Chapter 30

Marbled Murrelet Populations of Washington—Marine Habitat Preferences and Variability of Occurrence

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Abstract: Marbled Murrelets occur in Puget Sound marine habitats in relatively low numbers. The rates of occurrence of murrelets on censuses within marine habitats is generally low. Further analysis is required to determine if low occurrence rates are a general function of the movement of birds, or their consistent occurrence on particular censuses and not on others. Qualitative data indicate that Marbled Murrelet abundance in Puget Sound is now lower than earlier this century. Such long-term information is unavailable for Marbled Murrelets along the Pacific Ocean coast of Washington. Census data from nearshore waters of the Pacific Ocean off Grays Harbor indicate that Marbled Murrelet abundance is reduced there since 1989 and especially in 1993. This pattern is also reflected in several other more oceanic species suggesting basic and widespread changes in marine carrying capacity.

Early reports on the birds of Washington (Dawson and Bowles 1909, Jewett and others 1953) consisted primarily of interesting general accounts, whereas several recently published reports have focused specifically on marine birds in Washington (Briggs and others 1992; Cody 1973; Grover and Olla 1983; Manuwal and Campbell 1979; Manuwal and others 1979; Paine and others 1990; Speich and Wahl 1989; Wahl 1984; Wahl and Speich 1984; Wahl and Speich, in press; Wahl and others 1981; Wilson 1991). Despite these reported activities of researchers, including ourselves, little has been written of the habitat preferences of marine birds, including Marbled Murrelets, in Washington. Lately, a few general descriptions and quantifications of the abundance of marine birds based on marine habitats have appeared. While only the reports of Wahl and others (1981) and Long (1983) are pertinent to Puget Sound, and of Wahl (1984), Speich and others (1987), and Briggs and others (1992) to the Pacific Ocean coast, they only marginally included the Marbled Murrelet. The same paucity of information pertains to the foods of marine birds in Washington marine areas, with the exception of a few species specific studies (e.g., Rhinoceros Auklet [*Cerorhinca monocerata*] [Wilson and Manuwal 1986]). Little has been written that specifically deals with Marbled Murrelets in Washington marine waters (Speich and others 1992; Thoresen 1989; Varoujean and Williams, this volume).

Marbled Murrelets are found throughout the Puget Sound region, although their distribution varies spatially and temporally (Speich and others 1992; Wahl and others 1981; Wahl and Speich 1983, 1984). Speich and others (1992) attempted to establish the size of populations in each of the major marine areas of Washington, to determine if a seasonal change in numbers occurred, and to evaluate historical marine evidence for changes in the numbers of breeding birds. The results were a breeding population estimated at near 5,000 Marbled Murrelets, evidence of an influx of birds into at least Puget Sound during the winter, and an indirect conclusion that the breeding population in Puget Sound had declined from early periods, although the magnitude of the change is unknown and cannot be quantified. Our impression is that murrelets are variable in their occurrence, moving from one area to another, often in short time periods, although birds are often found in specific areas.

In this paper we quantify and discuss the seasonal geographic and marine habitat distribution, abundance and variability of Marbled Murrelets in Washington marine waters. Changes in abundance over the past 23 years of censusing continental shelf waters near Grays Harbor are explored.

Methods

The inland marine areas of Washington, better known as Puget Sound, are a complex of bays and passages, supporting a large variety of marine habitats and associated organisms (Long 1983, Simenstad and others 1979). They are connected by larger deep water areas such as the Strait of Juan de Fuca, Admiralty Inlet, Haro Strait, Rosario Strait and Georgia Strait, all distinct habitats. During the 1978 and 1979 National Oceanic and Atmospheric Administration (NOAA) Marine Ecosystem Analysis Program (MESA), marine bird surveys of northern Puget Sound (Wahl and others 1981) censuses were established and conducted. These quantified distribution and abundance of the marine birds found in all the major marine habitat types and geographic areas of northern Puget Sound. During the MESA program, northern Puget Sound was divided into 11 major regions and 72 subregions, largely based upon marine and terrestrial geography and water depth. Each subregion, and certainly each region, contained one or more distinct marine habitat types, based on water depth, marine substrate type, slope and, in part, geography. Each region, subregion and habitat type was overlain with one or more distinct marine census transects. These transects were fixed in location and were censused by one or more standardized census methods. Census methods included small aircraft, small boats, Washington State Ferries, and fixed locations at points, about bays, and along beaches. Census data were lumped by location, marine habitat, subregion and region, and time period, as appropriate. In the habitat analysis for this paper, censuses were combined by habitat type and

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time period. Densities were calculated by dividing the total numbers of Marbled Murrelets observed by the total area censused on all censuses within each habitat types for the specific time period. Data from 1978 and 1979 were combined.

Surveys similar to the MESA bird program, partially funded by NOAA and the Washington Department of Wildlife, were later established for southern Puget Sound (Wahl and Speich 1983, 1984). These surveys were designed to allow the quantification and appraisal of the general, seasonal distribution and abundance of all marine waterbird species in southern Puget Sound. This program consisted of one complete summer survey of the area and extensive winter surveys (as yet unpublished) over several years. All winter surveys were from light aircraft and summer surveys were from small boats and light aircraft following the methods set forth in Wahl and others (1981, see above). Results are expressed as birds per square kilometer and are summarized by geographic area, inshore or offshore, and time period.

There are only limited data from the Pacific Ocean coast of Washington that quantify the occurrence of Marbled Murrelets in marine habitats. The best data are for the southern outer coast, the coast south of Point Grenville, including the Grays Harbor Channel and habitats in the shelf waters off the mouth of Grays Harbor channel to the continental shelf break (Wahl 1984), and the onshore area in the vicinity of Point Grenville (Speich and others 1987, 1992). Along the north portion of the coast, the area north of Point Grenville, only limited data are available for the nearshore and offshore waters of the continental shelf (Speich and others 1992). Censuses of birds over the continental shelf, to the shelf break, off of Grays Harbor, were made from chartered fishing boats, from 1971 to the present. Census frequency, especially during the winter storm period, was often limited for access to the ocean due to rough bar and sea conditions. All birds observed were counted and summarized for transects of varying length within specific water depth intervals, and results are expressed as birds observed per linear kilometer, as described in specific detail by Wahl (1984). Observations of birds of specified nearshore water areas from three land locations near Point Grenville were accomplished with the aid of binoculars and telescopes during the spring-summer periods of 1984 and 1985 (Speich and others 1987). Observations were expressed as Marbled Murrelets observed per square kilometer for consecutive week periods. North of the Point Grenville study area, observations were made from boats (Zodiacs) while moving up and down the coast over nearshore waters of the continental shelf (Speich and others 1992). All birds observed in moving zones about the vessel were recorded, with results expressed as birds per square kilometer.

Results

Abundance and Occurrence by Habitat Types - Puget Sound

For northern Puget Sound, the seasonal densities and percent occurrence of Marbled Murrelets were determined for censuses within five broad habitat groups, each in turn subdivided into several more specific habitat types (*table 1*, *figs. 1-10*).

Open Water Greater than 20 m Depth

In Sequim and Discovery bays, the large sheltered bays at the eastern end of the Strait of Juan de Fuca, Marbled Murrelets reach peak abundance during the fall period (*table 1, fig. 1*). No other habitat within this habitat group had as high a density, 2.5 birds/km^2. The maximum density obtained during the winter period, 0.92 birds/km^2, was also from Sequim and Discovery bays. Concentrations of Marbled Murrelets were also reported from this area on Audubon Christmas Counts, according to summary statements by Speich and others (1992).

