ABUNDANCE AND REPRODUCTIVE INDICES OF MARBLED MURRELETS IN OREGON DURING 2001: RESULTS OF AT-SEA MONITORING.

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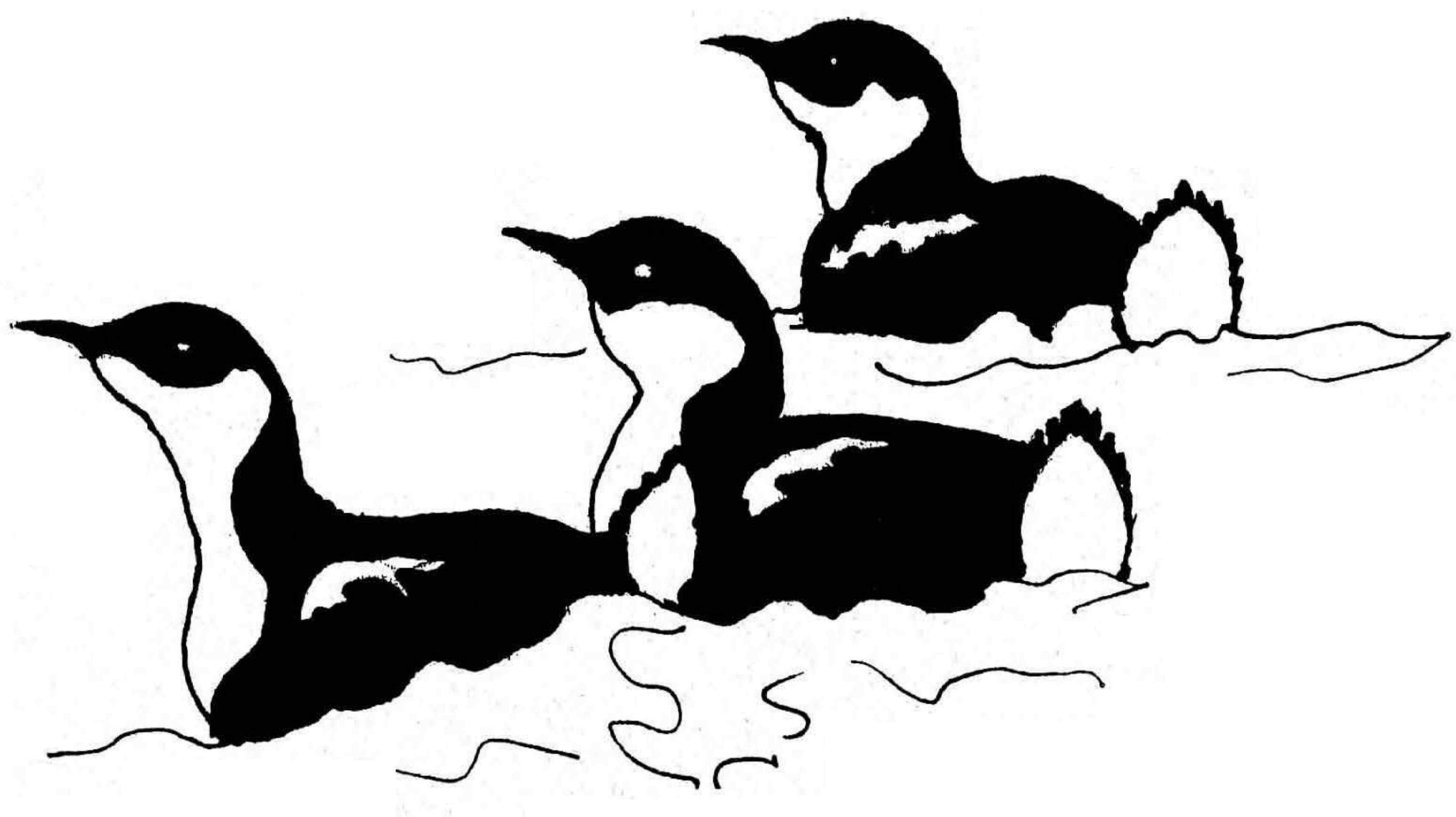

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SUMMARY

Marbled Murrelets have been surveyed by vessel along the Oregon coastline using a standard protocol since 1992. In 2000 the survey protocol remained the same, but a new design of transect layout was initiated in an attempt to minimize variability and obtain statistically sound measures of density, following the Effectiveness Monitoring Marbled Murrelet at-sea portion of the Northwest Forest Plan. This report summarizes results of the 2001 Monitoring Plan program in Marbled Murrelet Conservation Zone 3, and the northern (Oregon) portion of Zone 4, and compares those results to the 2000 pilot year. Also included are productivity indices, and a comparison of the new program to prior years results.

