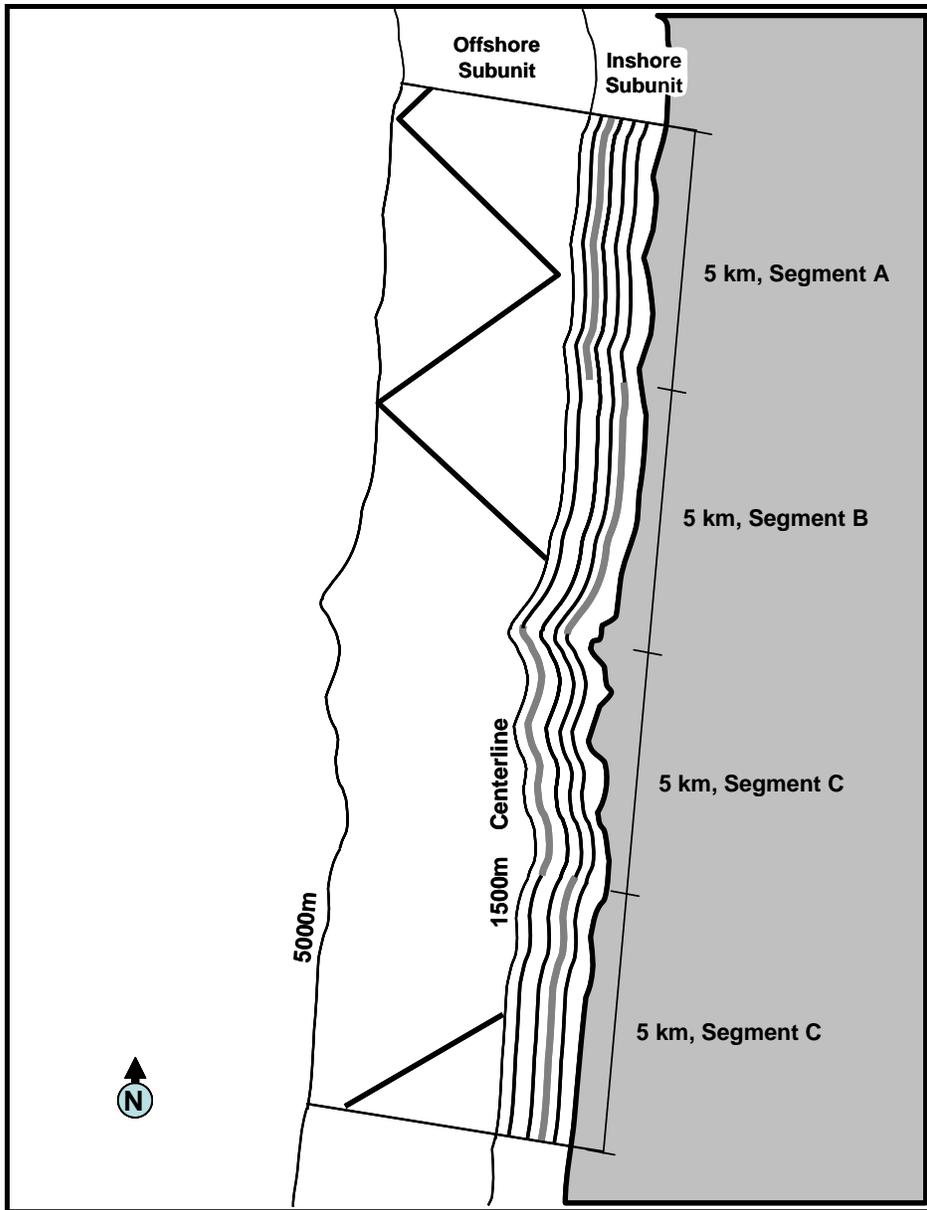


Figure 4. 2000-2007 Marbled Murrelet population densities (± 2 SE) for the Washington coast (Zone 2) and for the northern (Stratum 1) and southern (Stratum 2) portions of Zone 2.

