DISTRIBUTION OF MARBLED MURRELETS ALONG THE OREGON COAST IN 1992

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ABSTRACT—Strip transects from boat and light aircraft were used to quantify the distribution and abundance of marbled murrelets (*Brachyramphus marmoratus*) along the length of the Oregon coast. Murrelets were abundant in central Oregon between Newport and Coos Bay, with observed densities averaging 78 birds/10-km by 100-m strip (N = 90, SE = 5.9). Murrelets were relatively scarce north of Lincoln City ($\bar{x}$ = 6.8 birds/10-km by 100-m strip, N = 32, SE = 1.2), with small concentrations near coastal State Parks that contained old-growth forest stands. Murrelet abundance was variable from Coos Bay to the California border ($\bar{x}$ = 28.4, N = 22, SE = 5.9). Highest densities occurred in a narrow band and decreased sharply at > 1 km from shore. There was evidence of a northward and offshore shift of the population late in July, which may have been related to a prey shift from surf smelt (*Hypomesus sp.*) to Pacific sandlance (*Ammodytes hexapterus*) or to post-breeding dispersal. The abundance of marbled murrelets seen during this study suggests that the population in Oregon is higher than previously estimated.

Marbled murrelets (*Brachyramphus marmoratus*) are small diving seabirds that have the unique adaptation of flying inland to nest in large trees along the west coast of North America (Marshall 1988, Hamer and Nelson 1995a). At sea, marbled murrelets occupy inland passages, bays, and near-shore waters of the open coast; they rarely are seen over 3 km from shore (Sealy 1975b, Carter 1984, Carter and Sealy 1990, Rodway et al. 1992, Ralph and Miller 1995). Because detection and quantification of marbled murrelets is very difficult in their forest nesting habitat, surveys of the birds at sea is presently the most effective and accurate means of assessing population size and distribution. The need for information on abundance and distribution of marbled murrelets was accentuated by the species' listing as federally threatened in October 1992 (U.S. Fish and Wildlife Service 1992).

All of the 3 prior at-sea studies of marbled murrelets in Oregon (summarized in Nelson et al. 1992) were made along short sections of the coastline, and each study used different methods and observation vessels, making comparison difficult. Besides those at-sea counts, numerous observations from shore of marbled murrelets in Oregon have been made over the years (Nelson et al. 1992, Nelson and Hardin 1993). To this point, information on population size and distribution in Oregon has been derived from inland and shore-based observations and the work of Varoujean and Williams (1995).

Based on vessel and aerial transects, preliminary results of the first state-wide surveys of marbled murrelets along the Oregon coast are presented here. This ongoing research is directed towards establishing a population estimate and monitoring protocol for the species in Oregon.

METHODS

Vessel Surveys

A 6-m Boston Whaler powered by 2, 70-hp outboard motors was used for all surveys. A driver and 2 observers operated the boat. 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. Marbled murrelets sighted at any distance were reported, all other seabirds were reported when within 50 m of the boat and on the water (terns and pelicans were also recorded when flying). Data collected on murrelet detections included time of sighting, distance from the vessel, group size (defined as birds within 2 m of each other), side of vessel, behavior, and plumage notes. Behavior was categorized as flying from the surface in response to the vessel, flying by in transit, diving in response to the vessel, forage diving, or remaining at the surface during vessel passage. Prey taxa were identified whenever there was an opportunity to observe them sufficiently when held in birds' bills at the surface. Identifying prey in the bill was used very successfully for alcids on the Farallon Islands (Ainley et al. 1990). Distance was not reported until murrelets had either responded to the boat by flying or diving, or had passed by the boat. A bright float was deployed periodically at 50 m behind the vessel to aid in distance estimation.

Location was determined by distance travelled through the water between known landmarks on shore, using the speedometer and trip log functions on a sonar fish finder (Sidefinder brand). Speed was maintained at approximately 8 knots at all times. Other variables monitored included water temperature and depth, presence of sonar scattering layers, rip currents, type of shoreline (rocky, sandy beach, adjacent to river mouths, or a combination of the above), association of murrelets with other species, and weather conditions. Observing conditions, as they affected the detectability of murrelets, were categorized as excellent, very good, good, fair, and poor, corresponding to Beaufort sea states of 0, 1, 2, 3, and 4, respectively. Swell, difficult lighting, and fog were also noted when they reduced the quality of observing conditions by category. Transects were not initiated at Beaufort state 3 (fair observing conditions) and transects were terminated at Beaufort state 4 (poor observing conditions). To reduce observer fatigue, the driver alternated with observers periodically, and a rest stop was taken at least every 3 hr. To quantify distribution along the length of the Oregon coast, transect lines were run parallel to the shore at 200 to 500 m from shore, the area where murrelet abundance appeared highest based on the offshore, intensive transects (see below). These transects typically were run between 2 ports, located 25–140 km apart. A support person on shore drove the trailoring vehicle to the destination port and maintained radio contact with the boat.