Murrelet distribution was similar to other cold, upwelling years during 2001 in that they were concentrated close to shore. Mean density, was higher than in 2000, but lower than in prior years in Conservation Zone 3 (northern and central Oregon). The Marbled Murrelet population for Zone 3 was estimated at 6,673 birds by strip transect and 6,880 birds by line transect; Variance and confidence intervals around these estimates remained high. The statewide population estimate (including the Oregon portion of Zone 4) was of 9,333 birds.

Indices of productivity were higher than the long-term average, with a state average of 4.26 % of birds aged as hatch-year fledglings. This corresponds with a second season of high primary productivity and generally favorable marine conditions.

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DISCLAIMER

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 within old forests on the west coast, 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). From 1992 to 1999 Crescent Coastal Research (CCR) conducted standardized boat transects of the nearshore waters to monitor the abundance and distribution of Marbled Murrelets along the Oregon coast using a sampling design adapted from that of the USFS' Redwood Sciences Laboratories (RSL, see Ralph and Miller 1995). By 1994 we developed indices of productivity and tracked the relative reproductive success of the murrelets, as well as that of Common Murres, Pigeon Guillemots, and Rhinoceros Auklets (Strong 1996). During 2000 a new sampling design to monitor the murrelet population was initiated for our transects and for other researchers in the 3 state area by the At-Sea Working Group under the Effectiveness Monitoring (EM) component of the Northwest Forest Plan (Madsen et al. 1997, Bentivoglio et al. 2001). This report summarizes population estimation and productivity indice results of the 2001 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 20 ft. boats 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 route 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, or when conditions changed, 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. Observing conditions were adjusted downwards due to effects of glare, fog, swell, and other impairments to visibility.

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, but we have included and additional 20 km (1 PSU) into northern California to maintain consistency with earlier research and represent Oregon birds that may use California waters. Thus this region included 10 PSU, and CCR designated 10 samples 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 as used in 1992-1999 surveys. Surveys in Conservation Zone 4 were conducted cooperatively with RSL researchers to achieve a larger sampling effort.

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 4 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 locations 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 1997-1999). 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 95% 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. 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 the 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. In 2001 the inshore boundary of the sampled population was set at 350 m; an approximation of the navigable waters. This resulted in reduced area to which densities were extrapolated for population estimates. Year 2000 estimates were recalculated to reflect this revised area.

Within the inshore subunit, four 5 km sections of coast were set at stratified-random distances from shore for a total transect length of 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 (example of Fig. 2), 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 (see example of Fig. 2). 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 known, thus they can only be considered indices, which are comparable over years (but see Strong 1996, Kuletz and Kendall 1998). 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 also reported including all data after 10 July.

Determining the age of the birds is critical to obtaining valid productivity indices. The plumage of HY Marbled Murrelets at sea is very similar to the black-and-white basic plumage of older birds. Prior to August, HY Marbled Murrelets were easily told from older birds by bright white feathers on the belly, epaulets, and neck, compared with the overall darker appearance of alternate plumate or partially molted AHY birds. Difficulty in age determination does not arise until AHY birds are in an advanced stage of prebasic molt, which is usually seen by late July or early August in some birds. We tracked the progression of AHY molt through the season by categorizing the molt state of nearby murrelets seen with good lighting as follows:

CLASS 1) Very little or no molt, entirely in alternate plumage.
CLASS 2) Obvious body molt with lighter neck and body color, but estimated at less than

50% of alternate plumage lost or replaced.

CLASS 3) Over 50% of alternate plumage lost or replaced, but still clearly distinguishable from HY birds by brown feathers on back, breast, and belly. Molting birds were placed in class 3 if their throat and neck appeared whitish in overall color.

CLASS 4) Appears to be in basic plumage when seen from a distance. By definition class 4 birds were those that required close examination to verify age. This class included all HY as well as advanced-molt AHY birds.