Within this habitat group, the proportion of individual censuses with Marbled Murrelets was generally near, and often less than, 20 percent (0.2) (*table 1*, *fig. 2*). The exception was the summer period for Sequim and Discovery bays where Marbled Murrelets were observed on 50 percent of all censuses in the area, but the sample size (n = 2) is very small. Within this habitat group, the deep open waters within the San Juan Islands showed peak numbers (density) and occurrence rate during the summer and fall periods (*table 1*, *figs. 1* and *2*).

Bays with Steep and Gradual Slopes

Habitat types within the group, "bays—steep and gradual slopes", are described by location and type (*table 1*, *figs. 3* and *4*). These habitat types generally are characterized by low densities of Marbled Murrelets. High densities of four and five murrelets per square kilometer, were found in habitats on steep slope and sand substrate within Whatcom and Skagit counties (Chuckanut Bay) and within the San Juan Islands, during the winter period.

Although the densities of Marbled Murrelets in the habitat types of this group are low, the rate of occurrence of censuses with birds is nonetheless relative high. While the density of birds was relatively high during the winter in steep slope habitats with sand substrate within the San Juan Islands, birds were only observed on about half of censuses (*table 1*, *fig. 4*). This suggests that relatively large numbers of birds were present during the winter in this habitat type, but birds move about and were not always encountered on censuses. A similar pattern was observed in this habitat type in Whatcom and Skagit Counties, except in winter when birds were detected on a greater portion of censuses, about 80 percent. Similarly, during the spring period, birds were detected on about 90 percent of censuses, even though average density (1.42 birds/km^2) (*table 1*) was lower than the winter period density (3.92 birds/km^2).

Areas of Tidal Activity

The occurrence of Marbled Murrelets in areas of tidal mixing is not unexpected, as these are generally thought of as productive areas where prey concentrate in nutrient and food-

Table 1—Seasonal density and occurrence of Marbled Murrelets in northern Puget Sound marine habitat types

Habitat types - Locations	Spring					Summer					Fall					Winter				
	Density		Occurrence			Density		Occurrence			Density		Occurrence			Density		Occurrence		
	Birds/ km²	*s.d.*	No.	Pres.	P	Birds/ km²	*s.d.*	No.	Pres.	P	Birds/ km²	*s.d.*	No.	Pres.	P	Birds/ km²	*s.d.*	No.	Pres.	P
Open Water >20 m Depth																				
Sequim and Discovery Bays	0.00	(0.00)	17	0	0.00	0.33	(0.33)	2	1	0.50	2.54	(7.50)	13	3	0.23	0.92	(2.37)	18	3	0.17
Canadian Gulf Islands	0.02	(0.08)	53	3	0.06	0.43	(0.79)	19	5	0.26	0.24	(0.87)	79	15	0.19	0.10	(0.30)	94	11	0.12
Strait of Juan de Fuca	0.00	(0.00)	16	0	0.00	0.01	(0.01)	9	1	0.11	0.06	(0.23)	28	4	0.14	0.02	(0.07)	36	2	0.06
Haro Strait	0.00	(0.00)	14	0	0.00	0.00	(0.00)	6	0	0.00	0.00	(0.00)	23	0	0.00	0.02	(0.10)	32	1	0.03
Rosario Strait	0.21	(0.82)	48	7	0.15	0.01	(0.03)	13	1	0.08	0.41	(1.22)	64	16	0.25	0.16	(0.65)	76	6	0.08
Georgia Strait	0.37	(0.91)	44	8	0.18	0.00	(0.00)	9	0	0.00	0.16	(0.70)	41	6	0.15	0.11	(0.50)	47	2	0.04
Whatcom & Skagit Counties	0.12	(0.44)	27	2	0.07	0.00	(0.00)	5	0	0.00	0.32	(1.06)	26	3	0.12	0.20	(0.58)	33	4	0.12
San Juan Islands	0.17	(0.66)	100	9	0.09	0.32	(0.79)	30	7	0.23	0.80	(3.15)	166	39	0.23	0.07	(0.32)	191	11	0.04
Bays–Steep and Gradual Slopes																				
Steep-Sand/Strait of Juan de Fuca	0.01	(0.02)	11	1	0.09	0.28	(0.28)	2	1	0.50	0.00	(0.00)	9	0	0.00	0.01	(0.02)	12	2	0.06
Steep-Sand/Whatcom & Skagit Counties	1.43	(1.22)	8	7	0.88	0.11	(0.19)	4	1	0.25	0.22	(0.46)	18	6	0.33	3.92	(3.17)	15	12	0.80
Steep-Sand/San Juan Islands	0.22	(0.82)	22	2	0.09	0.11	(0.28)	12	2	0.17	1.15	(3.16)	26	5	0.19	5.08	(10.37)	48	26	0.54
Gradual-Sand-Eelgrass/ San Juan Islands	0.01	(0.07)	23	1	0.04	0.00	(0.00)	1	0	0.00	0.04	(0.12)	24	3	0.13	0.17	(0.45)	34	10	0.29
Gradual-Sand-Eelgrass/ Whatcom & Skagit Counties	0.13	(0.27)	43	15	0.35	0.31	(0.73)	17	8	0.47	0.06	(0.24)	72	16	0.22	0.06	(0.20)	82	17	0.21
Gradual-Sand-Mud Whatocm & Skagit Counties	0.14	(0.27)	13	5	0.38	0.40	(0.03)	2	2	1.00	0.01	(0.03)	16	2	0.13	0.67	(1.57)	18	8	0.44
Gradual-Sand-Mud/ San Juan Islands	0.75	(1.40)	6	2	0.33	0.00	(0.00)	4	0	0.00	0.30	(0.84)	9	1	0.11	0.00	(0.00)	13	0	0.00
Gradual-Rock-Cobble/ assorted sites	0.34	(1.05)	27	6	0.22	1.25	(3.54)	9	1	0.11	0.11	(0.43)	46	6	0.13	0.26	(0.56)	51	20	0.39
Areas of Tidal Activity																				
Various points	0.92	(1.48)	29	11	0.38	5.62	(10.10)	8	6	0.75	1.51	(4.35)	61	31	0.51	0.37	(1.08)	28	4	0.14
Passages/San Juan Islands	0.13	(0.35)	62	9	0.15	0.23	(0.53)	23	5	0.22	5.05	(32.62)	83	32	0.39	1.69	(2.97)	112	60	0.54
Admiralty Inlet	0.03	(0.07)	9	1	0.11	0.12	(0.17)	3	1	0.33	0.03	(0.11)	18	1	0.06	1.12	(2.19)	19	10	0.53