To quantify distribution in relation to distance from shore, repeated transect lines parallel to the coast, 3–5 km in length, were run at increasing distance from shore. We travelled perpendicular to the coast for 300–500 m out to sea between adjacent transect lines. When no murrelets were detected on the water for a full transect line we ended the survey and assumed an insignificant number of birds occurred beyond that transect line. This resulted in surveys of varying distance out to sea on different days, with less coverage of the areas farther offshore. No transect lines were run beyond 3 km. For these surveys, coastal sections were selected at various locations between Boiler Bay and Heceta Head in central Oregon (Fig. 1).

All information was recorded on audio tape recorders via an external microphone, passed between observers. Because speed was held nearly constant, time on transect could be converted to distance travelled between known land marks for murrelet density calculations.

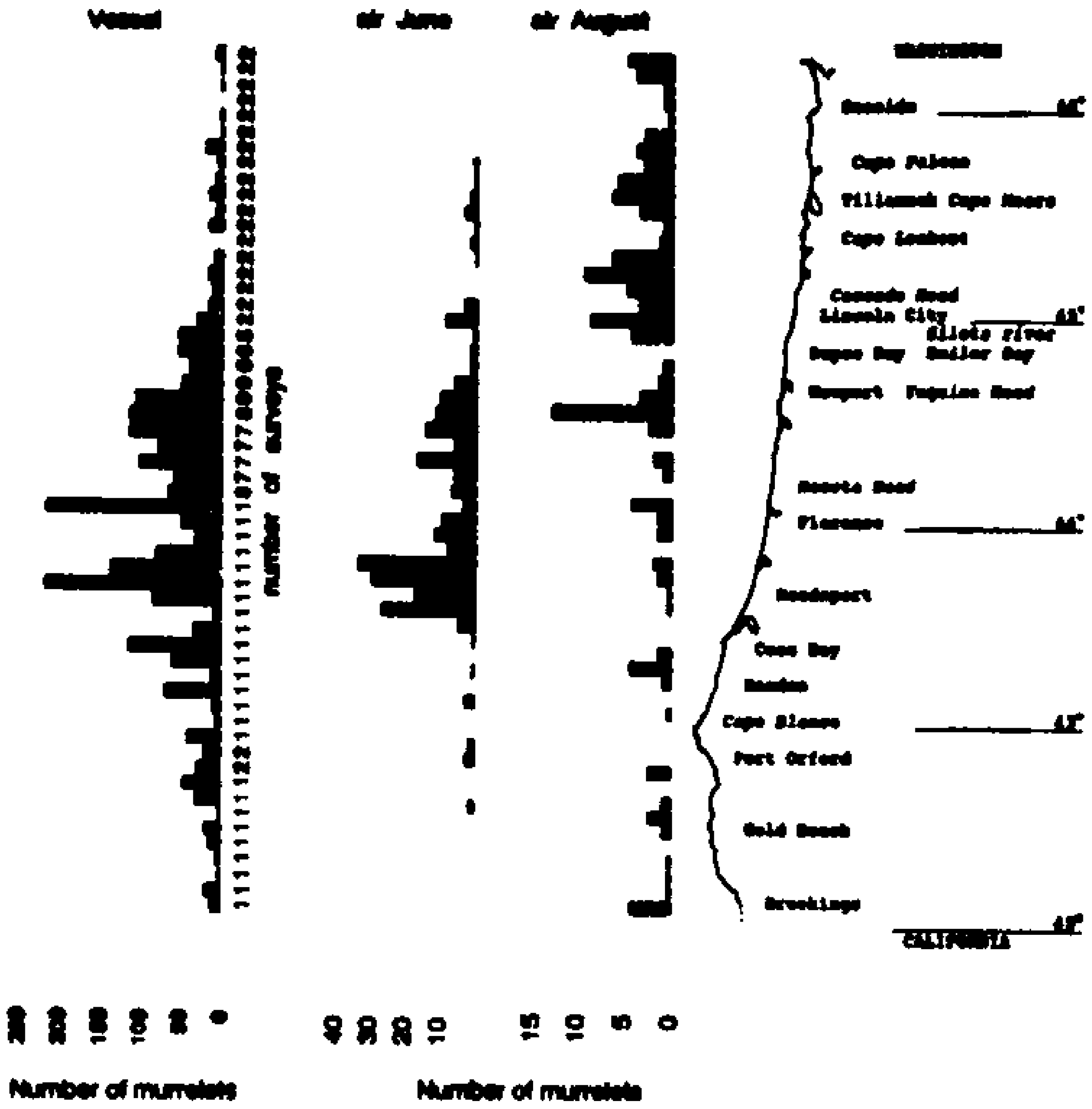

FIGURE 1. Density of marbled murrelets in 10-km by 100-m strip transect segments of the Oregon coast. Vessel transects were run between 1 June and 12 August 1992. Numbers under bars indicate number of times each 10-km section was surveyed. Aircraft transects at 60 m altitude were run in June and August 1992.