When birds in plumage class 4 (C4) were detected, the transect was halted and we approached more closely to record age determining characteristics. Characteristics that qualified a C4 bird as AHY were a) presence of dark brown alternate plumage feathers on back, neck, or breast, visible when viewed closely; b) presence of dark alternate plumage on the belly seen as it dove; or c) missing or molting flight feathers. Characteristics that qualified a bird as HY were a) crisp black and white plumage, sometimes with fine speckling on the breast; b) crisp plumage combined with an entirely white belly; and c) full, non-molting wings combined with other characteristics. The usefulness of these criteria was date-dependent and changed through August; presence of full, non-molting wings was the only conclusive criteria for HY age by late August, when all but the flight feathers of some AHY birds had been replaced with basic plumage (see Strong 1998). We also quantified behavioral components when examining C4 birds on an opportunistic basis; whether birds flapped their wings following the first dive due to our approach, frequency of dives, and how strongly the birds remained paired or in a group.

In August, transects were interrupted more frequently as the month progressed in order to examine birds in C4 molt. Transects resumed after every examination of a C4 bird and proceeded until the next C4 bird was encountered or the line was completed.

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 1997) 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. 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 statisticians (J. Baldwin). For Zone 4, line transect densities using both CCR and RSL data were reported here as provided by the EM statisticians for the entirety of Zone 4 stratum 1, and population estimates are given as a proportion of the stratum estimate corresponding to the area surveyed by CCR (71.4%).

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 1200 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.

RESULTS

Survey Effort

from 6 June to 26 August, a total of 35 days were spent conducting surveys at sea, during which 53 PSU were surveyed, covering a total of 1,891.6 Km of transects. In addition, we surveyed 179.2 km of inshore habitat over 16 days better assess distribution and obtain larger samples of aged murrelets (Tables 1, 2). During population monitoring (June and July) 27 of the targeted 30 PSU in Zone 3 and 8 of the planned 10 PSU in Zone 4 were completed. Redwood Sciences Laboratories provided data on an additional 4 PSU surveys in Zone 4. During the Productivity assessment period from 20 July to 26 August, we surveyed 17 PSU in Zone 3 and 6 in Zone 4, where 20 and 5 had been planned. The randomized clustering of surveys was not completed in the same order as originally laid out due to weather and other logistic constraints, however, an arbitrary selection of PSU clusters distributed in a disperse fashion through the season and along the coast was accomplished.

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). Exceptional concentrations were encountered in the vicinity of the Alsea River and the Siuslaw River, where densities on the inshore PSU ranged from 53 to 68 birds/km^2 on both June and July surveys (Primary Sampling Units 11 and 14). The highest density was encountered off the Alsea River on 21 July when 178.8 murrelets /km^2 were estimated during a supplementary inshore survey (not included in population estimation data).

In the Oregon portion of Zone 4 there was a fairly consistent geographic pattern during June and July. Density was high at the north end, between Coos Bay and Bandon (PSU 1), where a peak estimate of 73 birds/km^2 encountered on 8 June exceeded the highest PSU estimates of Zone 3. Murrelets were at moderate density at the south end of the state (9.5 birds/km^2 , PSU no's. 9 and 10), and relatively scarce in the rest of the region, although it was minimally sampled.

A distribution shift to the south is evident by comparing August densities with the June-July period. Densities at the north end of the state decreased from 1.35 birds/km^2 to 0.21 birds/km^2 and southern Oregon densities went from 8.36 to 18.50 birds/km^2 (for combined in and off-shore subunits). Central Oregon densities did not change appreciably from June-July (6.21 birds/km^2) to August (5.94 birds/km^2).

Murrelets were concentrated close to shore throughout the season and in all areas (Fig 1). The density of birds in the inshore unit (300 to 1500 m) averaged from 6.6 to 25.8 times that in the offshore subunit (1500 to 5000 m). Within the offshore subunit, all but 3 of 81 murrelet detections were in the inner half, less than 3300 m offshore. Of the higher density estimates for the offshore subunits (around the Alsea River and in the vicinity of Coos Bay in early June) the birds contributing to the estimate were encountered less than 3000 m offshore. The other location of higher offshore density was in southern Oregon (PSU 9) where dispersal farther offshore was noted in other years (Strong and Fisher 1998). There may have been some restriction closer to the coast in August in Zone 3, as more and more offshore subunit transects had zero detections recorded (Table 2) but it was not pronounced as densities were so low offshore anyway.