continues

Table 1—continued

Habitat types - Locations	Spring					Summer					Fall					Winter				
	Density		Occurrence			Density		Occurrence			Density		Occurrence			Density		Occurrence		
	Birds/ km²	*s.d.*	No.	Pres.	P	Birds/ km²	*s.d.*	No.	Pres.	P	Birds/ km²	*s.d.*	No.	Pres.	P	Birds/ km²	*s.d.*	No.	Pres.	P
Shorelines with Narrow Shelf																				
Kelp-Cobble/ Strait of Juan de Fuca	1.00	(2.49)	21	4	0.19	4.00	(4.24)	4	2	0.50	0.14	(0.68)	23	1	0.04	0.00	(0.00)	24	0	0.00
Kelp-Cobble/ Whatcom & Skagit Counties	0.54	(1.83)	49	9	0.18	1.05	(2.13)	16	6	0.38	1.01	(1.86)	65	28	0.43	0.10	(0.30)	54	7	0.13
Kelp-Cobble/ Whatcom County islands	0.68	(1.60)	27	5	0.19	0.71	(1.75)	7	1	0.14	19.98	(41.77)	32	18	0.56	3.07	(8.26)	34	13	0.38
Kelp-Cobble/San Juan Islands	0.04	(0.25)	45	1	0.02	0.06	(0.23)	15	1	0.07	4.90	(17.53)	66	17	0.26	3.17	(8.36)	64	18	0.28
Cobble-Rock/Strait of Juan de Fuca	0.68	(1.62)	17	4	0.24	0.11	(0.23)	5	1	0.20	0.45	(1.23)	30	8	0.27	0.13	(0.29)	32	5	0.16
Cobble-Rock/San Juan Islands	0.18	(0.73)	25	2	0.08	0.20	(0.57)	9	1	0.11	0.28	(0.99)	33	3	0.09	0.48	(1.09)	48	10	0.21
Sand-Mud/assorted sites	0.29	(0.00)	1	1	1.00	0.04	(0.04)	2	1	0.50	0.00	(0.00)	2	0	0.00	0.09	(0.16)	4	1	0.25
Shoreline with Broad Shelf																				
Eelgrass-Sand/Strait of Juan de Fuca	0.00	(0.00)	14	0	0.00	0.00	(0.00)	2	0	0.00	0.23	(0.74)	20	2	0.10	0.00	(0.00)	27	0	0.00
Eelgrass-Sand/ Whatcom & Skagit Counties	0.66	(1.83)	12	3	0.25	4.44	(6.29)	3	1	0.33	0.57	(1.40)	7	1	0.14	0.00	(0.00)	8	0	0.00
Kelp-Cobble/Strait of Juan de Fuca	2.03	(5.62)	49	17	0.35	2.13	(6.04)	15	5	0.33	0.01	(0.01)	81	1	0.01	0.43	(1.97)	87	15	0.17
Kelp-Cobble/San Juan Islands	0.00	(0.00)	4	0	0.00	0.28	(0.39)	3	1	0.33	0.12	(0.37)	10	1	0.10	0.26	(0.64)	7	1	0.14
Cobble-Rock/assorted sites	0.00	(0.00)	9	0	0.00	0.00	(0.00)	2	0	0.00	0.60	(1.36)	12	2	0.17	1.14	(2.16)	12	2	0.17
Sand-Mud/Strait of Juan de Fuca	3.33	(5.77)	4	1	0.25	0.00	(0.00)	1	0	0.00	0.00	(0.00)	5	0	0.00	0.00	(0.00)	5	0	0.00
Sand-Mud/ Whatcom & Skagit Counties	1.08	(4.15)	19	2	0.11	0.24	(0.53)	6	1	0.17	0.67	(1.78)	25	4	0.16	0.65	(1.80)	23	3	0.13
Sand-Mud/San Juan Islands	0.39	(0.55)	3	1	0.33	2.35	(0.00)	1	1	1.00	4.02	(7.95)	6	3	0.50	1.67	(3.47)	6	2	0.33

Legend: Density - *s.d.* = standard deviation; Occurrence - No. = number censuses performed, Pres. = number censuses birds present; P = proportion censuses birds present

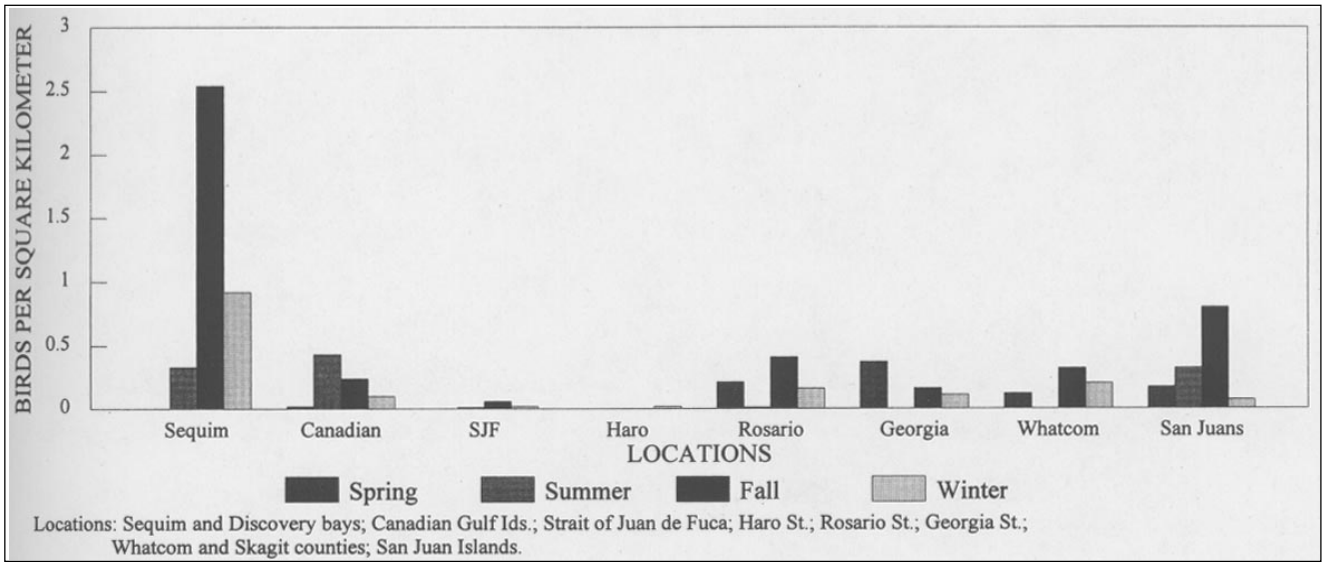

Figure 1—Seasonal abundance of Marbled Murrelets, open water greater than 20 m depth.

