MARBLED MURRELET ABUNDANCE AND REPRODUCTIVE INDICES IN OREGON DURING 2002

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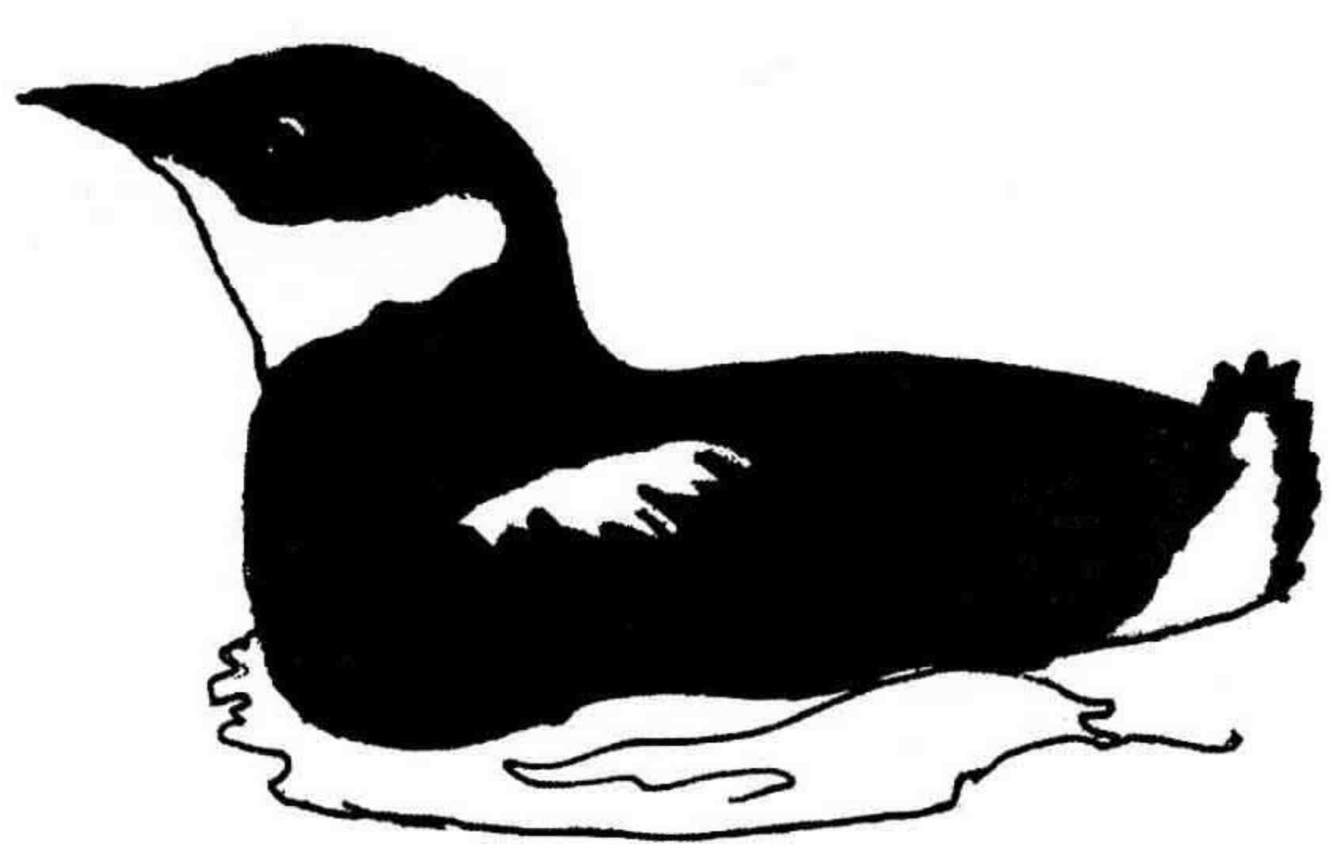

