MARBLED MURRELET ABUNDANCE AND REPRODUCTIVE INDICES IN OREGON DURING 2003

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By

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SUMMARY

Marbled Murrelets and other seabirds were surveyed using vessel transects throughout the coastal waters of Oregon in June, July, and August 2003. This is the fourth year that the Northwest Forest Plan Effectiveness Monitoring sampling design has been used, and the 12th since surveys began on the Oregon coast. In June and July 35 Primary Sampling Units (PSU) were surveyed, comprising 1410 km of transects, and those data were used to estimate population size. In Late July and August 255 km of additional transects were used to estimate relative productivity of murrelets.

The Zone 3 population estimate in 2002 was of 5,960 and 5,856 birds using strip and line transect analysis, respectively. The estimates were similar to the 2000 and 2001 estimates. Estimates for the Oregon portion of Zone 4 were 1,987 and 2,652 birds by strip and line methods, respectively, giving statewide estimates of 7,947 to 8,508 birds. This was similar to the past 3 years.

The state average index of productivity was of 6.16 % of birds aged as hatch-year fledglings in 2003. Indices of productivity were similar to the past 3 years, and higher than the long-term average. This corresponds with the continuing cool water oceanographic regime, and, combined with the population estimates, may represent some stabilization of the population.

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DISCLAIMER

The analysis and interpretation of data presented in this report are the product of Crescent Coastal Research and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

INTRODUCTION

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small diving seabird of the Alcid family which is on the Federally Threatened Species list, and is state listed as endangered or threatened in California, Oregon, and Washington (Nelson, 1997). Because their nests are dispersed and difficult to locate high in trees of mature coastal forests, most research on overall abundance and reproductive output is conducted at sea, where the birds are concentrated within a few km of shore on the open coast (Ralph and Miller 1995, Strong et al.1995, Becker et al. 1997). Standardized boat transects to survey murrelets in the nearshore waters of the Oregon coast from 1992 to 1999 produced evidence of a decline in numbers through this period (Strong 2003). In 2000 a new sampling design to monitor the murrelet population was initiated for all researchers in the Northwest Forest Plan area by the At-Sea Working Group under the Effectiveness Monitoring (EM) component of the Northwest Forest Plan (Madsen et al. 1999, Bentivoglio et al. 2002). This report summarizes population estimation and productivity indices obtained in the 2003 season and compares these data with earlier research in Oregon. The entirety of Marbled Murrelet Conservation Zone 3 (Columbia River to Coos Bay) and the Oregon portion of Zone 4 are included (see Fig. 1).

METHODS

Equipment

Vessel surveys were made from a 7 m boat equipped with marine radio, compass, Global Positioning System receiver (GPS), and digital sonar depth finder, which also relayed sea surface temperature. Other equipment included binoculars, digital watches, and micro tape recorders for each person, maps covering planned transect lines, and a lazer range finder. The deck of the boat is about level with the waterline; so standing observer viewing height was about 2 m above water. The GPS was loaded with the randomly selected transect routes prior to each survey.

Observation Protocol and Personnel Duties

Two observers and a vessel driver were on board for all transects. Each observer scanned a 90° arc between the bow and the beam continuously, only using binoculars to confirm identification or to observe plumage or behavior of murrelets. Search effort was directed primarily towards the bow quarters and within 50 m of the vessel, so that densities based on line and narrow strip transects will be at their most accurate (Buckland et al. 1993). All seabirds within 50 m of the boat and on the water were recorded, and all Marbled Murrelets sighted at any distance were recorded with the following information:

A) Time of sighting to the minute.
B) Group size; a group being defined as birds within a few m of each other or vocalizing to one another.
C) Side of vessel, categorized as port, bow, and starboard.
D) Estimated perpendicular distance from the transect line to each murrelet detection.
D) Behavior in one of 5 categories: fly in apparent response to the vessel, flying by in transit,