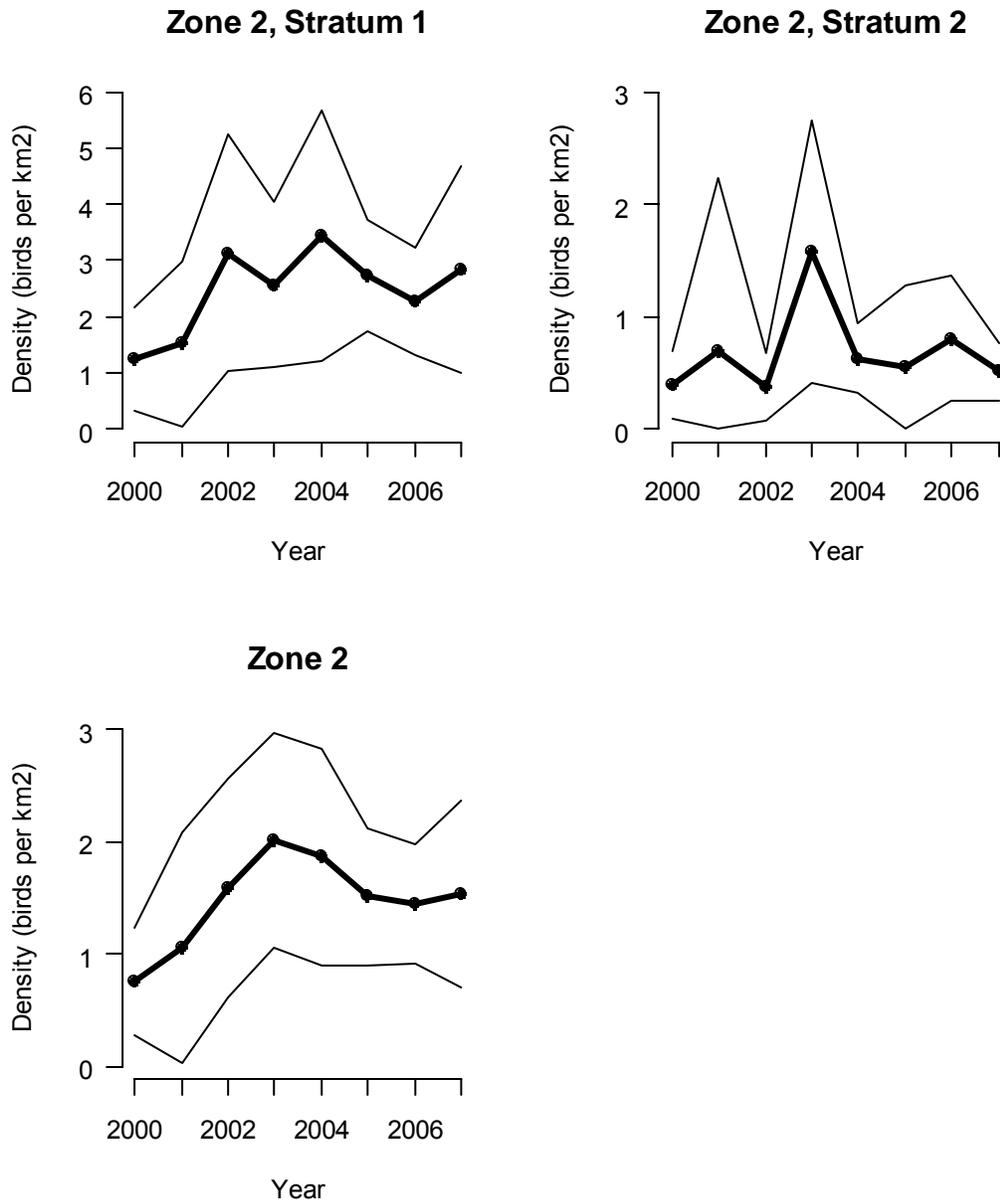


Figure 5. Mean number of marbled murrelets for the Washington coast (Zone 2) in nearshore and offshore segments by PSU in 2007.