Aerial Surveys

A single engine over-wing Cessna 187 or 206 aircraft was used for aerial surveys. On board we used 2 tape recorders with remote microphones, an inclinometer, digital watches, and maps of the coast. Two observers, a navigator, and the pilot were on board for all surveys. The pilot attempted to maintain an altitude of 60 m and a speed of 90 knots, except when a tailwind required speeds of up to 105 knots. Distance from shore was maintained at an estimated 300 m (approximately the same as for vessel transects) except when passing seabird nesting islands, where a wide berth was given (> 800 m) to avoid disturbance. The navigator, sitting in the right front seat, requested speed, altitude, and shore distance adjustments of the pilot when necessary, and recorded time to the second when passing landmarks on shore. Observers on either side of the aircraft continuously scanned a 50-m corridor of ocean surface that was calculated as an angle between 32° and 57° off horizontal. While maintaining their scan of the water surface, observers recited the number and species of birds seen and the time to the nearest 10 seconds, and recorded observing conditions.

Data Analysis

Statistical tests were performed using NCSS (Hintze 1992). Nonparametric tests were used in analyses

TABLE 1. Prey taxa identified in seabird bills on the water between 7 June and 12 August 1992.

Date	Location	Seabird species	Prey type
7 Jun	North of Heceta Head	Common Loon	Surf Smelt
15 Jun	South of Seal Rocks	Marbled Murrelet	Smelt sp.
15 Jun	North of Yachats	Marbled Murrelet	Smelt sp.
25 Jun	North of Seaside	Common Murre	Smelt sp.
25 Jun	North of Seaside	Common Murre	Smelt sp.
26 Jun	North of Cape Lookout	Common Murre	Smelt sp.
26 Jun	North of Cape Lookout	Common Murre	Smelt sp.
27 Jun	North of Heceta Head	Common Murre	Sandlance
14 Jul	Seaside	Common Murre	Smelt sp.
1 Aug	North of Newport	Common Murre	Sandlance
1 Aug	Boiler Bay	Marbled Murrelet	Sandlance
2 Aug	South of Newport	Marbled Murrelet	Sandlance
2 Aug	South of Newport	Heermanns' Gull	Sandlance
10 Aug	Otter Rock	Common Murre	Sandlance
11 Aug	South of Tillamook	Common Murre	Sandlance
11 Aug	South of Tillamook	Common Murre	Sandlance
11 Aug	South of Cape Lookout	Marbled Murrelet	Sandlance
11 Aug	North Cascade Head	Marbled Murrelet	Sandlance

(Kruskal-Wallis ANOVA) with a critical value selected at 0.05 for all tests.

RESULTS

Vessel transects were run on 37 days between 31 May and 12 August, on almost all days when observing conditions allowed. Of these, 27 days were used in distribution analyses. Aerial transects were flown on 23 and 24 June and on 4 and 5 August.

State-Wide Distribution

Using the at-sea data, the average daily observed densities varied from 6 murrelets/km^2 (SE = 0.6, N = 4 survey days) in the north to 71.1/km^2 (SE = 8.7, N = 15 survey days) in the central part of the state. Marbled Murrelets were relatively scarce north of the Siletz river mouth (44° 54′ N, 124° 02′ W), with small concentrations occurring near Cape Falcon, Cape Lookout, Cape Meares, and Cascade Head (Fig. 1). The species was abundant in central Oregon between the Siletz River mouth and Coos Bay (43° 20′ N, 124° 19′ W), with observed densities ranging from 31 to 218 birds/10-km by 100-m strip segment. Observed densities were variable off the southern Oregon coast, with high numbers counted north of Bandon, near Port Orford, and just north of the California border (Fig. 1).

Observed densities of marbled murrelets were much lower as measured by aerial surveys than from the boat ($\bar{x}$ = 9.9 birds/10-km by 100-m), but the distribution of birds in June was similar between aerial and boat surveys (Fig. 1). The aerial surveys on 23 and 24 June took place in windy and foggy conditions, which resulted in incomplete state-wide coverage and undoubtedly limited the number of birds seen. The August aerial surveys took place in ideal conditions. In August, there were very few birds south of Port Orford, and as many birds at the north end of the state as in central Oregon (Fig. 1). High survey speed was considered the primary reason for fewer detections and thus lower observed densities on aerial *vs.* vessel surveys.