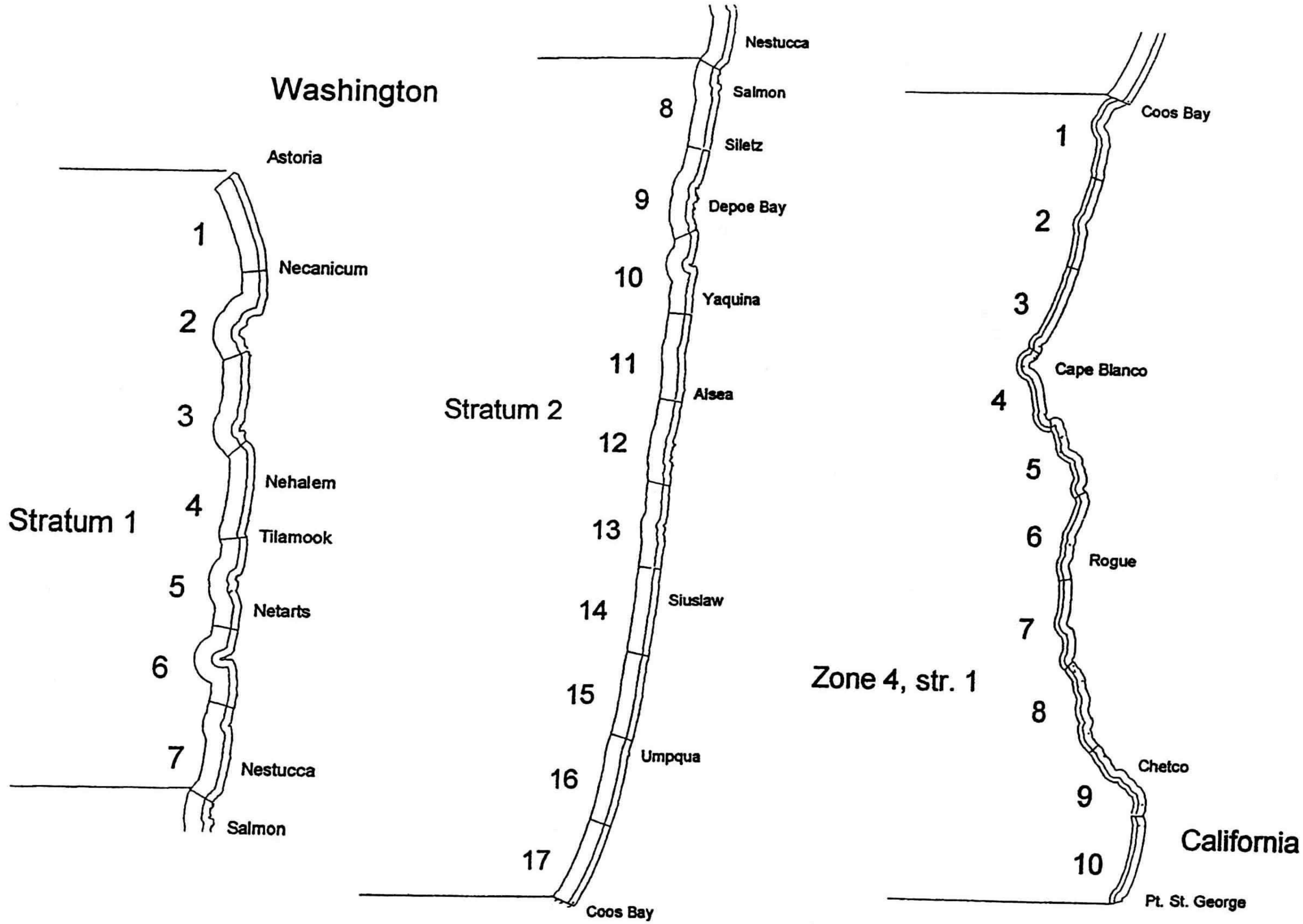

Figure 1. Primary sampling units (numbered) of the Northwest Forest Plan Marbled Murrelet population monitoring program in Oregon. Shown are the two strata of Conservation Zone 3 and the Oregon portion of stratum 1 of Conservation Zone 4.

dive in possible response to the vessel, diving not in response to the vessel (forage diving), and stay on the surface during vessel passage.

E) Molt class and age, and noteworthy behavior such as fish carrying, vocalizing, or unusual flight or diving behavior.