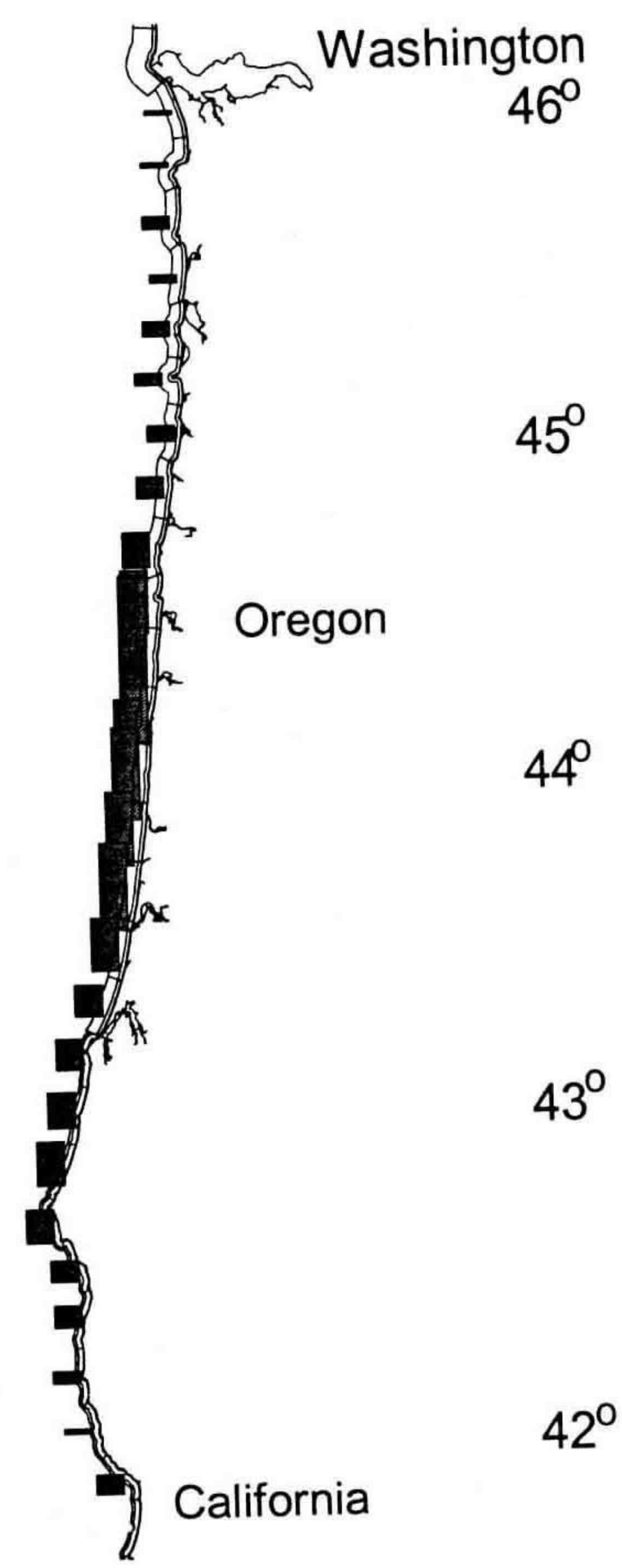

by

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Cover graphic: Vertical bars along the Oregon coast represent the mean relative number of Marbled Murrelets detected during Primary Sampling Unit surveys in June and July, 2002.

SUMMARY

Marbled Murrelets and other seabirds were surveyed using vessel transects throughout the coastal waters of Oregon in June July, and August 2002. This is the third year that the Northwest Forest Plan Effectiveness Monitoring sampling design has been used, and the 11th since surveys began on the Oregon coast. In June and July 45 Primary Sampling Units (PSU) were surveyed, comprising 1612 km of transects, and those data were used to estimate population size. In Late July and August 481 km of transect in 13 PSU surveys and 84 km of additional transects were used to estimate relative productivity of murrelets

The Zone 3 population estimate in 2002 was of 5,641 and 6,333 birds using strip and line transect analysis, respectively. These numbers are similar to the 2000 and 2001 estimates, and may indicate some stabilization of the population. The estimate for the Oregon portion of Zone 4 was of 1,916 and 2,408 birds by strip and line transect, respectively, with too much annual variation to assess change in abundance.

Indices of productivity were higher than the long-term average, with a state average of 6.52 % of birds aged as hatch-year fledglings. This corresponds with continued high primary productivity and generally favorable marine conditions during 2002.