Population Estimates

The population estimate for Zone 3 (northern and central Oregon) was 6,673 murrelets using strip transects, or 6,880 murrelets using line transects and the bootstrap procedure These estimates were slightly higher than those of 2000 (Table 3). The estimate for southern Oregon (a portion of Zone 4) was of 2,453 birds using line transect analysis, just 78% of that in 2000. The strip transect estimate for Zone 4 (3,304 birds) was high relative to earlier years and line transect analysis. Zone 4 strip transect results had uneven sampling effort which may have affected results. Water surface area to which densities were extrapolated for population estimation was changed slightly from that used in 2000 due to changes in definition of the study area and revised GIS analysis, however population estimates were also recalculated from the 2000 data to be comparable to 2001 in table 3. Also in 2001 murrelets flying by in transit were included in density calculations. I recalculated the 2000 density estimates to include birds in flight as well. Because most birds detected in flight were beyond our strip transect the change was slight.

When 2001 data were limited to include only nearshore transects (less than 1200 m offshore) comparable with the 1992-1999 coastline data, density in central Oregon was 25.28 birds/Km^2, much higher than in 2000 and similar to the 1997-1999 mean of 26.85 birds/Km^2 (Table 4). Inshore densities in northern Oregon were similar to 2000 and lower than earlier years. Murrelet density in southern Oregon was high relative to other years, but, as with population estimates above, it is likely the data were affected by repeated sampling in higher density PSU (1, 9) and lack of sampling in low density PSU (7, 8). Data from the extra (non-PSU) surveys were not included in this inshore density calculation, as they were biased towards areas of higher density.

Productivity

A total of 80 Hatch-year and 11 After-Hatch year advanced molt (C4) murrelets were aged out of 100 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). Of the 9 un-aged C4 birds, 5 were lost after their first dive or moved into the surf zone before age confirmation. It is likely that these un-aged birds were disproportionately HY based on these behaviors (see Strong 2001). Fourteen of the HY and 2 of the AHY were of unconfirmed age, where cues during observation were not adequate to confirm the age with certainty, but enough to be reasonably confident. These were included in the productivity index data used below. An unusually low proportion of AHY birds were in C4 molt stage by the end of the season, possibly indicating a late or very protracted nesting season.

There did appear to be a clumping of HY in certain areas, as indicated by the widely varying ratios by PSU in the latter half of the season (Table 2) and reflected in the very high variance in average percent HY by PSU. Clumped distribution of HY relative to the total murelet population was reported earlier in Oregon (Strong 1996) and in Alaska (Kuletz, and Piatt 1999).

The overall ratio of HY to AHY murrelets for the state was 39:1144 (3.33% HY) for all aged birds after 20 July. This is slightly higher than the long term average (Table 5) but there is reason to believe that productivity was better than indicated by this measure. Over half the HY recorded in 2001 were seen prior to 20 July, the start of the designated 'productivity season'. When all data after 9 July is included, the state mean ratio was 69:1552, or 4.26% HY. This is well above the long term average and second only to 2000. Average percent HY by PSU was 3.687% statewide for data after 10 July (std. dev. = 6.523, n = 47) or 3.031% after 20 July (std. dev. = 3.031, n = 36). Regional patterns of %HY by PSU was similar to the numeric ratio in Table 5 except that northern Oregon had 3.25% HY due to one sample skewing results upwards.

Oceanographically, 2001 was characterized by strong upwelling indices and high primary productivity. Evidence of 'a good year' were noted by the frequent sightings of sub-adult salmon rolling at the surface and exceptionally large and frequent schools of anchovy along the southern Oregon and northern California coast. Southern Oregon had the highest indices of productivity as well (Table 5). Returns of several salmon species to the Columbia and other river systems were at high levels, similar to the record 2000 season.

The density of Marbled Murrelet fledglings at sea was similar to the mean since 1996 (Table 6). Density of Common Murre fledglings has been high since 1999, corresponding with annual upwelling indices, but there was little relationship between upwelling and fledgling density for the other species.

DISCUSSION

This is the second year of notably high upwelling indices and corresponding higher productivity indices of the Marbled Murrelet. Murrelet abundance remained low relative to the early 1990's, but for the first year since 1992 showed some signs of increase or at least stabilization. This is consistent with the hypothesis submitted by Strong (2000) that, if nesting habitat loss in earlier decades has caused a population decline through the 1990's, the population may stabilize at a new, lower level supported by remaining habitat, and productivity indices would rise to a level supporting the maintenance of current numbers. It is not possible with present data to separate effects of elevated marine productivity from adequate nesting habitat for the remaining population on the higher productivity indices. A few more years of population estimates and greater annual variability in marine conditions should provide the basis for answering this question.