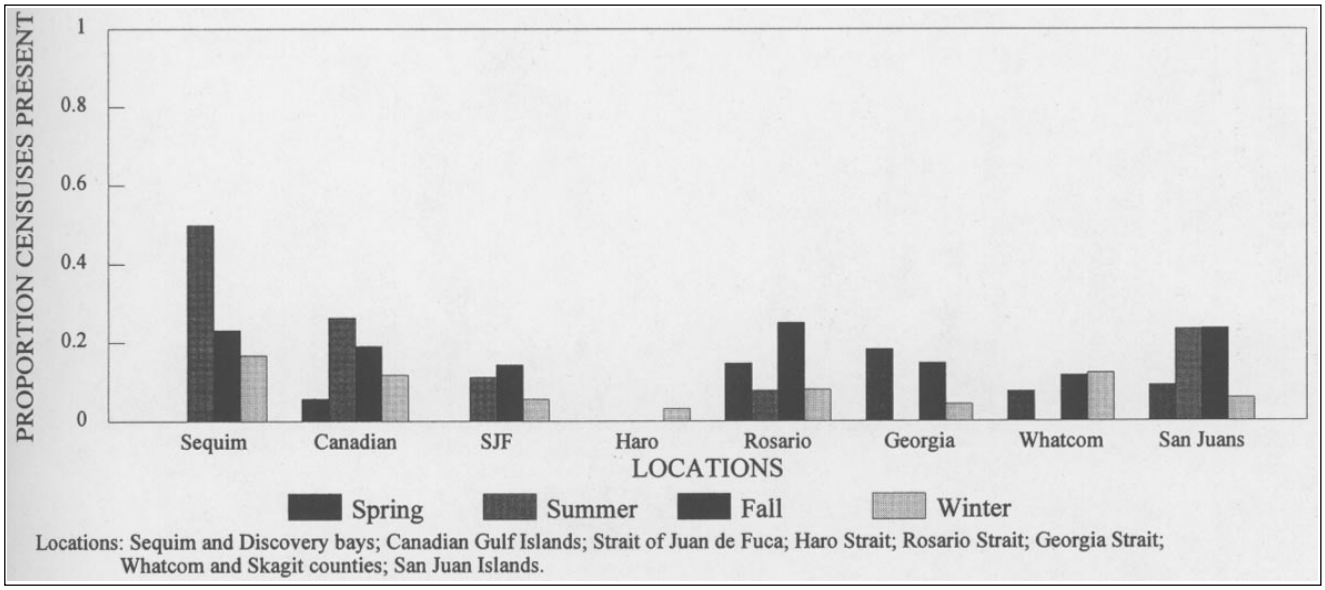

Figure 2—Seasonal presence of Marbled Murrelets, open water greater than 20 m depth.

rich upwelled or mixed waters. Within Puget Sound, such areas are normally associated with narrow passages or points where currents, and mixing, are intensified. The habitat types presented here reflect those conditions (*table 1*, *figs. 5* and *6*).

Highest densities were calculated from observations during the summer period from "Various Points" (*figs. 5* and *6*) where Marbled Murrelets were recorded on over 70 percent of all censuses. Densities of birds at these points were lower during the spring and fall, and the percent occurrence on censuses was lower, but on average, Marbled Murrelets were observed on about half of all censuses during this period. Only during winter did both the density and occurrence rate drop below values from other periods.

In Passages—San Juan Islands, the highest seasonal density was obtained for the fall period, 5.05 birds/km^2 (*table 1*, *fig. 5*), when birds were observed on about 40 percent of all censuses (*table 1*, *fig. 6*). There, numbers observed and percent occurrence of censuses were much lower during the spring and summer periods. During the winter period, the density (1.69 birds/km^2) was considerably lower, while birds were recorded on over 50 percent of all censuses.

Murrelets occurred at much lower rates on censuses in Admiralty Inlet, (*table 1*, *fig. 5*), compared to other tidal areas. However, more birds were likely present as the area of this tidal passage is larger than the other tidal habitat areas discussed. Similar to the other areas of tidal activity

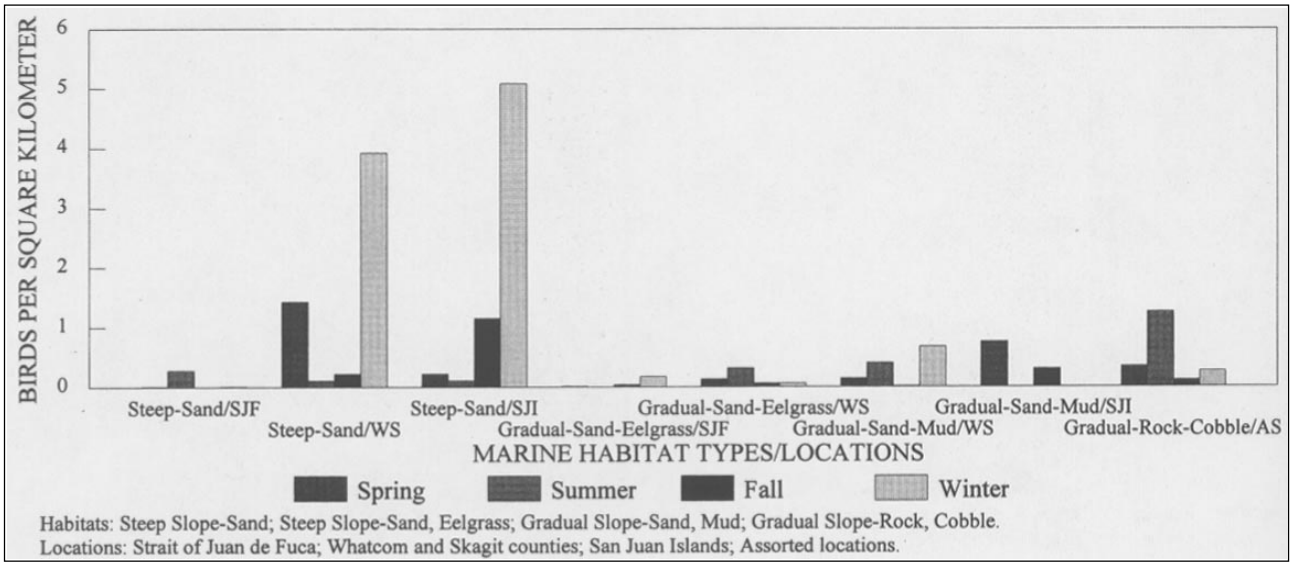

Figure 3—Seasonal abundance of Marbled Murrelets, bays - steep and gradual slopes.

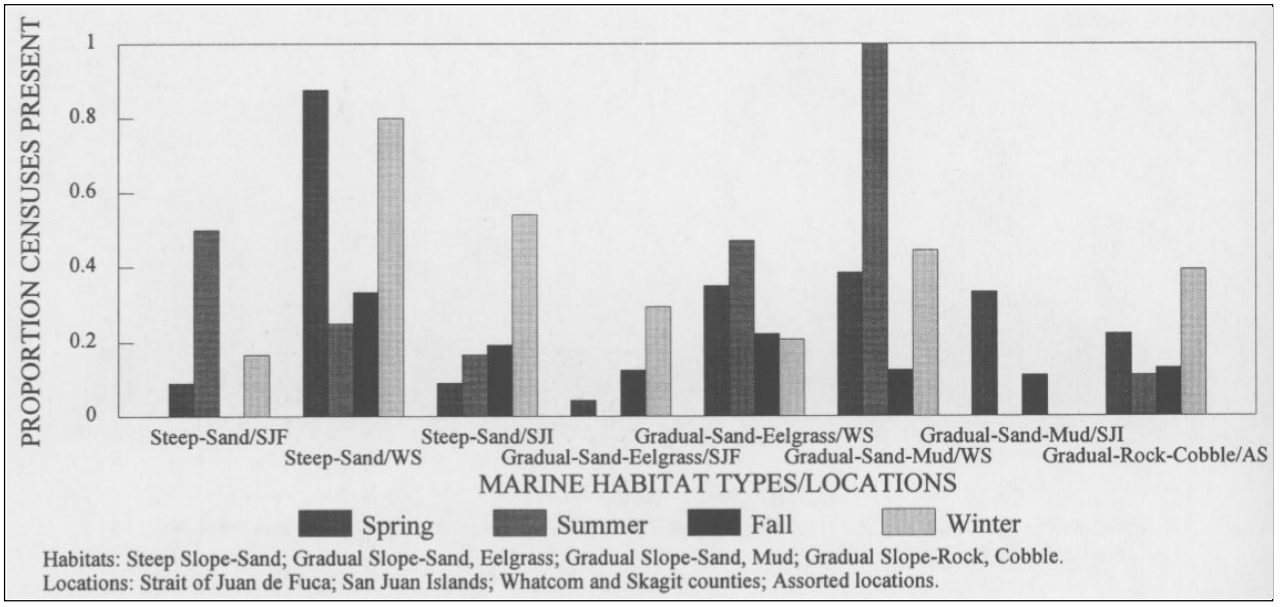

Figure 4—Seasonal presence of Marbled Murrelets, bays - steep and gradual slopes.

in Puget Sound, occurrence on censuses is quite variable (*table 1, fig. 6*).