ACKNOWLEDGMENTS

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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 Oregon Department of Fish & Wildlife or 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 2002 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.

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; 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,

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 (see 'productivity assessment'), 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 chosen targets, and then one would use the rangefinder and report the actual distance, and observers would adjust their calibration if necessary. If observers were consistently off the mark, we would continue until correct estimates were obtained.

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, 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

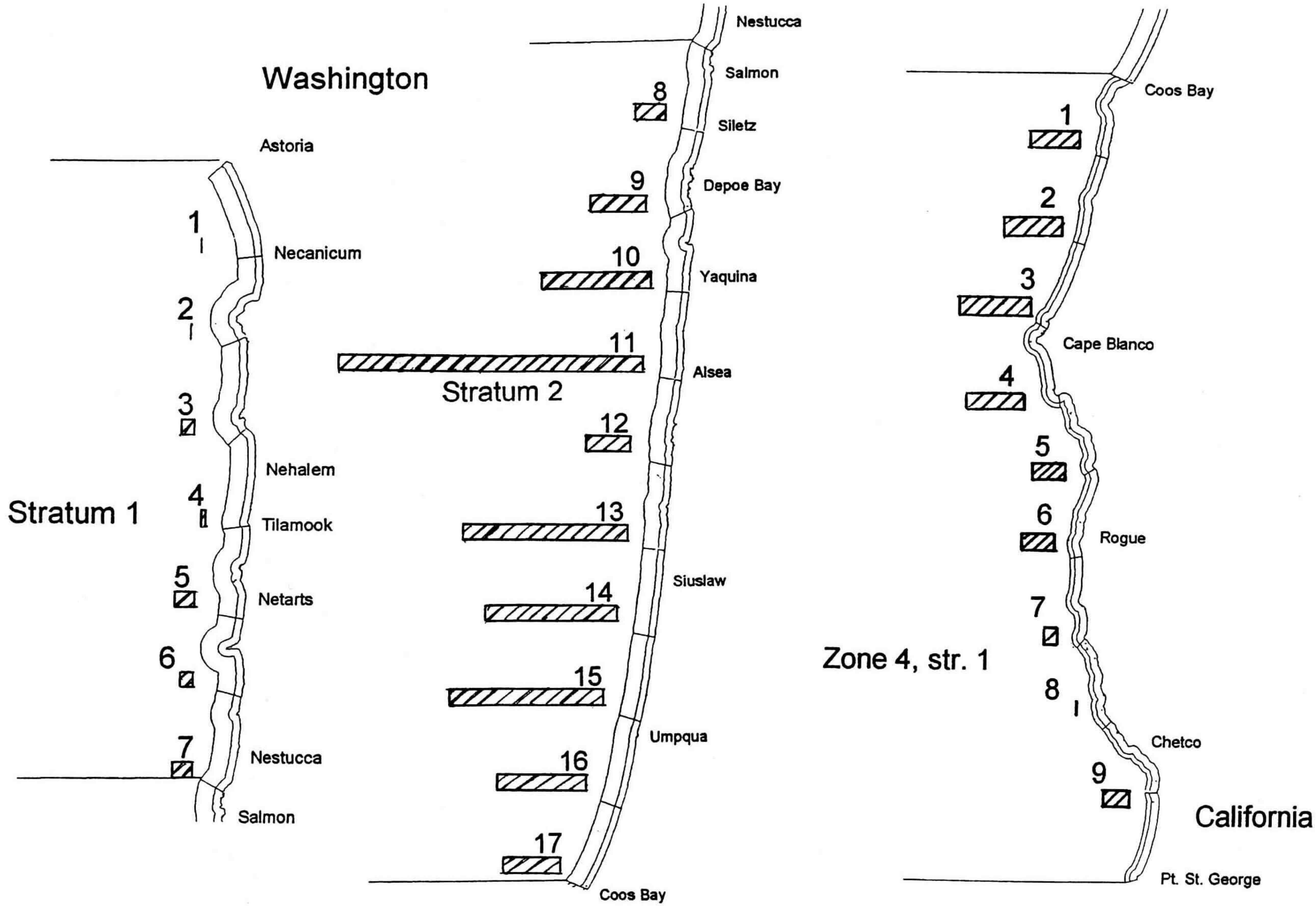

Figure 1. Primary Sampling Units in Oregon, showing the two strata of Zone 3 and the Oregon portion of Zone 4. Hatched bar length represents the mean number of murrelets seen in each PSU during surveys in June and July, 2002 (from Table 2). Surveys with no murrelets are shown by a I. Extra inshore survey data are not included.