The offshore subunit sampling area would appear to be excessively large based on the past two years since the Effectiveness Monitoring design was instigated. Certainly a 3000 meter outer sampling limit would have been adequate to sample waters containing over 99% of the entire population from these observations in the past two years. However, there does appear to be a relation of seasonal primary productivity to murrelet distribution In which the birds scatter more broadly over the inner shelf waters during in times of low productivity, and concentrate close to shore in high productivity years (Ainley et al. 1995, Strong 1996, Strong et al 1995). With the onset of a mild ENSO event predicted for the coming year (or following year in Oregon), we may both test the hypothesis above and the adequacy of the outer limit of the sampled area.

Zone 4 population estimates varied more drastically than in Zone 3 both between methods and between years (Table 3). There is high geographic variability in distribution of murrelets in Zone 4 stratum 1, particularly in the Oregon portion. Even with a high level and even distribution of sampling, variance for the region would be expected to remain high. Based on prior observations in June and July, sampling in 2001 was biased towards coverage of high density areas and missed some low density areas, thus the population estimates may not be wholly reliable.

It would be of great value to have other means of population and productivity monitoring to evaluate the conclusions from these at-sea surveys. Radar monitoring of a few selected drainages in Oregon could provide a cost effective means of assessing change in the nesting population of murrelets on a small scale. Radar surveys from 1996 to 1999 can be used as a baseline by which to assess more recent changes (Cooper et al. 2000).

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Table 1. Summary of survey effort during June, July (the population assessment period), and August (data from July were used in productivity assessment as well as population). Extra surveys were conducted in nearshore waters as time allowed to better describe distribution and age ratios.

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 stratum 1	645	328	8	39	2	223.2	5	-	0
stratum 2	934	730	19	51.5	3	260.2	7	54.2	7
Total Z 3	1,579	1,058	27	90.5	5	483.6	12	54.2	7
Zone 4 (Oregon)	528.5	194	8	11	1	156	6	23.9	3
All	2,107.5	1,252	35	101.5	6	639.6	18	78.1	10

Table 2. Summary of daily survey coverage, Marbled Murrelets detected, and age ratios for the Oregon coast during 2001. Refer to Fig. 1 for PSU locations. EX following PSU number indicates extra inshore survey effort at 400-800 m offshore.

Date	Zone	Stratum	PSU	Transect length (km) inshore	Transect length (km) offshore	Total murrelets Detected Inshore	Total murrelets Detected offshore	Known-age Murrelets AHY	Known-age Murrelets HY
June 6	3	1	7	20	23.6	26	0	23	0
6	3	2	8	20	17.2	45	1	45	0
7	3	2	11	20	17.2	124	17	129	0
8	4	1	1	20	6.0	146	4	124	0
8	3	2	17	20	17.2	19	1	15	0
8	3	2	16	20	17.2	15	10	15	0
8	3	2	16EX	7.5	-	8	-	8	0
9	3	2	15	20	17.2	93	4	85	0
19	4	1	9	20	6.0	19	0	19	0
19	4	1	9EX	11	-	15	-	15	0
20	3	2	13	20	17.2	35	0	32	0
20	3	2	14	20	17.2	137	2	131	1
21	3	1	4	20	24.6	4	0	2	0
21	3	1	5	20	24.6	19	6	24	1
22	3	1	6	20	24.6	5	4	7	0
23	3	2	9	20	17.2	65	3	53	0
23	3	2	10	20	17.2	89	3	74	6
25	3	2	11	20	17.2	106	0	63	0
25	3	2	12	20	17.2	21	1	20	0
26	4	1	3	20	6.0	15	0	14	1
26	4	1	4	20	6.0	10	0	9	1
July 7	3	1	1	20	24.6	14	0	14	0
12	3	2	10	20	17.2	15	2	14	1
13	3	2	8	20	17.2	16	0	12	0
13	3	2	9	20	17.2	43	0	35	8
14	4	1	10	20	17.2	19	0	17	0
15	4	1	6	10	3.0	0	0	-	
16	4	1	5	20	6.0	5	2	4	0
18	4	1	1	20	6.0	62	1	48	9
19	3	2	12	20	17.2	45	0	30	4
19	3	2	13	20	17.2	66	2	63	4
20	3	2	14	20	17.2	100	3	65	3
20	3	2	14EX	19	-	126	-	119	1
21	3	2	11	20	17.2	127	0	108	2
21	3	2	11EX	25	-	447	-	325	5
27	3	1	3	20	24.6	7	0	7	0

Table 2, continued.