Seasonal Changes in Distribution

Both aerial and vessel survey data indicated that there was a northward shift in abundance of murrelets near the end of July. Six transects off the central Oregon coast from Newport to Florence (72 km) between 7 June and 13 July averaged 722 birds (SE = 51) on the water within 50 m of the vessel. On 23 July, 447 birds were counted in this area, and on 2 August only 145 birds were seen, representing a 500% decrease between the first 6 wk and the last 2 wk of the study (observing conditions were similar on all surveys; very good to excellent). Conversely, counts of the 85-km section between Tillamook Bay and Lincoln City in northern Oregon increased from 63 birds on 26 June to 123 birds on 11 August. Aerial surveys also showed a pronounced northward shift between June and August (Fig. 1). The observed change in distri-

TABLE 2. Number of marbled murrelets counted during transects parallel to shore at increasing distances from shore. Flying birds were not included.

		Distance offshore									
		<500		500–990		1000–1490		1500–1990		2000+	
Date	Time	km	*N*	km	*N*	km	*N*	km	*N*	km	*N*
15 Jun	1130–1230	5.3	73	3.5	32	5.0	0				
28 Jun	0840–1000	6.5	52	7.0	52	5.8	7				
28 Jun	1200–1240	3.4	15	4.6	24	4.2	0				
12 Jul	0710–1040	7.2	151	9.6	72	3.3	7	5.0	1		
16 Jul	0730–0800	5.8	43	3.6	3	3.4	0				
01 Aug	1020–1150	3.8	34	5.5	69	3.8	16	3.6	12	3.8	4
07 Aug	0900–1050	22.6	47	9.4	17	4.0	0				
10 Aug	0900–1050	4.3	36	4.1	35	6.5	12	3.6	3	3.8	0
Average birds/km		7.66		6.43		1.17		1.31		0.53	

bution occurred when there was an apparent switch in prey species for many seabirds. On the few occasions when we could determine prey species (from birds that remained at the surface with portions of their catch visible in the bill), we noted that surf smelt (*Hypomesus sp.*) were taken until late July. After 15 July, Pacific sandlance (*Ammodytes hexapterus*) were the only prey seen (Table 1).

Offshore Distribution

Marbled murrelet abundance decreased sharply in the 1st kilometer and was very low beyond that (Table 2). In central Oregon, murrelets were more abundant and concentrated close to shore early in the season. The apparent shift in distribution offshore took place in the same time period as the movement to the north, between 25 July and early August.

Relation to Shore Type and Environmental Parameters

There was a significant difference in the number of murrelets occurring offshore from 4 categories of shore types ($\chi^2 = 22.4$, df = 3, $p<0.001$, sample area between Newport and Florence). Mixed rock and sandy shorelines had the most birds offshore (11.8 murrelets/km), followed by sandy beach (9.3/km), and rocky or within 3 km of a major river mouth (6.8/km each). Marbled murrelets were consistently scarce around the rocky shoreline of Heceta Head and Cape Foulweather. Their distribution along beaches or mixed rocky and sandy shorelines was highly variable, both within days at different locations and between days at the same location (Fig. 2).

The near-shore bathymetry of most of the Oregon coast is monotonous, with a gradual sandy slope. The along-shore transects were carried out at depths of 4–7 m, and there was no apparent relation between murrelet abundance with water depth, when accounting for distance from shore. We did not note any change in distribution due to tide or time of day, and there were no large movements of murrelets flying by on any of our surveys.

Detection Distance

The number of murrelets reported decreased at increasing distance from the vessel (Fig. 3). Distances were reported when birds responded to the boat or were passed, not when the birds were first sighted. There was a bias against birds being reported at < 20 m, because they usually responded to the vessel between 10–40 m. This had the affect of increasing the number of detections reported at the 20–40 m distances. The decrease in number of birds beyond 50 m likely represents a true decrease in detection of birds. The number of birds reported was not significantly different for different observing conditions ($\chi^2 = 6.2$, df = 3, $p = 0.1$), because numbers were highly variable (Fig. 2) and we had small samples in fair or poor conditions. The average distance at which birds were reported, however, was greater in good to excellent conditions (57–62.7 m) than in fair or poor conditions (46 and 20 m, $\chi^2 = 13.3$, df= 4, $p = 0.004$). Because only 8% of the observations took place in fair or poor conditions and only observations up to 50 m were used in density calculations, these data were quite robust with respect to viewing conditions.