Distance estimates were calibrated by using a radar rangefinder on floating targets within the launch port on each morning. All observers would estimate distance to 5 or more chosen targets, and then one would use the rangefinder and record the actual distance when perpendicular to the target, and observers would adjust their calibration if necessary. If observers were consistently off the mark, we would continue until correct estimates were obtained (see Appendix A for results of this exercise).

Association with other species or water characteristics (ie; current zones, scattering layers, kelp) were also recorded. All data were recorded on cassette tapes and later transcribed to forms and entered on computer. At the beginning and end of each transect segment the time, location, water temperature and depth, weather and observing conditions were recorded. Observing conditions as they related to murrelet detectibility were rated excellent, very good, good, fair, and poor corresponding approximately with beaufort sea states of 0 to 4, respectively.

The vessel driver maintained a speed of 10 knots, monitored the transect route, and watched for navigational hazards. The driver participated in searching for murrelets when not otherwise occupied. Transects were paused sometimes to rest, make observations, or for equipment reasons, and resumed at the same approximate location where they left off. A break from duties was taken at least every 3 hours. This protocol is as has been used since 1996, with minor variations in earlier years.

Population Monitoring

A thorough description of the EM Plan population monitoring program can be found in Bentivoglio (2002) at *www.reo.gov./monitoring/murrelet*. An overview as it applies to Marbled Murrelet Conservation Zone 3 and the Oregon portion of Zone 4 follows.

The time period designated for monitoring the population of murrelets was selected between 20 May and 31 July, on the basis that most breeding murrelets will be associated with nesting habitats during the incubation and nestling stages in this time (Hamer and Nelson 1995). Surveys during the final 10 days of July were used for both population and productivity assessment.

Transects were conducted within 20 km long Primary Sampling Units (PSU) arranged in a contiguous format along the coast (Fig. 1). The 20 km length was selected as a distance which can be surveyed in the morning hours before seasonal afternoon winds become strong. If wind remained light, then two PSU were sampled in a day. A goal of at least 30 PSU samples within each Conservation Zone has been set as an estimate of that needed to make an inference about population size with relatively low variance, and what can be accomplished within time and budget limitations. Within Conservation Zones, strata were established to concentrate effort in regions that had higher murrelet abundance in prior years, to minimize variance in these more important areas. Two strata were distinguished within Conservation Zone 3 for this purpose: a northern stratum from the Columbia River to Cascade Head (140 km, 7 PSU with 10 samples designated), and a southern stratum, from Cascade Head to Coos Bay (200 km, 10 PSU with 20 samples designated, see Fig. 1). In Conservation Zone 4 the Oregon coast extends for approximately 180 km, including 9 PSU, and 10 samples were to be completed there. Zone 3 strata 1 and 2, and Zone 4 PSU's 1-9 correspond exactly with north, central, and southern regions used in 1992-1999 surveys. Surveys in Conservation Zone 4 were conducted cooperatively with the USFS Redwood Sciences Laboratories (RSL).

Primary Sampling Units were surveyed in spatial and temporal clusters, in which the boat was stationed at one or two adjacent ports where 1 to 5 PSU were sampled over 1-3 days. The clusters were distributed through the season and survey region to avoid potential bias of sampling one area or time period more than others. Persistent wind or other rough conditions sometimes prevented planned surveys, in which case surveys were suspended or were moved to another region.

On the open west coast, Marbled Murrelets concentrate within a few kilometers of shore, with peak densities found within 1.5 km of shore (Rachowics and Beissinger 1999, Ralph and Miller 1995, Strong et al 1995). To address this, the working group designated two subunits corresponding to areas with relatively high nearshore and low offshore density, and used the following density dependent formula to sample more heavily in the nearshore area and generate a minimum variance for the two areas:

$$ratio = a_i[d_i / a_o[d_o$$

where *ratio* is the proportion of survey effort devoted to inshore and offshore subunits, based on the area (*a*) and density (*d*) of each (densities for Zone 3 were from offshore distribution samples from 1992-1999). Researchers in each conservation zone selected their own boundaries between inshore and offshore subunits, and the outer limit of the offshore unit, beyond which was excluded from the target population sampling area. Based on an examination of data from 1992 to 1999, I considered a 5000 m outer limit of the sampled population as conservative with respect to including over 98% of the population within our boundaries, including a consideration for annual variability. To determine the boundary between the high density inshore subunit and the low density offshore subunit, I examined where peak densities occurred in the 83 samples of offshore distribution from 1992-1999. Peak density occurred at 500 m in 49 cases, at 1000 m in 20 cases, and at 1500 m in 12 cases, and at 2000 m in 2 instances (2.2%). I selected 1500 m as capturing the zone of high density. The intent of this selection was to avoid 'diluting' density estimates in their zone of peak occurrence with the generally lower values found offshore, while still maintaining some room for annual variability. In Zone 4 RSL selected 2000 m as the inshore/offshore subunit boundary, and 3000 m as the outer limit, using different selection criteria (see Bentivoglio et al. 2002). Using the area of water surface from GIS mapping and densities of murrelets from prior surveys in the above formula, and with an inshore subunit transect length set at 20 km, we computed an offshore transect length of 24.6 km in Zone 3 stratum 1, and of 17.2 km in stratum 2. In Zone 4, the offshore sampling effort was just 6 km based on RSL data using the smaller offshore area between 2000 and 3000 m. The inshore boundary of the sampled population was set at 350 m on the entire outer coast, an approximation of the navigable waters.

Within the inshore subunit, four 5 km sections of coast were set at stratified-random distances from shore for a total transect length of approximately 20 km, the length of the PSU. These segments were themselves divided into 4 categories of distance-to-shore and a specific distance, as well as the order of the categories, was chosen at random. Thus all categories of distance-to-shore within the inshore subunit were represented in each PSU survey. For example, distances may be at 450, 1450, 750, and 950 m in one PSU and 1350, 550, 850, and 650 m in another (the 50 m break points were selected to avoid overlap between subunits). Within the offshore subunit, a zig-zag pattern of transect was conducted with a randomized starting point. Several cycles of zig-zags were conducted, ending at the same distance offshore as at the start, so that all shore distances had equal contribution to the detection rate. One subunit transect was conducted first, and the alternate subunit was surveyed on the return trip.

Index of Productivity

The primary index of productivity for Marbled Murrelets was a simple ratio of hatch-year fledglings (HY) to after-hatch-year (AHY) birds, given as a percent HY. How these indices represent actual production of young per breeding pair is not well known, thus they can only be considered indices, which are comparable over years. Age ratios were also computed as an average of the ratio in each PSU, grouped by stratum, Zone, or the state. All data after 20 July (when most HY are present at sea) were used to produce an overall ratio of HY:AHY for comparison with earlier years. In 2001 many HY were at sea by mid July, so ratios were reported including all data after 10 July. Age of murrelets was determined by examination of plumage and behavior (see Ralph and Long 1995, Strong 1998, Strong and Carten 2000).

Data Management and Analysis

Density of murrelets was calculated using simple strip transects of 100 m width and with line transect analysis using program DISTANCE (Laake 2001, ver. 3.5) and a bootstrap procedure to obtain valid variance estimates from a randomized selection of the data (see Bentivoglio 2002). For all density calculations and population estimates, only June and July data were used, and only surveys conducted in fair to excellent observing conditions were used. Water surface area of each PSU and stratum were computed using GIS. Density and population data for line transect analysis were produced by the Effectiveness Monitoring at-sea statistician (J. Baldwin). RSL data were included in population estimation analysis, but not in productivity assessment.

To compare density data with years prior to the Effectiveness Monitoring design, transects within the inner subunit were subdivided to include only those surveys within 1250 m of shore, comparable with the coastline transects from 1992 to 1999. Strip transect densities were computed using a 100 m wide strip (50 m on either side of the vessel) for the 3 regions of the coast, as was done on the earlier surveys.

Table 1. Summary of survey effort by CCR and RSL during the population assessment period (June - July), and August 2003. Extra surveys were conducted in nearshore waters as time allowed to obtain more productivity data (Zone 4 productivity surveys were in late July).