Date	Zone	Stratum	PSU	Transect length (km) inshore	Transect length (km) offshore	Total murrelets Detected Inshore	Total murrelets Detected offshore	Known-age Murrelets AHY	Known-age Murrelets HY
27	3	1	4	20	24.6	2	0	2	0
28	3	1	4EX	20	-	0	0	-	
28	3	1	5	20	24.6	47	0	40	1
29	3	1	5EX	19	-	38	-	36	0
29	3	1	6	20	19.8	0	0	-	
August 5	3	2	9	20	17.2	30	1	23	0
6	3	2	15	20	17.2	70	0	62	1
6	3	2	15EX	10	-	29	-	24	1
6	3	2	16	20	17.2	32	-	30	0
6	3	2	16EX	10	-	1	-	1	0
14	4	1	8	20	6.0	9	2	8	1
14	4	1	9	20	6.0	62	3	54	1
14	4	1	9EX	11	-	19	-	18	0
15	4	1	6	20	6.0	28	5	33	0
15	4	1	7	20	6.0	4	0	0	0
16	4	1	1	20	6.0	43	2	36	4
16	4	1	1EX	4.9	-	28	-	24	3
16	4	1	2	20	6.0	76	2	72	4
16	4	1	2EX	8	-	3	-	3	0
17	3	2	11EX	10	-	39	-	37	2
17	3	2	12	20	17.2	31	0	22	0
17	3	2	12EX	5.2	-	25	-	21	1
17	3	2	13	20	17.2	17	0	12	0
17	3	2	14EX	3	-	14	-	7	0
18	3	1	7	20	24.6	1	0	1	0
18	3	2	8	20	17.2	16	0	16	0
19	3	2	10	20	17.2	87	0	64	11
19	3	2	10EX	5	-	4	-	4	0
24	3	1	4	20	24.6	3	0	2	1
25	3	1	5	20	24.6	4	0	3	0
25	3	1	6	20	24.6	9	0	4	1
26	3	1	1	20	24.6	0	0		
26	3	1	2	20	24.6	0	0		

Table 3. Marbled Murrelet estimates of density and population size in Conservation Zone 3 and the Oregon portion of Zone 4 during 2000 and 2001, using 100 m wide strip transects and line transects. Line transect estimates are from Bentivoglio 2002 and Jodice, 2002 for 2001 and 2002, respectively.

	Strip Transect			Line Transect		
Year and region	Density	Std. error	Pop. est.	Density	Std. error	Pop. est.
2000						
Zone 3 stratum 1	1.071	0.842	691	1.531	0.448	988
Stratum 2	5.287	1.252	4,938	6.158	1.878	5,752
Zone 3 total	3.662	0.782	5,629	4.268	1.271	6,740
Zone 4, Oregon	4.375	1.999	2,312	5.973	1.403	3,151
2001						
Zone 3 stratum 1	1.350	1.204	871	1.629	0.434	1,051
Stratum 2	6.213	2.862	5,803	6.241	1.001	5,829
Zone 3 total	4.338	1.666	6,673	4.358	0.662	6,880
Zone 4, Oregon	6.251	4.186	3,304	4.648	2.173	2,453

Table 4. Marbled Murrelet densities (birds/km^2) in the inshore waters (250 to 1200 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	2528	16.23	13	14.78	22.08	10

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)	23/795	(2.81)	14/262	(4.895)	39/1144	(3.23)
2001*	2/111	(1.77)	44/1110	(3.81)	23/331	(6.52)	69/1552	(4.26)

* Including all data after 10 July.

Table 6. hatch-year (HY) densities of 4 alcid species along 3 regions of the Oregon coast during August, 1996 - 2001. KM is the kilometers of survey effort of inshore waters on which the density was based.

		Species			
	KM	Common Murre	Pigeon Guillemot	Marbled Murrelet	Rhinoceros Auklet
1996					
Northern	136	0.59	0.22	0.51	0.37
Central	556	0.79	0.22	0.38	0.13
Southern	138	0.81	1.38	1.38	0.19
STATE	830	0.76	0.41	0.57	0.18
1997					
Northern	91	0.67	1.47	0.53	0.13
Central	163	2.23	1.75	0.56	0.28
Southern	160	4.34	1.03	1.25	0.22
STATE	414	2.70	1.41	0.82	0.22
1998					
Northern	146	14.00	0.64	0.77	0.90
Central	264	1.07	0.68	0.64	0.61
Southern	126	0.00	0.19	0.58	0.29
STATE	536	4.34	0.55	0.66	0.61
1999					
Northern	198	22.22	0.70	0.35	0.50
Central	298.5	20.77	1.21	0.69	0.74
Southern	141	29.35	1.70	0.50	0.28
STATE	637.5	23.19	1.16	0.54	0.56
2000					
Northern	120	18.25	0.68	0.17	0.15
Central	218	36.97	1.01	2.34	0.28
Southern	140	14.20	1.50	1.36	0.71
STATE	478	25.60	1.07	1.51	0.37
2001					
Northern	120	5.08	0.83	0.17	0.25
Central	178	45.56	1.07	0.90	0.11
Southern	144	29.24	0.35	0.97	0.14
STATE	442	29.25	0.77	0.72	.16