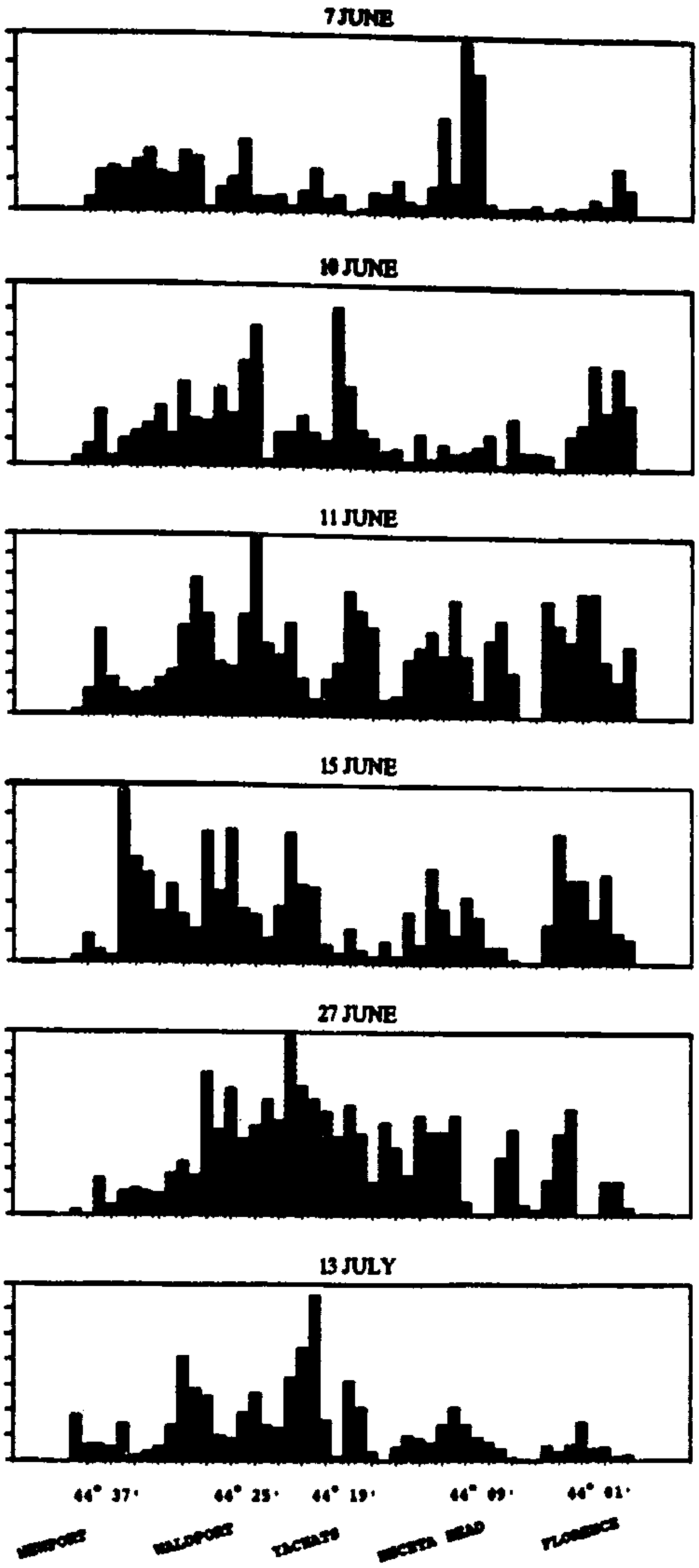

FIGURE 2. Number of murrelets seen in 1.6-km intervals from Newport to Florence (72 km) on 6 days between 7 June and 13 July 1992. The total number counted on the water within 50 m of the vessel on each day was 868, 643, 567, 629, 784, and 842, respectively .