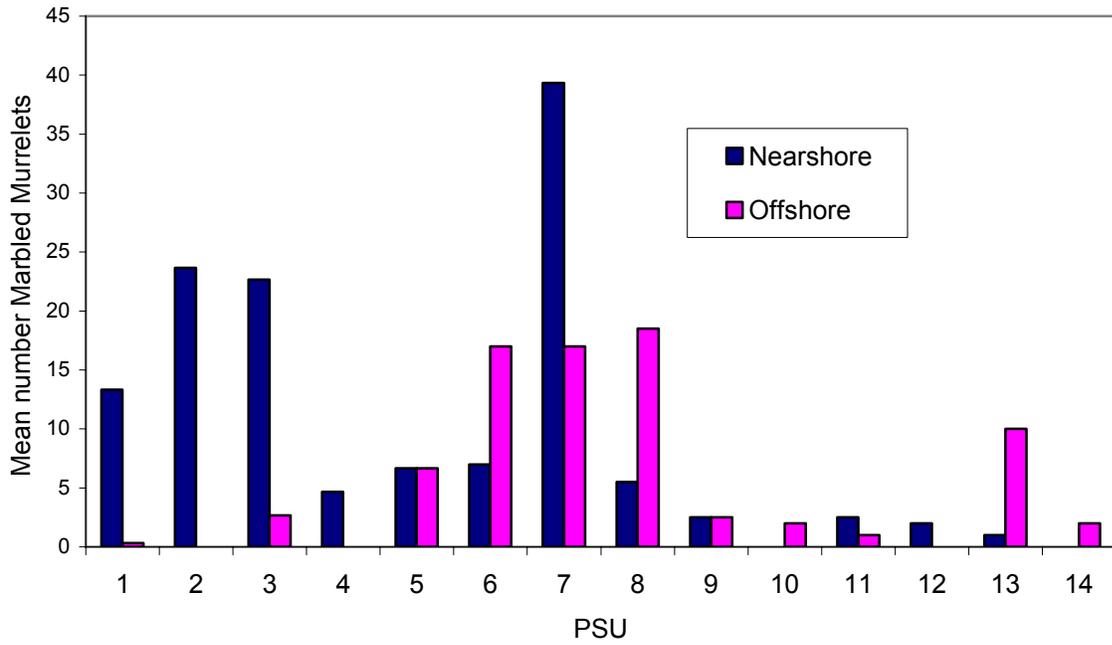


Figure 6. 2000-2007 Marbled Murrelet population densities (± 2 SE) for the inland waters of Washington (Zone 1).