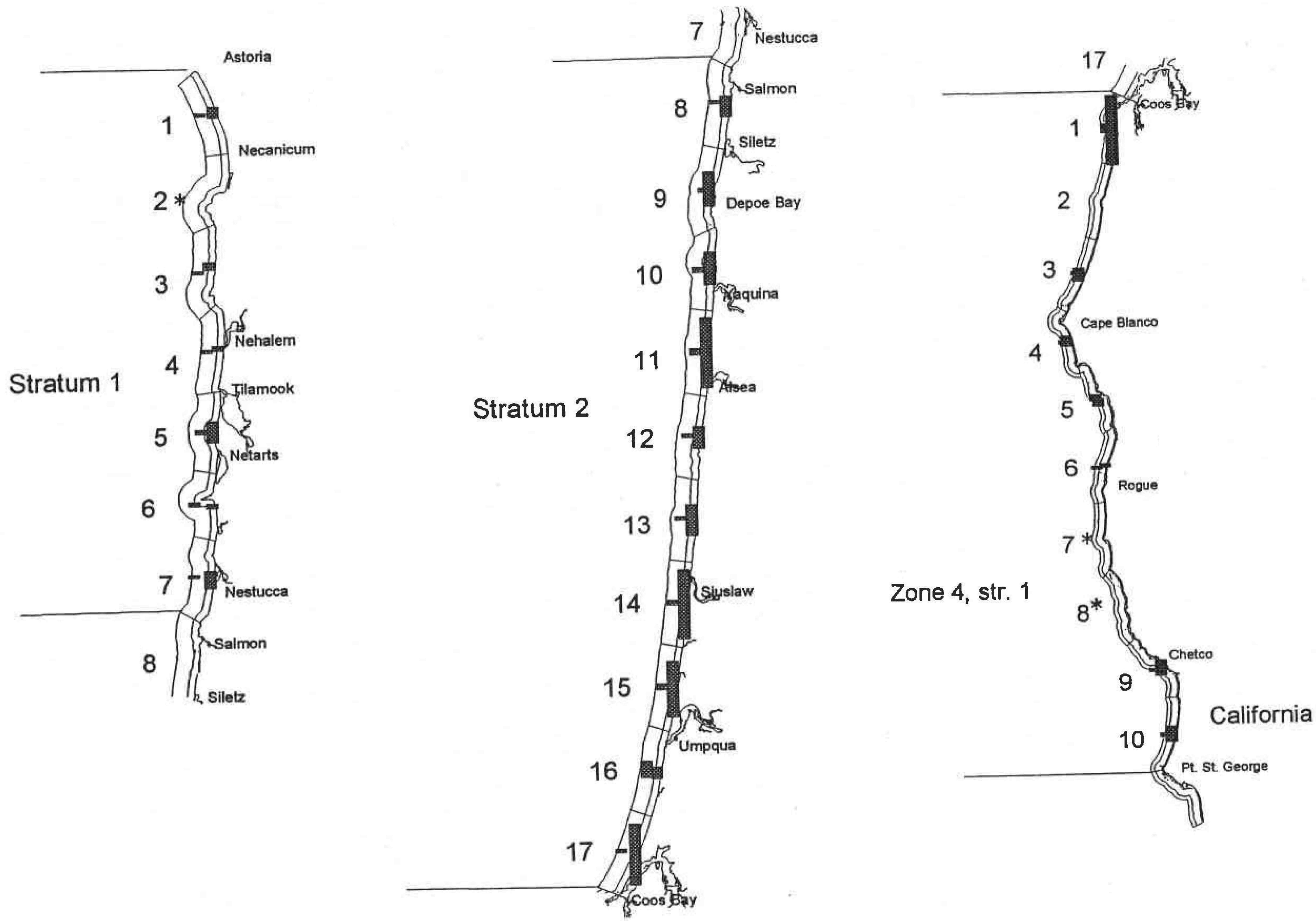

Figure 1. The Oregon coast showing Primary Sampling Units (PSU) in two strata of Conservation Zone 3 and the Oregon portion of Zone 4. Rectangles in the PSU represent mean relative densities of Marbled Murrelets from strip transects in inshore and offshore subunits of each PSU during June and July. Asterisks indicate PSU not sampled.