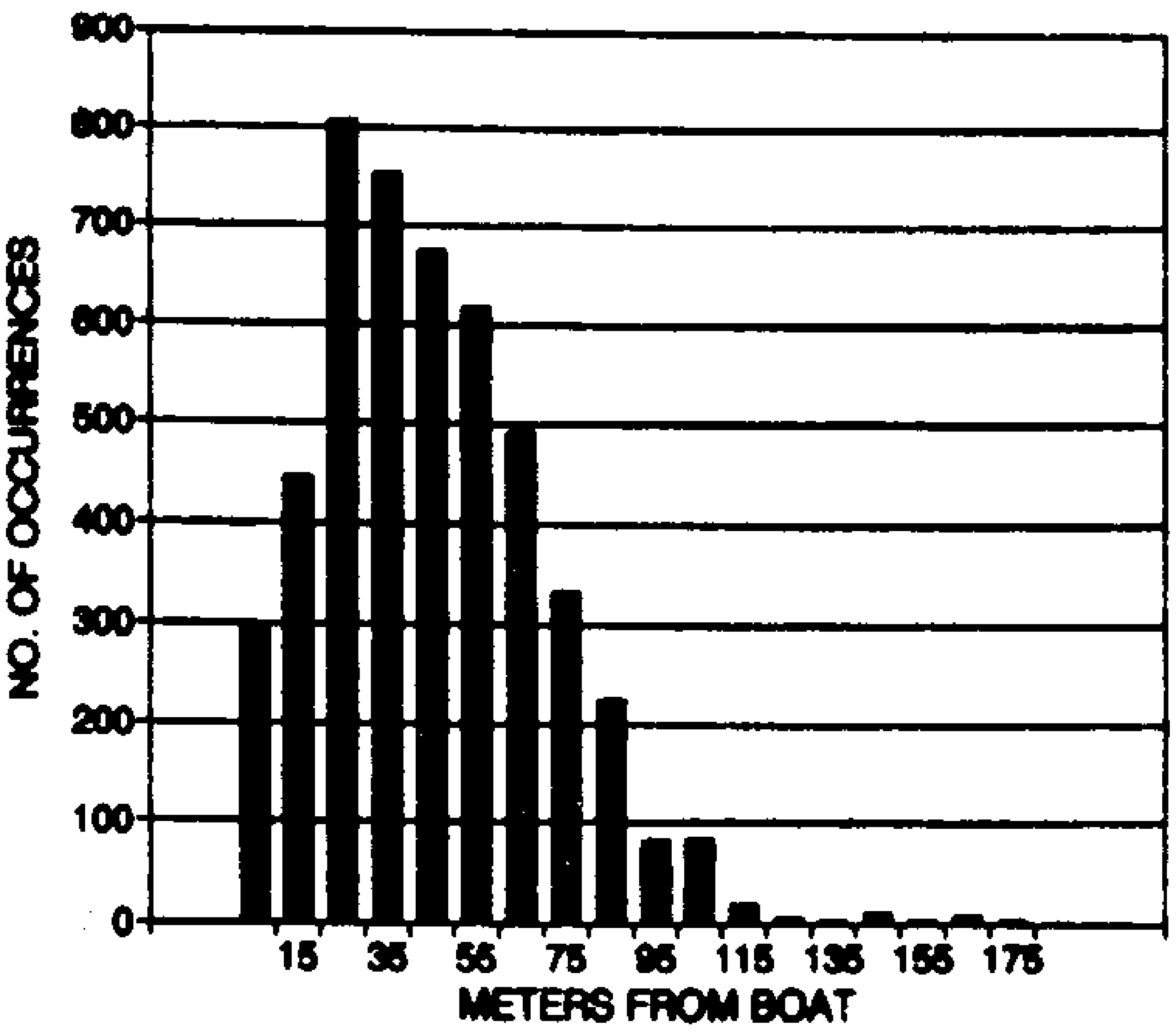

FIGURE 3. Distance from the boat at which murrelet sightings were reported. Distance was reported after birds responded to the boat or were passed by the boat.

Behavior

Marbled murrelets did not feed within multispecies flocks, and where these flocks were present, murrelets were scarce. Murrelets were considered in a 'group' if individuals were seen less than 2 m from one another. They almost always occurred as single birds or in pairs (Fig. 4). The largest group recorded was 15 birds. Murrelets were very sensitive to the passing vessel. Of 4721 detections where behavior was tabulated, 1103 (23.6%) dove and 725 (15.4%) flew in apparent avoidance of the boat. However, almost all responses to the vessel occurred at less than 50 m, so we were unlikely to miss birds due to their reaction to the boat (flying or diving).