Shorelines with Narrow Shelf

This group is represented by three specific habitat types, Kelp and Cobble, Cobble and Rock, and Sand and Mud. Within this general habitat group, there is considerable variation in densities (*table 1, fig. 7*) and in the proportion of censuses on which they are recorded (*table 1, fig. 8*). The highest density (19.98 birds/km^2) determined for any habitat in Puget Sound occurred in the fall in the Kelp and Cobble substrate in the Whatcom County islands area, where birds were also recorded on half of all surveys. A relatively high density (5.05 birds/km^2) was also determined for the fall period for Kelp and Cobble substrate in the San Juan Islands. Otherwise, with a couple of additional exceptions, densities of murrelets in this habitat group were generally low (*table 1, fig. 7*).

Shorelines with Broad Shelf

This group is represented by four habitat types, Eelgrass and Sand, Kelp and Cobble, Cobble and Rock, and Sand and Mud. Here again the variation in densities of Marbled Murrelets between and within habitat types is apparent (*table 1, fig. 9*), although sample sizes in some cases are small

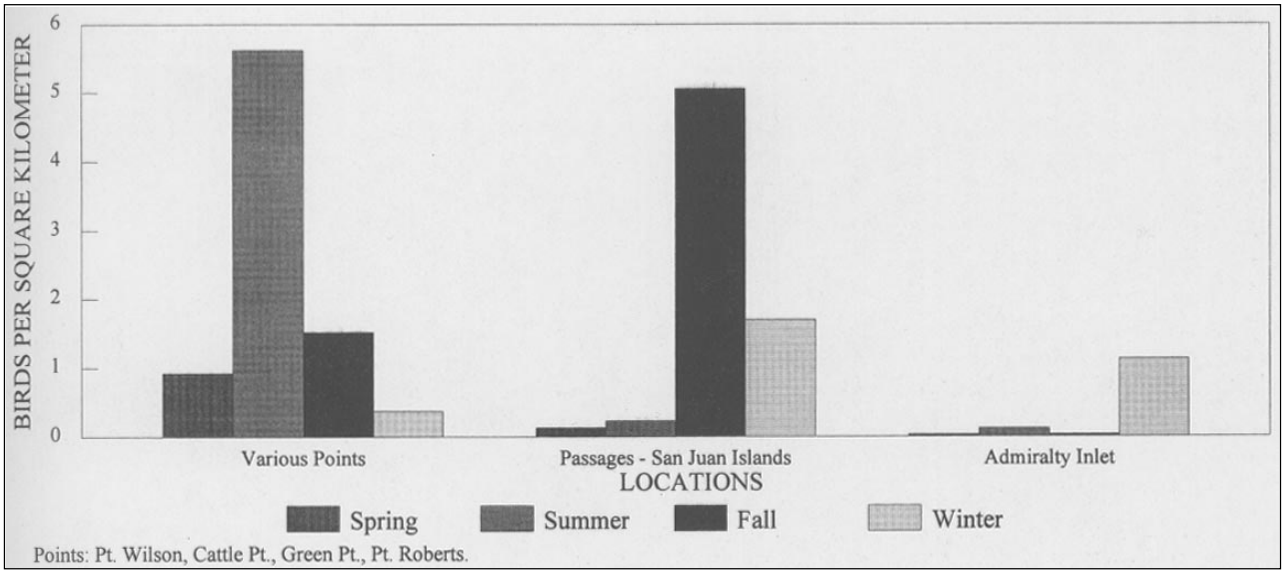

Figure 5—Seasonal abundance of Marbled Murrelets, areas of tidal activity.

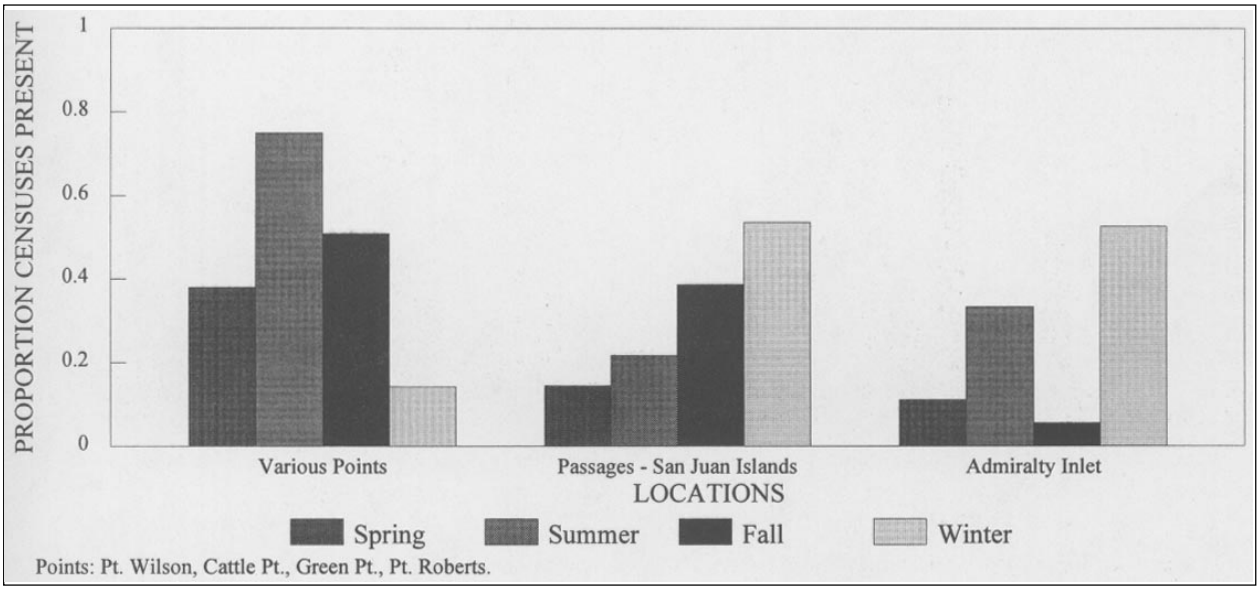

Figure 6—Seasonal presence of Marbled Murrelets, areas of tidal activity.

(*table 1*). The highest calculated densities occurred in Eelgrass and Sand substrate in Whatcom and Skagit Counties during the summer, Cobble and Rock substrate of "Assorted Areas" during the winter, and in the Sand and Mud substrate in the San Juan Islands during the fall. The last habitat type had overall the highest determined seasonal densities.

Overall within this habitat group, the proportion of censuses with murrelets was below 40 percent (*table 1*, *fig. 10*). The only exceptions were the spring and summer periods of the Sand and Mud substrate in the San Juan Islands, however small sample sizes (*table 1*) suggest caution in interpreting those values. As elsewhere, there is considerable seasonal within and between habitat variation.

Abundance and Occurrence by Habitat Types - Pacific Coast

Grays Harbor Channel and Shelf Waters

Over a 23-year period, Marbled Murrelets were recorded in Grays Harbor channel in every month. The general pattern of occurrence was one of high average densities during the spring, fall, and winter months (*table 2, fig. 11*), and higher densities in habitats closer to shore. Overall, the highest densities occurred in Grays Harbor Channel, followed by Grays Harbor Channel to 20 m depth, and 20 to 50 m depth. Only rarely were they recorded in deeper habitat areas. The highest densities occurred during the spring months and highest average density occurred in Grays Harbor Channel in March.