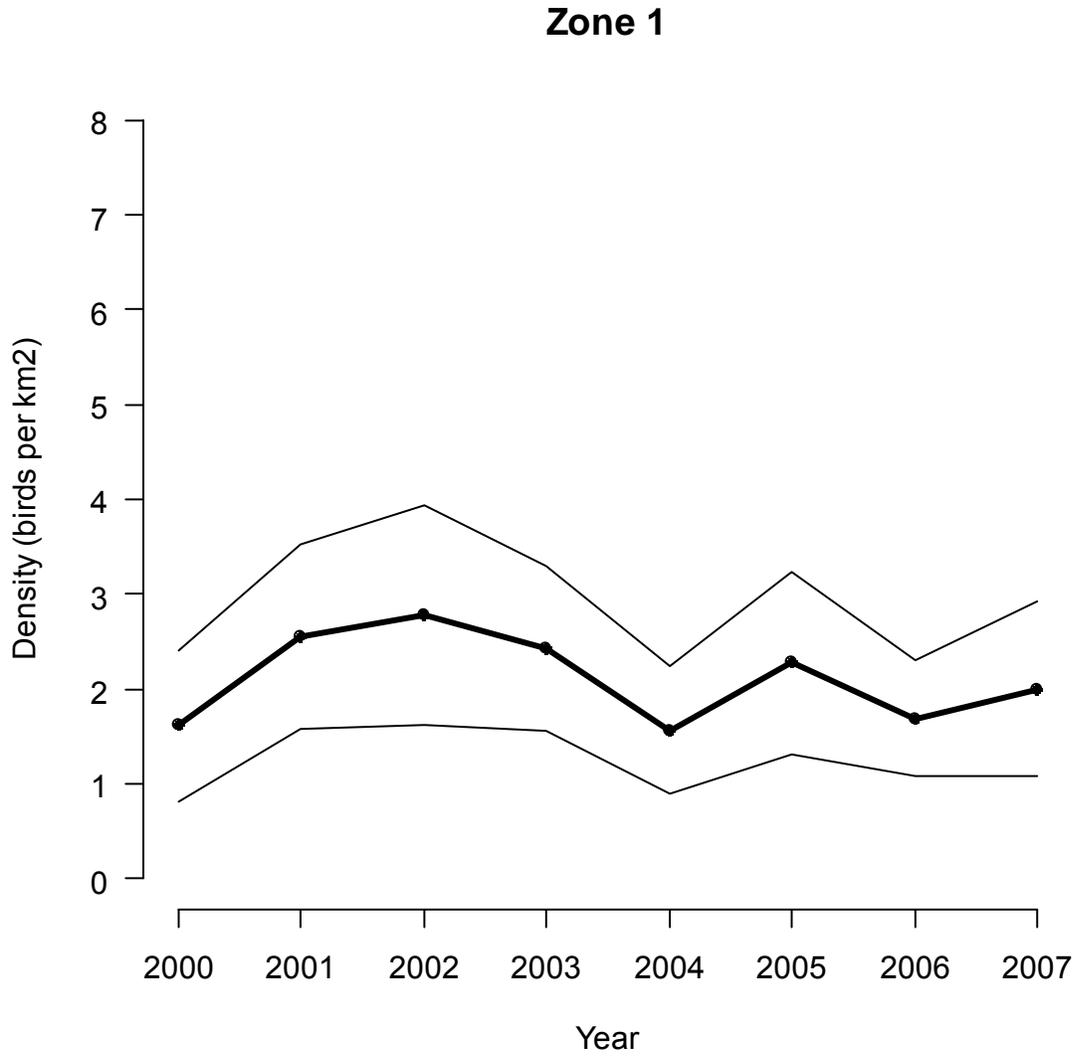


Figure 7. 2000-2007 Marbled Murrelet population estimates for Conservation Zones 1-5 and the sum of all zones. Zone 5 was not sampled in 2006.

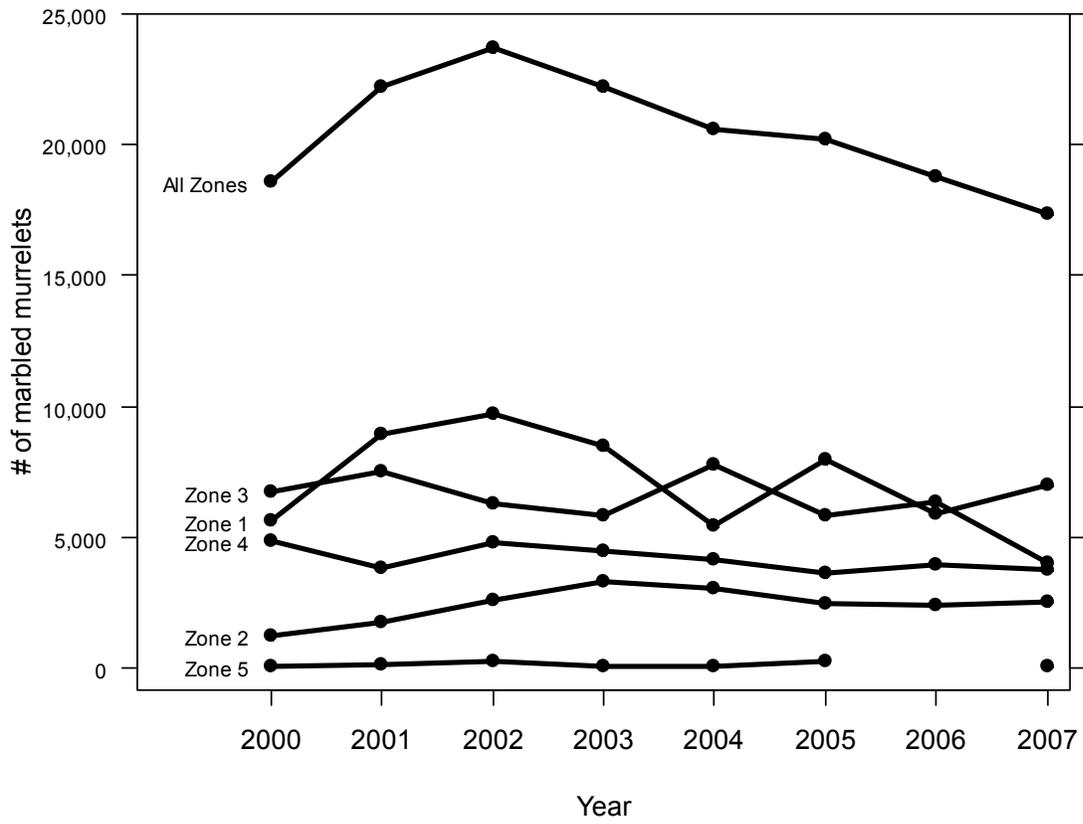


Table 1. Marbled Murrelet population size, density estimates, and associated variance for Zone 2 during 2000-2007 breeding seasons. The overall Zone 2 summary for each year is provided under Stratum = "0".