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 1-10 correspond exactly with north, central, and southern regions used in 1992-1999 surveys, although in 2002 Zone 4 surveys extended only through PSU 9. 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 whose locations were selected randomly at the start of the season. The boat was stationed at one or two adjacent ports where 1 to 6 PSU were sampled over 1-3 days, and then moved to the next sampling area. Persistent wind or other rough conditions sometimes prevented planned surveys, in which case surveys were suspended or were moved to another region. Although sampling was intended to be randomly ordered, it ended up being modified by weather conditions. However, clusters of PSU samples were disperse in location and timing through the season.

On the open west coast, Marbled Murrelets concentrate within a few kilometers of shore, with peak densities found within 1.5 km of shore (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. 2.1) 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 less than 1250 m offshore, comparable with the coastline transects from 1992 to 1999. Strip transect densities were computed 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 (May - July), and August (data after 19 July were used in productivity assessment as well). Extra surveys were conducted in nearshore waters as time allowed to obtain more aged bird data.

Zone and stratum	Water surface 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							2		
stratum 1	645	606.0	13	-	0	90.1		9.1	1
stratum 2	934	642.3	18	9.3	2	130.2	4	45.9	6
Total Z 3	1,579	1,248.3	31	9.3	2	220.3	6	55	7
Zone 4 (Oregon)	528.5	364.0	14	8.0	1	52.0	2	28.5	2
All	2,107.5	1,612.3	45	17.3	3	272.3	8	83.5	16

RESULTS

Survey Effort

from 22 May to 26 August, a total of 41 days were spent conducting surveys at sea, during which 53 PSU were surveyed, covering a total of 1,884.6 km of transects (Table 1). In addition, CCR surveyed 100.8 km of inshore habitat over 9 days to obtain larger samples of aged murrelets (Tables 1 and 2). During population monitoring (June and July) we completed 31 PSU surveys in Zone 3 and 8 of the 10 PSU surveys planned in Zone 4. Redwood Sciences Laboratories conducted 6 additional surveys in the Oregon portion of Zone 4 and those data are included here. During the Productivity assessment period from 20 July to 26 August, we surveyed 11 PSU in Zone 3 and 2 in Zone 4.

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, Fig 1). As in 2001 the highest concentrations were encountered in the vicinity of the Alsea River in PSU 11 and around the Siuslaw river (PSU 13 and 15, Fig. 1).

In the Oregon portion of Zone 4 densities were moderate in the northern 4 PSU and in PSU 9 by California, and lower between (Fig. 1). This is comparable with the 2001 data except that the very high concentration in PSU 1 during 2001 seems spread over the northern 4 PSU in 2002. Murrelets were concentrated close to shore throughout June and July in all areas. The density of

Table 2. Summary of survey coverage and the number of Marbled Murrelets detected in Oregon during the 2002 field season. AHY and HY applies only to murrelets whose age was determined and after-hatch-year or hatch-year fledglings, respectively.