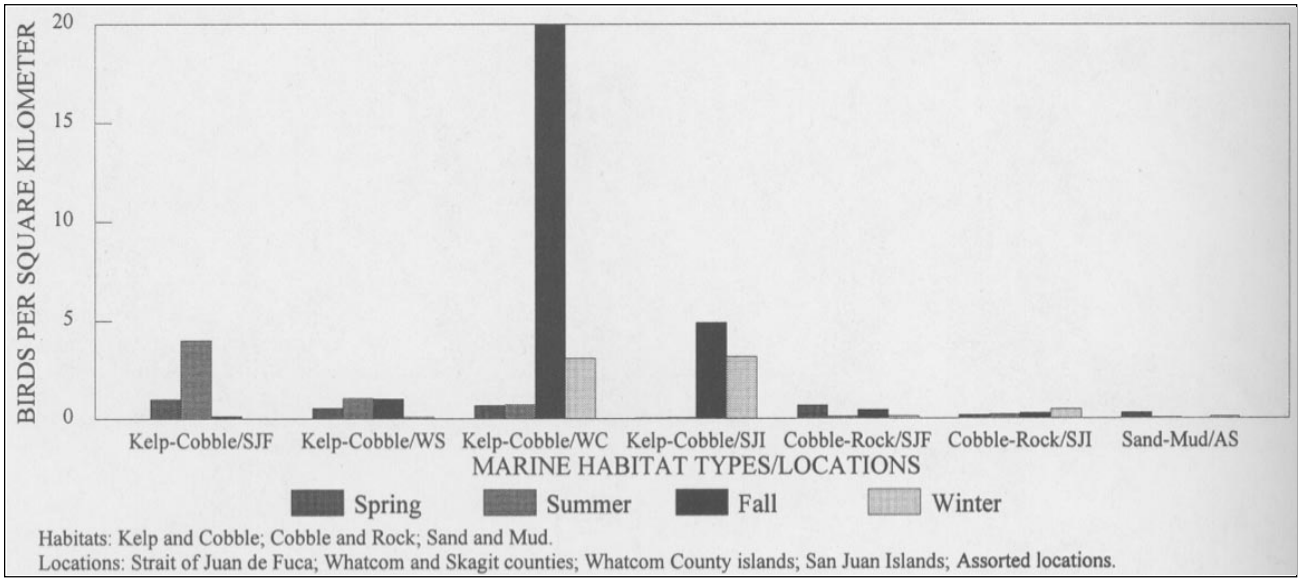

Figure 7—Seasonal abundance of Marbled Murrelets, shorelines with narrow shelf.

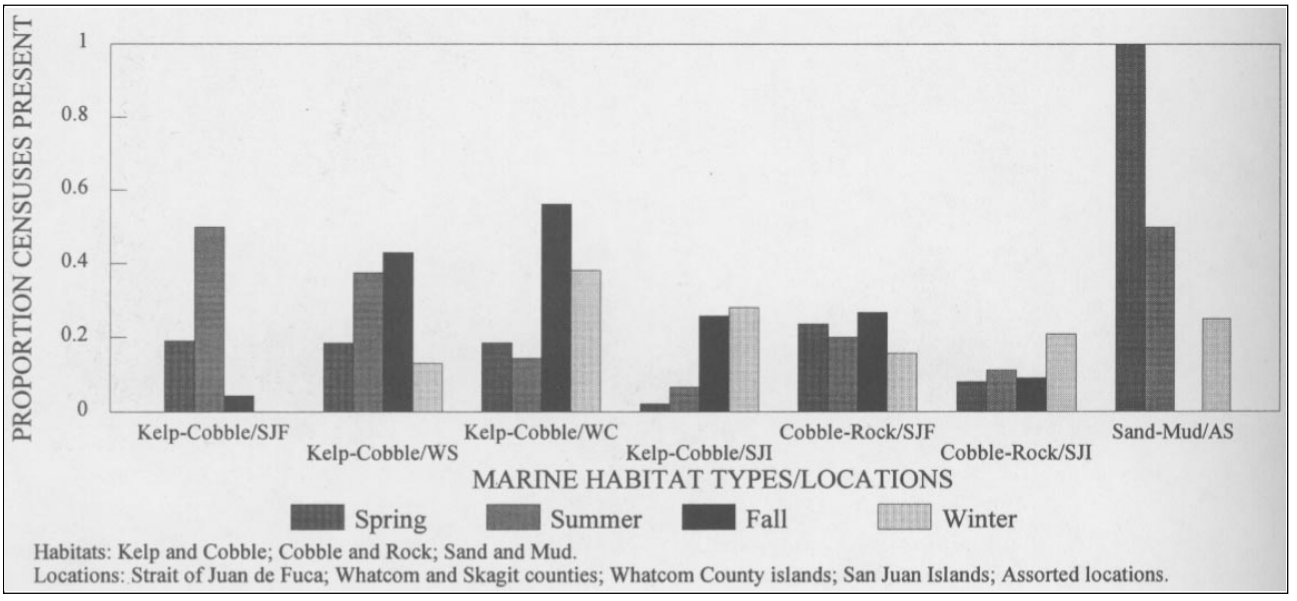

Figure 8—Seasonal presence of Marbled Murrelets, shorelines with narrow shelf.

The percent of censuses that Marbled Murrelets were recorded in each of the habitat types, by month, followed the same pattern as shown by densities according to Wahl's unpublished observations. Overall, though, sample size is small, with highest occurrence recorded during the winter, spring, and summer periods. Interestingly, over a period of 23 years, murrelets were recorded on every census in Grays Harbor Channel in February, March, November, and December. They were also recorded in the habitat area from Grays Harbor Channel to 20 m depth in February, March, and November. Even though the proportion of censuses on which murrelets were recorded was often high, densities were often low (e.g., February).

Point Grenville Inshore Waters

During the spring and summer periods of 1984 and 1985 Marbled Murrelets were irregularly observed in the inshore waters near Point Grenville (Speich and others 1987). These data, previously reported in Speich and others (1992), showed that they were absent from about 25 to 30 percent of all censuses, mainly in April. In both years peak densities were recorded in July, and in August 1985.