Zone and stratum	Water area (km^2)	June and July				August			
		PSU surveys		Extra surveys		PSU surveys		Extra surveys	
		Km.	No.	Km.	No.	Km	No.	Km.	No.
Zone 3									
stratum 1	645	338.6	8	35.1	2	76.3	3	29.8	3
stratum 2	934	793.2	22	9.9	1	37.2	1	86.0	4
Total Z 3	1,579	1,131.8	30	45.0	3	113.5	4	115.8	7
Zone 4 (Oregon)	528.5	279.0	11		1	26.0	1	-	-
All	2,107.5	1,410.8	41	45.0	4	139.5	5	115.8	7

RESULTS

Survey Effort

from 4 June to 8 August a total of 40 boat days were spent conducting surveys at sea, during which 42 PSU were surveyed, covering a total of 1,550.3 km of transects (Table 1). In addition, CCR surveyed 156.8 km of inshore habitat over 11 days to obtain larger samples of aged murrelets . During population monitoring (June and July) we completed 30 PSU surveys in Zone 3 and 5 PSU surveys in Zone 4. Redwood Sciences Laboratories conducted 6 additional surveys in the Oregon portion of Zone 4 during June-July, and 1 in August; those data are included here. During the productivity assessment period from 20 July to 10 August, we conducted 9 PSU surveys in Zone 3 and 1 in Zone 4, with 115.8 km and 56.8 km of extra transects in Zones 3 and 4, respectively. The extra surveys, conducted throughout the inshore subunits of selected PSU's, were considered more efficient in collecting productivity data that regular PSU transects.

Distribution

In Zone 3, Marbled Murrelets were generally scarce north of Cascade Head (stratum 1) and at highest densities nearshore from Cascade Head to Coos Bay (stratum 2). As in the prior two years, highest concentrations were encountered in the vicinity of the Alsea River in PSU 11 and around the Siuslaw river (PSU 13 and 14).

In the Oregon portion of Zone 4 densities were highest in the north (Cape Arago area, PSU 1) and south (Brookings area, PSU 9) ends of the region, but moderate overall compared with Zone 3. As in Zone 3, this is comparable with the prior two years.

Table 2. Marbled Murrelet estimates of density and population size in Conservation Zone 3 and the Oregon portion of Zone 4 from 2000 to 2003, using line transect analyses. Estimates are from the Northwest Forest Plan Effectiveness Monitoring Program (Huff 2003) and are rounded to the nearest 100 birds. Statewide density estimate are area-weighted means, statewide error terms are not available.

	Density	Std. error	Population estimate	95% Confidence interval
2000				
Zone 3 Stratum 1	1.53	0.400	1,000	500 - 1,500
Stratum 2	6.14	1.53	5,700	3,200 - 8,900
Zone 4, Oregon	6.02	2.03	2,900	2,100 - 5,800
STATE TOTAL	4.70		9,600	5,800 - 16,200
2001				
Zone 3 Stratum 1	1.78	0.43	1,200	600 - 1,700
Stratum 2	6.84	0.96	6,400	4,400 - 7,900
Zone 4, Oregon	4.65	1.29	2,200	1,600 - 4,000
STATE TOTAL	4.74		9,600	5,600 - 13,600
2002				
Zone 3 Stratum 1	0.79	0.27	500	300 - 900
Stratum 2	6.17	1.45	5,800	3,600 - 9,200
Zone 4, Oregon	5.24	0.82	2,500	1,700 - 3,300
STATE TOTAL	4.29		8.800	5,600 - 13,400
2003				
Zone 3 Stratum 1	1.205	0.280	777	466 - 1,137
Stratum 2	5.438	0.961	5,079	3,254 - 6,732
Zone 4, Oregon	5.019	0.819	2,652	1,821 - 3,959
STATE TOTAL	4.037		8,508	5,541 - 11,828

Murrelets were concentrated close to shore throughout June and July in all areas. The density of birds in the offshore subunit (1500 to 5000 m) was just 6% of that in the inshore subunit (300 to 1500 m) in Zone 3 and 14.5% of the inshore subunit in Zone 4.

Population Estimates
The population estimate for Zone 3 (northern and central Oregon) was 5,961 murrelets using strip transects, or 5,856 murrelets using line transects and the bootstrap procedure (Table 2). Line transects typically produce higher estimates than do strips, and the higher strip estimate was unusual in this year. The estimate for southern Oregon (a portion of Zone 4) was of 1,987 birds using strip transect analysis, and 2,652 birds using line transect analysis, very similar to prior years.