Year	Zone	Stratum	Density	StdErr	% Std. Err.	Birds	Birds 95% CL Lower	Birds 95% CL Upper	Area (km^2)
2000	2	1	1.2287	0.4592	37.4%	890	422	1,712	724.470
2000	2	2	0.3903	0.1525	39.1%	361	190	713	925.934
2000	2	0	0.7583	0.2394	31.6%	1,252	727	2,228	1,650.404
2001	2	1	1.5059	0.7368	48.9%	1,091	186	2,254	724.470
2001	2	2	0.6987	0.7697	110.2%	647	104	2,449	925.934
2001	2	0	1.0531	0.5164	49.0%	1,738	575	3,888	1,650.404
2002	2	1	3.1313	1.0485	33.5%	2,269	397	3,471	724.470
2002	2	2	0.3790	0.1511	39.9%	351	0	542	925.934
2002	2	0	1.5871	0.4850	30.6%	2,619	565	3,784	1,650.404
2003	2	1	2.5615	0.7374	28.8%	1,856	1,073	3,168	724.470
2003	2	2	1.5744	0.5839	37.1%	1,458	521	2,355	925.934
2003	2	0	2.0077	0.4800	23.9%	3,314	1,959	5,039	1,650.404
2004	2	1	3.4367	1.1146	32.4%	2,490	1,236	4,000	724.470
2004	2	2	0.6281	0.1570	25.0%	582	330	864	925.934
2004	2	0	1.8610	0.4822	25.9%	3,071	1,742	4,596	1,650.404
2005	2	1	2.7283	0.4965	18.2%	1,977	1,212	2,641	724.470
2005	2	2	0.5568	0.3579	64.3%	516	146	1,552	925.934
2005	2	0	1.5100	0.3069	20.3%	2,492	1,629	3,642	1,650.404
2006	2	1	2.2608	0.4774	21.1%	1,638	1,009	2,413	724.470
2006	2	2	0.8025	0.2782	34.7%	743	364	1,355	925.934
2006	2	0	1.4426	0.2641	18.3%	2,381	1,672	3,430	1650.404
2007	2	1	2.8383	0.9187	32.4%	2,056	885	3,341	724.470
2007	2	2	0.5064	0.1309	25.8%	469	240	664	925.934
2007	2	0	1.5300	0.4123	26.9%	2,525	1,271	3,811	1,650.404

Table 2. Number of Marbled Murrelets (MaMu) in the nearshore (N) and offshore (O) subunits and distance surveyed (km) in each PSU during the 2007 survey season in Zone 2. Segments A and B of PSU 12 not surveyed.

Date	PSU	Replicate	N (km)	MaMu N	O (km)	MaMu O	Total (km)	MaMu Total
05/15/07	4	1	17.84	2	23.72	0	41.55	2
05/15/07	6	1	18.88	8	23.94	4	42.83	12
05/16/07	5	1	16.65	15	23.76	8	40.41	23
05/17/07	7	1	19.59	2	23.63	2	43.21	4
05/23/07	8	1	18.85	5	31.01	16	49.85	21
05/24/07	9	1	21.80	2	30.08	3	51.88	5
05/25/07	11	1	19.19	2	37.52	2	56.71	4
05/29/07	10	1	21.80	0	38.04	2	59.84	2
05/30/07	12	1	9.41	2	30.91	0	40.32	2
05/31/07	3	1	17.88	4	22.41	6	40.29	10
06/05/07	2	1	22.10	28	24.07	0	46.17	28
06/06/07	1	1	18.37	8	23.91	1	42.28	9
06/08/07	4	2	18.70	5	23.60	0	42.30	5
06/12/07	6	2	19.66	8	23.77	31	43.43	39
06/13/07	5	2	20.85	1	23.76	1	44.61	2
06/14/07	7	2	19.65	110	23.68	35	43.32	145
06/19/07	2	2	21.08	19	23.57	0	44.65	19
06/19/07	3	2	18.55	17	22.90	0	41.45	17
06/20/07	1	2	17.73	11	23.78	0	41.51	11
06/26/07	13	1	21.56	1	37.94	10	59.50	11
06/27/07	14	1	19.33	0	38.22	2	57.54	2
07/10/07	4	3	19.33	7	23.73	0	43.05	7
07/11/04	5	3	19.71	4	23.45	11	43.16	15
07/11/07	6	3	19.12	5	23.25	16	42.37	21
07/12/07	7	3	19.53	6	27.67	14	47.20	20
07/13/07	3	3	18.82	47	22.96	2	41.78	49
07/17/07	1	3	18.27	21	23.36	0	41.63	21
07/17/07	2	3	20.16	24	23.07	0	43.23	24
07/23/07	8	2	19.03	6	23.74	21	42.77	27
07/25/07	11	2	20.15	3	32.34	0	52.49	3
07/26/07	9	2	21.73	3	36.13	2	57.86	5

Table 3. Number of Marbled Murrelets observed by PSU and replicate during 2004-2007 seasons in Zone 2. Segments A and B of PSU 12 not surveyed in 2007.