Month	Day	Zone	Stratum	PSU	Transect type	Transect length (km)	Marbled Murrelets Total	AHY	HY	Research group
May	22	4	1	7	Near shore PSU	20.0	2	2		RSL
	22	4	1	7	Offshore PSU	6.0	0			RSL
	22	4	1	9	Near shore PSU	20.0	6	5		RSL
	22	4	1	9	Offshore PSU	6.0	1	1		RSL
	24	4	1	6	Near shore PSU	20.0	26	23		RSL
	24	4	1	6	Offshore PSU	6.0	0			RSL
June	10	3	2	10	Near shore PSU	20.1	59	54		CCR
		3	2	10	Offshore PSU	17.2	4	4		CCR
		3	2	11	Near shore PSU	20.0	258	224		CCR
		3	2	11	Offshore PSU	17.2	11	11		CCR
	11	3	1	7	Near shore PSU	19.9	17	15		CCR
		3	1	7	Offshore PSU	24.7	2	2		CCR
		3	2	8	Near shore PSU	19.8	39	33		CCR
		3	2	8	Offshore PSU	17.2	0			CCR
	13	4	1	1	Near shore PSU	20.0	33	30		CCR
		4	1	1	Offshore PSU	6.0	0			CCR
		3	2	17	Near shore PSU	19.9	57	44		CCR
		3	2	17	Offshore PSU	17.2	2	2		CCR
		4	1	5	Near shore PSU	20.0	21	21		RSL
		4	1	5	Offshore PSU	6.0	0			RSL
	14	4	1	2	Near shore PSU	20.0	38	31		CCR
		4	1	2	Extra	8.0	37	36		CCR
		4	1	2	Offshore PSU	6.0	1	1		CCR
		4	1	3	Near shore PSU	20.0	62	59		RSL
		4	1	3	Offshore PSU	6.0	0			RSL
		4	1	4	Near shore PSU	20.0	37	29		RSL
		4	1	4	Offshore PSU	6.0	0			RSL
	15	4	1	8	Near shore PSU	20.0	0			CCR
		4	1	8	Offshore PSU	6.0	0			CCR
	16	3	2	15	Near shore PSU	20.1	131	104		CCR
		3	2	15	Offshore PSU	17.2	6	6		CCR
		3	2	16	Near shore PSU	20.0	23	13		CCR
		3	2	16	Offshore PSU	17.2	2	2		CCR
	21	3	1	1	Near shore PSU	20.0	2	2		CCR
		3	1	1	Offshore PSU	6.1	0			CCR
		3	1	2	Near shore PSU	19.9	0			CCR
		3	1	2	Offshore PSU	24.7	2	2		CCR
	22	3	1	3	Near shore PSU	20.3	11	11		CCR
		3	1	3	Offshore PSU	24.7	3	3		CCR
		3	1	4	Near shore PSU	19.9	4	4		CCR
		3	1	4	Offshore PSU	24.7	2	2		CCR
	23	3	1	5	Near shore PSU	20.0	15	13		CCR
		3	1	5	Offshore PSU	24.7	1	1		CCR
		3	1	6	Near shore PSU	18.3	15	15		CCR
		3	1	6	Offshore PSU	24.7	0			CCR
	28	4	1	6	Near shore PSU	20.0	11	11		CCR
		4	1	6	Offshore PSU	6.0	4	3		CCR
	29	4	1	9	Near shore PSU	20.0	31	23	1	CCR
		4	1	9	Offshore PSU	6.0	0			CCR
	30	4	1	7	Near shore PSU	20.0	16	16		CCR
		4	1	7	Offshore PSU	6.0	0			CCR
July	1	3	2	14	Extra	5.0	37	35	2	CCR
		3	2	14	Extra offshore	4.3	0			CCR
	7	3	2	9	Near shore PSU	20.2	42	25	3	CCR
		3	2	9	Offshore PSU	17.2	0			CCR
		3	2	10	Near shore PSU	20.5	95	77	4	CCR
		3	2	10	Offshore PSU	16.2	5	1		CCR
	8	3	2	12	Near shore PSU	20.0	30	30		CCR
		3	2	12	Offshore PSU	17.2	0			CCR
		3	2	13	Near shore PSU	20.1	110	108		CCR
		3	2	13	Offshore PSU	17.2	0			CCR
	9	3	2	14	Near shore PSU	20.0	85	83	2	CCR
		3	2	14	Offshore PSU	17.2	3	3		CCR
	10	3	2	16	Near shore PSU	20.0	97	93	4	CCR