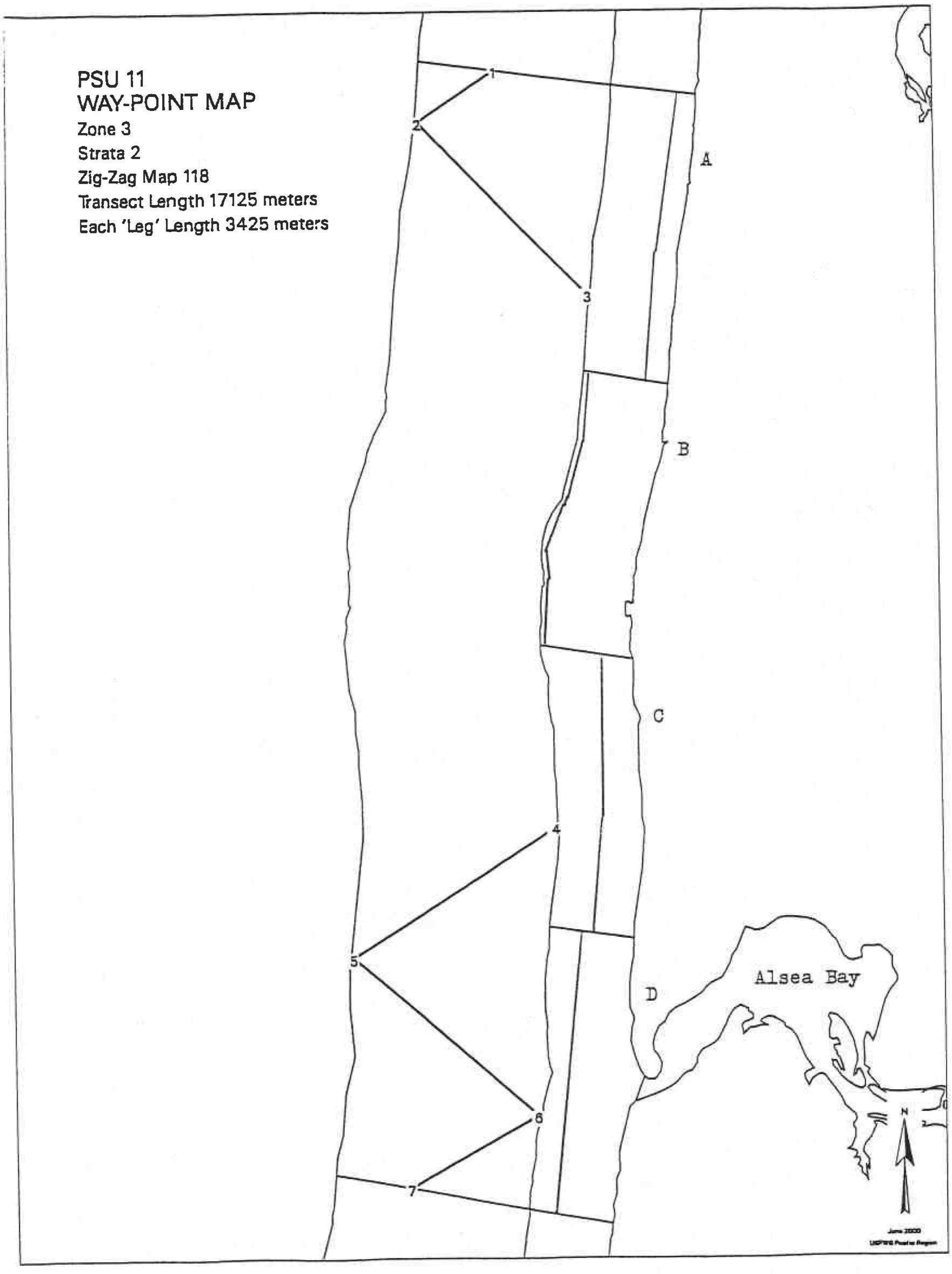

Figure 2. An example of stratified-random transect lines within 5 km long near shore subunit segments (A - D), and off shore subunit zig-zag sampling with a random starting point.