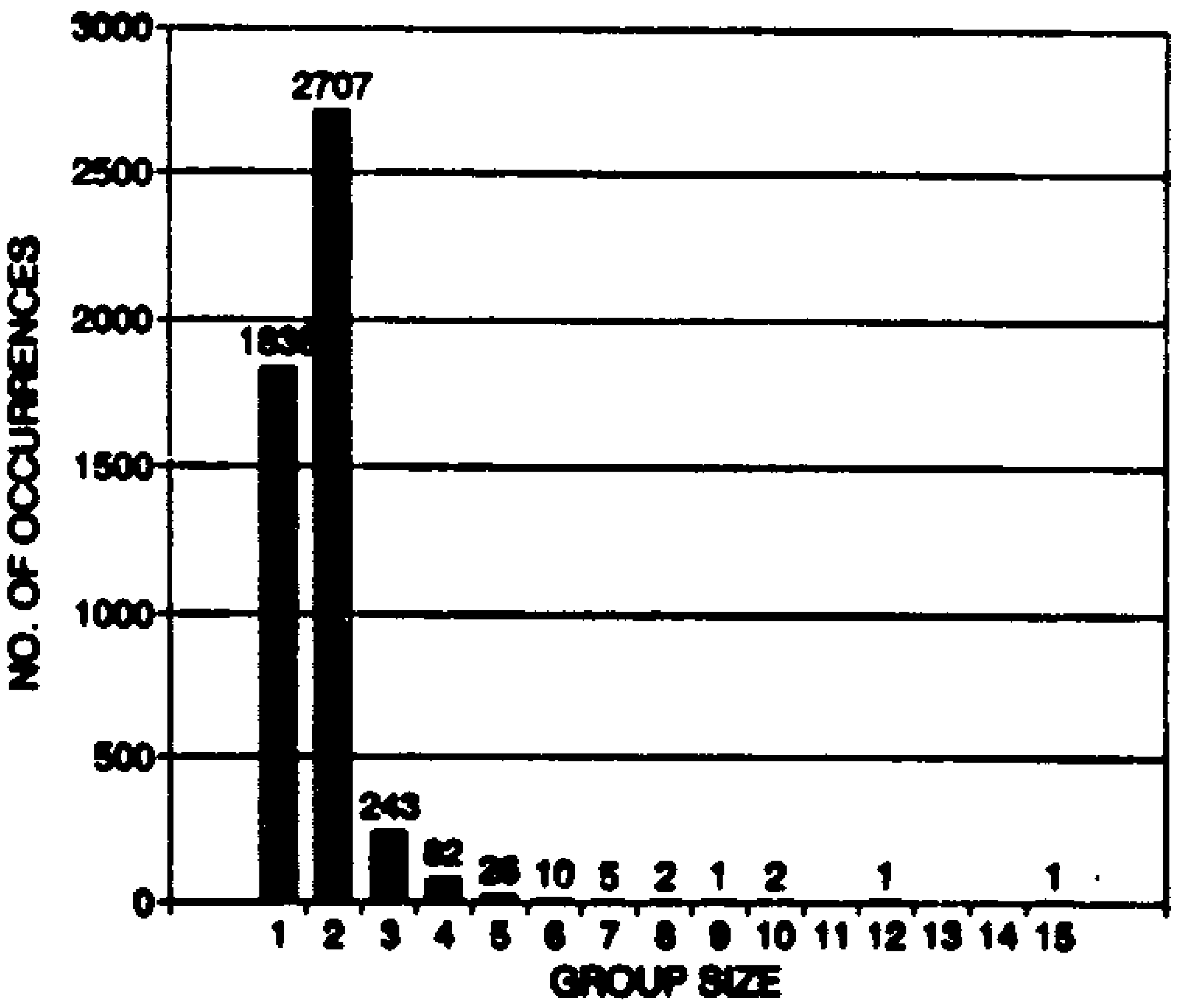

FIGURE 4. Occurrences of marbled murrelets by group size ($N = 4918$ group detections). Groups were defined as birds within 2 m of one another.

Population

A minimum marbled murrelet population on the Oregon coast resulting from these surveys was 3012 birds. This was the sum of all birds counted while on extensive coastline transects, averaging the numbers for repeated coastal sections, and not including transects after 23 July, when a shift in distribution was apparent. This was the number of birds actually counted within 500 m of shore. This figure does not account for birds farther out to sea (Table 2), or for additional birds within the 500 m that were not detected, therefore this count probably does not represent the total population.

One possibility of double-counting exists. Of the 15.4% of birds that flew in response to our vessel, some flew in the same direction and may have landed within detection distance of our transect line and been recounted. However, marbled murrelets take off into the wind, and we typically travelled south with the wind on our transects, so the proportion of flying birds that could be double counted was assumed to be small. Between days, murrelets were equally likely to move out of areas to be counted as into them in their shifts along the coast (Fig. 2), so we did not correct for these movements.

TABLE 3. Number of fledglings seen on each vessel survey day between 7 June and 12 August 1992. Total indicates number of adult and fledgling murrelets at all distances (assuming fledglings have an equal likelihood of being detected).

Date	Latitudes surveyed	Total	Fledglings	% fledglings
7–14 June (no fledglings seen)				
15 Jun	44°37′–44°01′	730	1	0.14
16 Jun	44°01′–43°20′	996	1	0.10
19 Jun	42°45′–42°30′	33	0	—
25 Jun	45°38′–46°04′	48	2	4.17
26 Jun	45°38′–44°45′	75	2	2.68
27 Jun	44°37′–44°01′	1245	1	0.08
28 Jun	44°37′–44°47′	310	2	0.06
12 Jul	44°45′–44°37′	370	13	3.51
13 Jul	44°37′–44°01′	1239	1	0.08
14 Jul	46°12′–45°34′	60	1[a]	1.67
18 Jul	44°37′–44°47′	170	5	2.94
19 Jul	43°20′–42°45′	656	6	0.91
20 Jul	42°03′–42°45′	311	13	4.18
23 Jul	44°37′–44°01′	642	3	0.47
30 Jul	44°37′–44°57′	90	3	3.33
1 Aug	44°37′–44°47′	159	9	5.67
2 Aug	44°37′–44°01′	367	1	0.27
3 Aug	44°45′–44°55′	86	7	8.74
6 Aug	44°01′–44°25′	143	1	0.70
10 Aug	44°37′–44°47′	277	11	3.97
11 Aug	45°34′–44°45′	194	31	15.98
12 Aug	44°37′–44°21′	124	1	0.81