Continental Shelf Waters

Earlier, Speich and others (1992) suggested that the Marbled Murrelet population on the Pacific Ocean Coast of Washington was largely found north of Point Grenville with

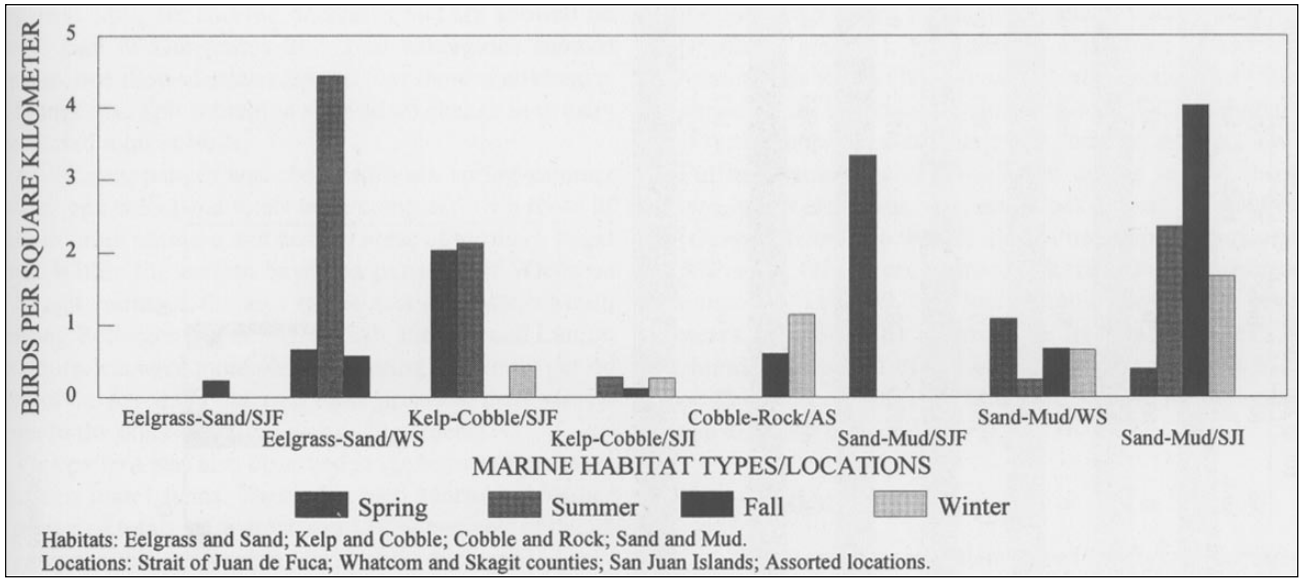

Figure 9—Seasonal abundance of Marbled Murrelets, shorelines with broad shelf.

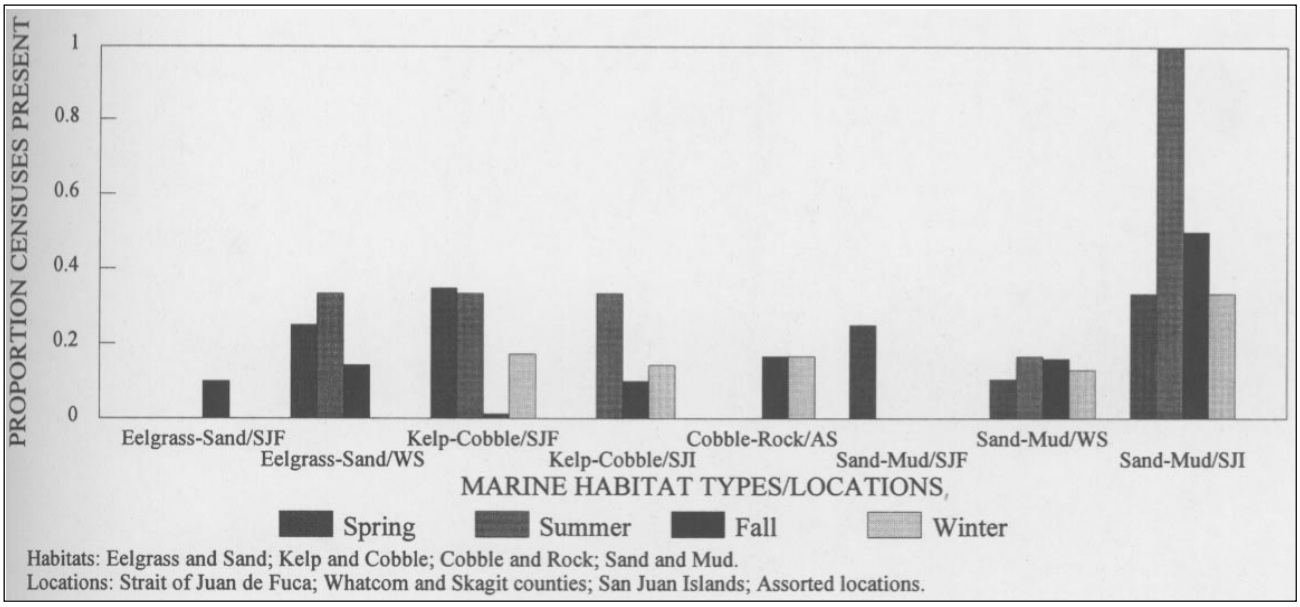

Figure 10—Seasonal presence of Marbled Murrelets, shorelines with broad shelf.

an uncertain number found in the waters off the southern coast. However, the numbers there were thought to be low. This pattern was confirmed by the August 1993 aerial survey of the coast (Varoujean and Williams, this volume).

Regional Distribution and Variability - Puget Sound

During the 1978 and 1979 survey of northern Puget Sound (Wahl and others 1981), Marbled Murrelets were found differentially distributed temporally and spatially through the study area. Overall, the results of surveys during the spring-summer and winter periods showed on average that the obtained densities and the proportion of surveys with murrelets were higher during the winter, compared with the spring-summer period (see appendices 1 and 2, and fig. 3 in Speich and others [1992]). Indeed, the calculated total for northern Puget Sound was higher in winter than the spring-summer period.

Not only were changes at the region level apparent, but changes within each region, at the subregion level were also found (see appendices in Speich and others [1992]). For example, along the Strait of Juan de Fuca, at the north end of the Olympic Peninsula, the densities (and calculated totals) of murrelets decreased during the winter period in seven of the 20 subregions (35 percent), remained the same in nine of the 20 (45 percent) and increased in three (15 percent). There were no increases of densities in subregions west of

Table 2—Monthly rates of occurrence of Marbled Murrelets in nearshore habitats off Grays Harbor, Washington, recorded and averaged over a 23-year period

Month	Grays Harbor Channel			Grays Harbor Channel to 20 m			20 to 50 m depth			50 to 100 m depth			100 to 200 m depth			200 to 1000 m depth		
	No. birds	No. km	Birds/ km	No. birds	No. km	Birds/ km	No. birds	No. km	Birds/ km	No. birds	No. km	Birds/ km	No. birds	No. km	Birds/ km	No. birds	No. km	Birds/ km
January	22	21.0	1.05	18	33.5	0.54	0	69.3	0	0	129.7	0	0	201.6	0	0	189.2	0
February	1	6.0	0.17	4	10.0	0.40	2	10.5	0.19	0	38.0	0	0	50.5	0	0	23.0	0
March	42	15.2	2.76	4	4.4	0.91	2	31.7	0.06	0	25.6	0	6	46.5	0.13	0	22.5	0
April	99	77.2	1.28	91	66.3	1.37	0	120.6	0	2	287.0	0.01	0	313.1	0	2	198.6	0.01
May	173	334.1	0.52	121	289.4	0.42	18	447.4	0.04	20	798.6	0.03	2	1249.2	0	0	696.1	0
June	28	47.2	0.59	30	54.8	0.55	3	62.2	0.05	0	97.3	0	0	156.5	0	0	83.7	0
July	81	305.2	0.27	31	378.2	0.08	10	502.4	0.02	0	792.2	0	0	1442.0	0	0	735.4	0
August	42	608.9	0.07	13	564.9	0.02	0	845.8	0	0	1659.9	0	0	2489.9	0	0	1472.2	0
September	15	513.8	0.03	5	524.2	0.01	2	880.0	0	0	1715.9	0	0	2921.0	0	0	1361.4	0
October	65	238.6	0.27	50	242.0	0.21	4	420.5	0.01	0	851.0	0	0	1200.1	0	0	658.7	0
November	29	16.3	1.78	4	10.5	0.38	4	28.0	0.14	2	49.9	0.04	0	80.2	0	0	13.1	0
December	2	6.5	0.31	15	13.7	1.09	0	17.6	0	0	25.6	0	0	45.8	0	0	15.1	0
Total	599	2190		386	2191.9		45	3436.0		24	6470.7		8	10196.4		2	5469.0	