When data were limited to include only nearshore transects (less than 1300 m offshore) comparable with the 1992-1999 coastline survey effort, density in central Oregon was 23.18 birds/Km^2, very close to the 1997-2001 mean of 24.18 birds/Km^2 (Table 3). Inshore densities in northern Oregon were similar to the last 3 years at 3.26 birds/km^2, and lower than earlier years. In southern Oregon, inshore density of 11.96 birds/km^2, above the 4 year average since the EM plan was implemented, but lower than in 2001 (Table 3). The strip transect estimate for Zone 4 in 2001 was biased high due to disproportionate sampling in the highest density area (PSU 1, see Strong 2002). There is high heterogeneity in distribution of murrelets in southern Oregon, such that different PSU sampling between years can affect results.

Productivity
A total of 44 Hatch-year murrelets were seen and aged in 2003. This is less than in recent years because the productivity surveys ended by the 10th of August, rather than the 25th in other years due to budget limitation.

The overall ratio of HY to AHY murrelets for the state was 40:609 (6.16% HY) for all aged birds after 20 July. This is essentially equal with the average of the past 4 years (Table 4). Though indices in recent years have been higher since 1999, the difference was not significant (Mann-Whitney U, p=0.17).

Oceanographically, 2003 was irregular. Upwelling indices were small or negative early in the spring (March-May) and then became very strong from June through August (NOAA site *http://orpheus.pfeg.noaa.gov/research*). This corresponds with strong negative anomalies early in the spring, followed by positive anomalies during summer. Though murrelet productivity indices were comparable with recent years, most of the young were seen at the very end of July and in August, suggesting a late nesting season. Though not quantified here, Common Murres appeared to have had a relatively poor reproductive season.

Table 3. Marbled Murrelet densities (birds/km^2) in the inshore waters (250 to 1250 m out to sea) for 3 regions of the Oregon coast from 1992 to the present. Data are based on 100 m wide fixed strip transects during June and July.

	Region								
	Northern Oregon Zone 3 stratum 1			Central Oregon Zone 3 stratum 2			Southern Oregon Zone 4 to Pt. St. George		
Year	mean	std. dev.	n days	mean	std. dev.	n days	mean	std. dev.	n days
1992	7.45	2.23	3	83.65	28.37	12	23.05	3.86	2
1993	15.40	13.54	3	41.00	27.59	15	11.85	9.68	4
1995	8.55	0.95	2	62.55	25.89	7	22.20	13.05	5
1996	6.65	3.20	3	35.10	20.21	7	13.45	11.95	6
1997	7.25	12.73	4	27.85	13.60	13	6.35	2.91	7
1998	6.90	3.29	4	28.75	4.70	13	7.15	7.25	5
1999	6.11	5.94	3	23.96	23.47	12	5.42	7.41	5
2000	3.69	6.05	8	17.37	19.65	9	4.73	9.18	6
2001	3.17	2.30	7	25.28	16.23	13	14.78	22.08	10
2002	3.48	2.33	8	21.84	15.95	13	6.79	6.13	11
2003	3.26	6.08	7	23.18	34.22	16	11.96	15.21	10

DISCUSSION

This is the fifth year since a regime shift in oceanic conditions (Hayward et al. 1999) and the fourth of higher productivity indices of the Marbled Murrelet. Murrelet abundance has remained low relative to the early 1990's, but appears to have been more or less stable for the past few years. The time series is too short to assign significance to these patterns, but thus far the data are consistent with the hypothesis that, if nesting habitat loss in earlier decades has caused a population decline through the 1990's, the population should stabilize at a new, lower level supported by remaining habitat, and productivity would rise to a level supporting current numbers. Confounding this concept are the effects of oceanic regime shift which also corresponds with the higher productivity indices. Additional years of population and productivity monitoring will be necessary to separate effects of marine and terrestrial habitat change on Marbled Murrelet demography.

Table 4. Number of after hatch year (AHY) and hatch year fledgling (HY) Marbled Murrelets and percent HY for 3 regions of the Oregon coast. Data include all aged birds after 20 July, 1992 to 2003.