[a]probable

Productivity

Fledgling marbled murrelets were easily distinguished from after-hatch-year birds during the study period by their bright white underparts, throat, neck, and scapulars. We noted after-hatch-year murrelets beginning molt by mid-July, but when our surveys ended on 12 August, fledglings were still readily distinguished with crisp plumage and sharp contrasts between the black back and white scapulars, neck, and belly. The number of fledglings was very low all season, with most being seen at the end of the study period (Table 3). The high number of fledglings seen in the north on 11 August coincided with an increase in after-hatch-year murrelets in the north (see *Seasonal Changes in Distribution*). It is likely that those fledglings had moved with older birds along the coast from their nesting areas.

In the 35 km between Newport and Boiler Bay, fledglings were concentrated in 3 areas: on the south side of Yaquina Head (44° 40′ N, 124° 05′ W), near Otter Rock and Devil's Punchbowl (44° 44′ N, 124° 04′ W), and around Boiler Bay (44° 50′ N, 124° 04′ W). Of these, the south side of Yaquina Head most consistently had fledglings present. Fledglings were never abundant on the 74-km section between Newport and Florence, though this area held consistently high numbers of after-hatch-year murrelets in June and July (Fig. 2, Table 3).

DISCUSSION

Distribution

The distribution of marbled murrelets observed along the Oregon coast (prior to 24 July) follows quite closely what has been assimilated from other surveys and from land-based observations (Nelson et al. 1992). We noted that the highest density of birds along shore usually occurred in a narrow band (< 300 m wide) that was closer to the shore (< 500 m) than average high-density areas reported by Ralph and Miller (1995). This suggests that extrapolation of density distributions offshore is not necessarily valid for different sections of coast. Distribution and movement patterns on the open Oregon coastline were different from those found in sounds and inland passages of Washington and British Columbia (Carter and Sealy 1990, Prestash et al. 1992, Rodway et al. 1995, Speich and Wahl 1995), mainly in that there appeared to be little effect of time-of-day or tide. This is likely due to the relatively small effect of tides on currents and, presumably, prey availability, on the open coast.

There is evidence that the observed northward and offshore shift in distribution late in the summer was influenced by a change in prey availability (Table 1). However, many birds were probably completing the nesting period at this same time, and the shift in distribution could be ultimately considered a post-breeding dispersal.

Abundance and Productivity

By extrapolation from survey data near central Oregon harbors, Varoujean and Williams (unpubl. data) estimated 6000 marbled murrelets in Oregon (about 2500 breeding pairs). Synthesizing all available information from shore- and sea-based observations, Nelson et al. (1992) estimated that 1000 breeding pairs occurred off Oregon. The estimated overall densities of marbled murrelets reported here were higher than previously reported by Varoujean and Williams (unpubl. data): $\bar{x}$ = 52.3 birds/km^2, N = 144 km^2, compared to 12.5/km^2, N = 24.5 km^2. This suggests that the Oregon population is larger than previously suspected. However, existing data on distribution offshore limit precision and accuracy in extrapolating these data to a population estimate.

Observed densities on aerial surveys were considerably lower than on boat surveys ($\bar{x}$ = 9.9 birds/km^2), probably because most murrelets were not detected at the required aircraft speeds. Banking on turns, slight variation in altitude, and bird behavior (diving) also probably reduce the number of detections from aircraft. Aerial surveys are valuable in documenting distribution along the open coast, but appear to have limitations in estimating abundance of murrelets (Briggs et al. 1985).

To maintain their population with an annual recruitment rate represented by the number of fledglings observed in this study (Table 3), marbled murrelets would have to be exceptionally long-lived with virtually no subadult mortality (Beissinger 1995). Alternatively, fledglings may have been distributed differently from adults and were under-represented in these surveys (see Anderson and Beissinger 1995). Also, many offspring may not have fledged by the termination of the study on 12 August, resulting in the low number of fledglings observed (see Hamer and Nelson 1995b). A final possibility is that production of young was very low in 1992. In view of the loss of nesting habitat, considered the prime cause of the species' decline (Marshall 1988, U.S. Fish and Wildlife Service 1992, Kelson et al. 1995), population size and nesting success are areas of concern that should be emphasized in future studies.

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