Table 2, continued

Month	Day	Zone	Stratum	PSU	Transect type	Transect length (km)	Marbled Murrelets Total	AHY	HY	Research group
July	10	3	2	16	Offshore PSU	17.2	0			CCR
		3	2	17	Near shore PSU	20.0	17	17		CCR
		3	2	17	Offshore PSU	17.2	1	1		CCR
	14	3	1	3	Near shore PSU	20.0	6	3	3	CCR
		3	1	3	Offshore PSU	24.7	0			CCR
		3	1	4	Near shore PSU	19.8	3	3		CCR
		3	1	4	Offshore PSU	24.7	0			CCR
	15	3	1	1	Near shore PSU	22.4	0			CCR
		3	1	1	Offshore PSU	24.7	0			CCR
		3	1	2	Near shore PSU	19.5	0			CCR
		3	1	2	Offshore PSU	24.7	0			CCR
	17	3	2	11	Near shore PSU	20.0	129	129		CCR
		3	2	11	Offshore PSU	17.2	8	8		CCR
	18	3	2	15	Near shore PSU	20.2	68	67	1	CCR
		3	2	15	Offshore PSU	17.2	3	3		CCR
	19	4	1	2	Near shore PSU	20.0	40	32	1	CCR
		4	1	2	Offshore PSU	6.0	0			CCR
		4	1	3	Near shore PSU	20.0	36	35	1	CCR
		4	1	3	Offshore PSU	6.0	0			CCR
	23	3	2	9	Near shore PSU	20.0	34	32	2	CCR
		3	2	9	Offshore PSU	17.2	0			CCR
	24	3	1	7	Near shore PSU	20.7	9	8	1	CCR
		3	1	7	Offshore PSU	24.7	1	1		CCR
		3	2	8	Near shore PSU	20.7	1	1		CCR
		3	2	8	Offshore PSU	17.2	4	4		CCR
	27	3	1	5	Near shore PSU	20.5	11	10	1	CCR
		3	1	5	Offshore PSU	21.3	0			CCR
	28	3	1	6	Near shore PSU	20.9	5	5		CCR
		3	1	6	Offshore PSU	25.2	0			CCR
August	14	3	2	10	Extra	8.5	69	65		CCR
		3	2	11	Extra	5.0	19	9	1	CCR
	15	3	2	10	Extra	10.0	74	66	1	CCR
	16	3	2	12	Near shore PSU	20.1	4	3	1	CCR
		3	2	12	Offshore PSU	17.2	0			CCR
	17	3	1	4	Near shore PSU	20.5	4	3	1	CCR
		3	1	4	Offshore PSU	24.7	0	2		CCR
	18	3	1	3	Extra	9.1	0			CCR
		3	1	3	Near shore PSU	20.1	31	22	8	CCR
		3	1	3	Offshore PSU	24.7	0			CCR
	19	3	2	8	Near shore PSU	10.0	0			CCR
		3	2	8	Offshore PSU	8.6	0			CCR
		3	2	9	Extra	5.0	9	7	2	CCR
	22	3	2	9	Extra	7.4	61	50	3	CCR
		3	2	9	Near shore PSU	19.8	28	26	1	CCR
		3	2	9	Offshore PSU	17.2	1	1		CCR
	24	3	2	13	Near shore PSU	20.1	27	20	2	CCR
		3	2	13	Offshore PSU	17.2	0			CCR
	25	4	1	1	Near shore PSU	20.0	59	43	5	CCR
		4	1	1	Extra	5.5	18	16		CCR
		4	1	1	Offshore PSU	6.0	2	2		CCR
		3	2	17	Extra	10.0	10	10		CCR
	26	4	1	8	Extra	7.0	3	3		CCR
		4	1	9	Near shore PSU	20.0	38	38		CCR
		4	1	9	Extra	16.0	0			CCR
		4	1	9	Offshore PSU	6.0	0			CCR

birds in the offshore subunit (1500 to 5000 m) was less than on tenth of that in the inshore subunit (300 to 1500 m) in Zone 3 and 13% of the inshore subunit in Zone 4.

Population Estimates

The population estimate for Zone 3 (northern and central Oregon) was 5,641 murrelets using strip transects, or 6,333 murrelets using line transects and the bootstrap procedure. In spite of relatively large confidence intervals, the point estimates were very similar to the prior 2 years, with less than 10% difference between years (Table 3). The estimate for southern Oregon (a portion of Zone 4) was of 1,916 birds using strip transect analysis, just 69% of that in 2001, but similar to that of 2000 (Table 3). The line transect estimate for the Oregon portion of Zone 4 was of 2,408 birds, similar to 2001 but only 76% of that in 2000. There is high heterogeneity in distribution of murrelets in southern Oregon, such that different PSU sampling between years can affect results dramatically. The strip transect estimate for Zone 4 in 2001 was biased high due to disproportionate sampling in the highest density PSU (see Strong 2002). In Zone 4 line estimates do not correlate with strip estimates since line transect estimates were a proportion (0.76) of the estimate for all of stratum 1, whereas strip transects were based only on Oregon data.