Year	Northern		Central		Southern		State total	
	HY/AHY	(%HY)	HY/AHY	(%HY)	HY/AHY	(%HY)	HY/AHY	(%HY)
1992	7/99	(6.60)	70/2229	(3.04)	20/967	(2.03)	97/3295	(2.86)
1993	7/441	(1.56)	16/1606	(0.99)	No data		23/2047	(1.11)
1994	6/119	(5.04)	23/883	(2.54)	19/555	(3.31)	48/1557	(2.99)
1995	14/100	(12.28)	33/1199	(2.68)	33/728	(4.34)	80/2027	(3.80)
1996	7/91	(7.14)	62/2343	(2.58)	22/716	(2.98)	91/3150	(2.81)
1997	4/51	(7.27)	26/1265	(2.01)	17/340	(4.76)	47/1656	(2.76)
1998	9/93	(8.82)	30/1500	(1.96)	11/440	(2.44)	50/2033	(2.40)
1999	7/79	(8.14)	38/1522	(2.44)	20/639	(3.03)	65/2240	(2.82)
2000	3/49	(5.77)	54/702	(7.14)	29/232	(11.55)	86/983	(8.04)
2001*	2/111	(1.77)	44/1110	(3.81)	23/331	(6.52)	69/1552	(4.26)
2002	11/49	(18.33)	14/277	(4.81)	5/104	(4.59)	30/430	(6.52)
2003	5/51	(8.93)	23/658	(3.33)	14/155	(8.28)	40/609	(6.16)

* Including all data after 10 July.

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Appendix. A. Results of perpendicular distance estimation excercise.

Estimated perpendicular distance to targets among all observers ranged from 22% less to 16% above of the true distance, with average differences from 5.4% short to 2.3% above the true values for the whole season (Table A1). There did not appear to be any trend towards improved estimation ability through the season for individual observers. On some trials observers deviated by more than the 10% level considered acceptable by the EM at-sea population monitoring group, however, all observers showed high levels of accuracy and precision when considered through the season. PW, the only inexperienced observer during the season, was the only one to show a consistent (underestimating) bias. The overall deviation through the season for all observers combined was only 0.44% different from true, suggesting that this aspect of data quality was high. Trials were conducted in calm conditions on targets usually larger than Marbled Murrelets as it was generally too difficult to get lazer readings on Marbled Murrelets at sea. I consider it unlikely that actual field estimates differed much from these data, however, since observers frequently discussed and compared estimates in the field and found good agreement between estimates.

Table A1. Mean percent deviation in perpendicular distance estimates from true (lazer) perpendicular distance from targets for 6 observers on the Oregon coast in 2003. Values shown are means of 5 - 10 trials per day on targets from 18 to 110 m from the vessel.

	Observers						
	DW	BO	CS	DC	PW	JJ	DATE
		2.181	10.413	-0.948			6/10/03
		1.722	12.398	7.650			6/11/03
		-0.972	6.981	9.148			6/12/03
		-6.315	3.339	16.062			6/13/03
		-21.693	-11.805	-2.100			6/14/03
		-13.618	-8.008	-0.030			6/22/03
		5.953	2.612	-2.074			6/23/03
	10.390	-2.193		-0.404			6/25/03
	-7.503	-11.600		-3.287			6/29/03
	0.359	-5.076		0.669			7/1/03
	-3.586	-1.644		3.055			7/2/03
		1.819		1.111		-1.249	7/8/03
		-2.441		2.803		-7.190	7/9/03
		-17.035		0.470		5.902	7/10/03
		-4.337		4.485		3.995	7/11/03
	8.796	7.195		13.470			7/12/03
		0.038	-7.784	1.222			7/14/03
	2.325	1.441		3.019			7/15/03
	-2.710	4.325		1.196			7/16/03
		3.334	6.467		-6.663		7/24/03
		-0.353		6.916	-0.805		7/25/03
		14.489		-4.544	-6.270		7/26/03
		7.337		-2.312	-7.770		7/28/03
		-10.385	2.851	-6.889			7/31/03
	-17.063	-8.692	8.218				8/5/03
	-6.326	-19.369	2.244				8/7/03
Average	-1.70	-2.92	2.33	2.12	-5.38	0.37	