Stratum	PSU	2004			2005			2006			2007		
		Replicate			Replicate			Replicate			Replicate		
		1	2	3	1	2	3	1	2	3	1	2	3
1	1	8	26	14	18	14	8	4	1	1	9	11	21
	2	17	6	7	28	5		21	0	22	28	19	24
	3	30	22	6	18	17		5	11	9	10	17	49
	4	2	5	7	3	15	1	34	4	13	2	5	7
	5	25	44	11	18	18	12	17	8	12	23	2	15
	6	112	215	23	40	48	90	36	72	48	12	39	21
	7	38	42	26	65	30		23	22	2	4	145	20
	8	19	37	1	11	24	26	3	27	8	21	27	
2	9	18			9			16			5	5	
	10	3			23			6			2		
	11	5			0			9			4	3	
	12	1									2		
	13	5			5			0			11		
	14	4			0			4			2		

Literature Cited

- Huff, M. H. 2006. Introduction to effectiveness monitoring of the Northwest Forest Plan for Marbled Murrelets. Pages 1-8 in Huff, M.; Raphael, M.G.; Miller, S.L.; Nelson, S.K.; Baldwin, J.; tech. coords. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of populations and nesting habitat for the Marbled Murrelet. Gen. Tech. Rep. PNW-GTR-650. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: PNW-GTR-650.
- Huff, M.H., C.J. Ralph, S. Miller, M. Raphael, C. Thompson, C. Strong, J. Baldwin, T. Max, and R. Young. 2003 *draft*. Quality Assurance Project Plan, Marbled Murrelet Long-term Population Monitoring, Marbled Murrelet Module, NWFP Interagency Regional Monitoring.
- Mack, D.E., M.G. Raphael, R.J. Wilk. 2003. Protocol for monitoring Marbled Murrelets from boats in Washington's inland waters. USDA Forest Service Pacific Northwest Research Station, Olympia Forestry Sciences Laboratory, Olympia, WA.
- 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. USDA Forest Service General Technical Report PNW-GTR-439. Pacific Northwest Research Station, Portland, OR.
- Miller, S.L.; Ralph, C.J.; Raphael, M.G.; Strong, G.; Thompson, C.; Baldwin, J.; Huff, M.H. 2006. At-sea monitoring of Marbled Murrelet population status and trend in the Northwest Plan area. Pages 31-60 *in*: Huff, M.; Raphael, M.G.; Miller, S.L.; Nelson, S.K.; Baldwin, J.; tech. coords. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of populations and nesting habitat for the Marbled Murrelet. Gen. Tech. Rep. PNW-GTR-650. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: PNW-GTR-650.
- Raphael, M.G., D. Evans Mack, and R.J. Wilk. 1999. Sampling Marbled Murrelets at sea: tests of survey methods and designs. Draft Report, February 17, 1999.
- Raphael, M.G., J. Baldwin, G.A. Falxa, M.H. Huff, M.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.
- Strong, C. S. 1998. Techniques for Marbled Murrelet age determination in the field. *Pacific Seabirds* 25(1): 6-8.
- Thompson, C.W. 1997a. Distribution and abundance of Marbled Murrelets and Common Murres on the outer coast of Washington. 1997 completion report to the *Tenyo Maru* Trustees Council. Unpubl. Report, Washington Dept. of Fish and Wildlife, Mill Creek, WA.
- Thompson, C.W. 1997b. Distribution and abundance of Marbled Murrelets on the outer coast of Washington. Winter 1996-1997. Unpubl. Report for the Washington Dept. of Natural Resources.
- Thompson, C.W. 1999. Distribution and abundance of Marbled Murrelets and Common Murres on the outer coast of Washington, Summer 1997 through winter 1998-1999. Unpubl. Report for Washington Dept. of Fish and Wildlife, Mill Creek, WA.
- U.S. Fish and Wildlife Service. 1997. Recovery Plan for the Threatened Marbled Murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Portland, Oregon. 203 pp.