When 2001 data were limited to include only nearshore transects (less than 1250 m offshore) comparable with the 1992-1999 coastline survey effort, density in central Oregon was 21.84 birds/Km^2 , slightly lower than the 1997-2001 mean of 24.62 birds/Km^2 (Table 4). Inshore densities in northern Oregon were similar to the prior two years at 3.48 birds/km^2, and lower than earlier years. In southern Oregon, inshore density of 6.79 birds/km^2 was similar to recent years (Table 4).

Productivity

A total of 52 Hatch-year and 41 After-Hatch year advanced molt (C4) murrelets were aged out of 102 black-and white (C4) birds detected, for an ageing success rate of 91%. This is similar to the ageing success rate in other years (range 81-91%, Strong and Carten 2000).

The overall ratio of HY to AHY murrelets for the state was 30:430 (6.52% HY) for all aged birds after 20 July. This is notably higher than the long term average of 3.38% HY and second only to 2000 (Table 5).

Oceanographically, 2002 was characterized by cool water and high primary productivity (NOAA Pac. Fish. Ecol. Lab.) Returns of several salmon species to the Columbia and other river systems were at high levels, similar to the record 2000 season. Exceptionally low sea surface temperatures were present in August, and this was associated with a seafloor anoxic ‘dead zone’ in central Oregon (NOAA CoastWatch). There is no evidence that this deep anoxic area affected the near-shore seabird community.

Table 3. Marbled Murrelet estimates of density and population size in Conservation Zone 3 and the Oregon portion of Zone 4 from 2000 to 2002, using 100 m wide strip transects and line transects. Line transect estimates are from the Northwest Forest Plan Effectiveness Monitoring program.

	Strip Transect			Line Transect		
Year and region	Density	Std. error	Pop. estimate +/- 95% C.I.	Density	Std. error	Pop. estimate +/- 95% C.I.
2000						
Zone 3 stratum 1	1.071	0.254	691	1.531	0.448	987 499 - 1,636
Stratum 2	5.287	1.251	4,938	6.158	1.878	5,751 3,176 - 10,351
Zone 3 total	**3.662**	**0.623**	**5,629 3,600 - 7,658**	**4.268**	1.271	**6,738 3,940 - 11,707**
Zone 4, Oregon	4.375	1.998	2,312 146 - 5027	5.973	1.403	3,151
2001						
Zone 3 stratum 1	1.350	0.505	871 164 - 1,688	1.629	0.434	1,050 554 - 1,676
Stratum 2	6.213	0.926	5,803 3,986 - 7,620	6.241	1.001	5,829 4,420 - 7,962
Zone 3 total	**4.227**	**0.566**	**6,673 4,836 - 8510**	**4.358**	**0.662**	**6,880 5,389 - 9,243**
Zone 4, Oregon	6.036	2.076	3,304 889 - 5,719	4.648	2.173	2,453
2002						
Zone 3 stratum 1	0.569	0.188	367 136 - 681	0.793	0.291	511 262 - 1,038
Stratum 2	5.647	1.160	5,274 2,987 - 7,560	6.234	1.387	5,822 3,536 - 9,035
Zone 3 total	**3.574**	**0.573**	**5641 3,794 - 7488**	**4.012**	**0.887**	**6,333 3,988 - 9,908**
Zone 4, Oregon	3.626	0.720	1,916 1,094 - 2,738	5.015	2.659	2,408 1,653 - 4,013

Table 4. 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

DISCUSSION

This is the fourth year of strong upwelling and the third of higher productivity indices of the Marbled Murrelet. Murrelet abundance remained low relative to the early 1990's, but appears to have been more or less stable for the past few years. This is consistent with the hypothesis submitted by Strong (2003) 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. Additional years of population and productivity monitoring will verify this.

Table 5. 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 2000.

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)

* Including all data after 10 July.

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