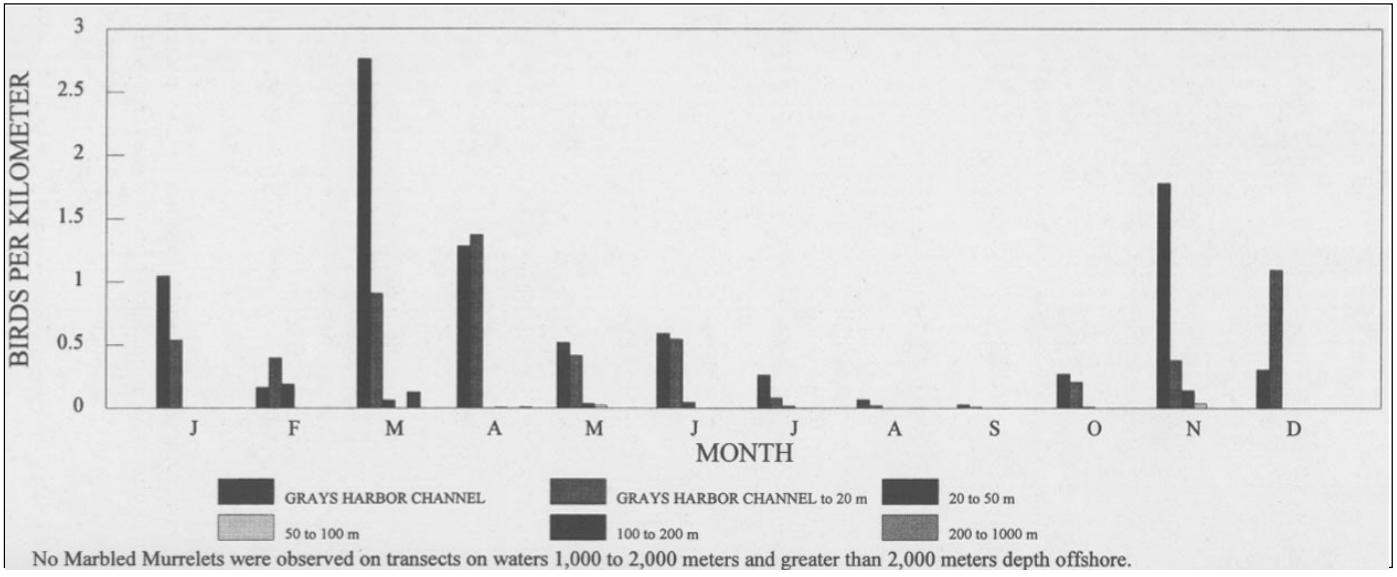

Figure 11—Monthly abundance of Marbled Murrelets in Grays Harbor habitats, 1971 through 1993. See *table 2* for sample parameters.

Dungeness Spit: six showed decreases and six showed no change. East of Dungeness Spit, four subregions showed increases, one showed a decrease and four showed no change. The Dungeness Spit subregion showed no change in density or projected total of birds.

A different pattern was observed when spring-summer densities and calculated totals were compared with those of winter in more northern and eastern areas of northern Puget Sound. Within the eastern bays and passages of Whatcom and Skagit counties, the area to the east of Rosario Strait, including Bellingham, Padilla, Samish, Fidalgo and Lummi bays, murrelets were more plentiful during the winter period in five of the seven (71 percent) subregions and there was no change in the other two subregions (29 percent).

This pattern was also observed in the bays and passages of the San Juan Islands. There, Marbled Murrelet densities and projected totals were greater in 11 (52 percent) of the 21 subregions of this geographic area. Values decreased in only five subregions (24 percent) and remained the same in five others (24 percent).

Long-Term Trends in Abundance and Occurrence - Puget Sound

As reported earlier (Speich and others 1992), there are no data that will allow for the quantification of long term changes in the abundance of Marbled Murrelets in Washington marine waters. Qualitative statements in early accounts suggest that the species was once more abundant than present in Puget Sound waters.

Long-Term Trends in Abundance and Occurrence - Pacific Ocean Coast

There are no data that we are aware of that allow a direct appraisal of the long term stability, or instability, of populations along the Pacific Ocean coast of Washington, over the last century, or even over the last several decades. The only quantified information available is the data set collected by Wahl from offshore birding trips from Grays Harbor to over the continental shelf break, covering the years 1971 through 1993 (*table 3*, *fig. 12*). Therein, no long term trend in the abundance of Marbled Murrelets is evident, except that since 1989, yearly abundance is visibly diminished. The lowest level of murrelet abundance over the entire study period occurred in 1993.

We are unable to directly predict if the pattern of abundance observed in nearshore waters near Grays Harbor are indicative of abundance patterns along the entire outer coast of Washington. However, some insight is obtained by considering the yearly patterns of relative abundance of other marine bird species occurring in nearshore and continental shelf waters off of Grays Harbor. Several marine species, consisting of four families of birds, and comprising local breeders, migrants, and winter visitors, were less abundant in recent years in the Grays Harbor study area. Wahl's unpublished observations are summarized below. The lowest abundances since 1971 were recorded during the past two years for eight species (Sooty Shearwater [*Puffinus griseus*], Red-necked Phalarope [*Phalaropus lobatus*], Sabine's Gull [*Xema sabini*], Arctic Tern [*Sterna paradisaea*], Common Murre [*Uria aalge*], Cassin's Auklet [*Ptychoramphus aleuticus*], Rhinoceros Auklet, Tufted Puffin [*Fratercula cirrhata*]),and during one of the last two years for two species (Fork-tailed Storm-Petrel [*Oceanodroma furcata*], Red Phalarope [*Phalaropus fulicaria*]). Of interest, Common Murre abundance decreased noticeably in 1989, and has remained low, after several years (1980-1988) of relative high abundance. The abundance pattern of the last species corresponds to that observed for the Marbled Murrelet, relative low abundance since 1989 (*fig. 12*).

Discussion

The overall pattern of abundance (density) and occurrence of Marbled Murrelets observed in the marine habitats of Puget Sound is one of variability. Our impression of Marbled Murrelets in Puget Sound before this limited analysis was of a species that moves about a great deal on several temporal scales: seasons, daily, and hourly. Indeed, we have often observed Marbled Murrelets foraging in a particular area then departing that area in a short period of time, and flying out of our sight to another unknown location. Such movements may account for the generally low probability of encountering murrelets on censuses within habitat types. Thus, the observed occurrence patterns are not surprising. However, there are sources of noise in the original census program that could give a partially false impression of this species' patterns of occurrence. Specifically, not discounting our general impression of variability, we have noticed that they are often found in specific areas, while other areas are less likely to contain them. Thus, since any specific habitat type presented is usually represented by several spatially distinct censuses and the mixing of censuses, some often with and without detecting murrelets, leads to lowered occurrence rates. We predict that this will be the case, and that the habitat spatial scale we presented here for Puget Sound will turn out to be too coarse.

Our field observations of Marbled Murrelets in Puget Sound, during the course of formal censuses and otherwise, suggest that the foraging distribution is closely linked to tidal patterns, in particular to specific locations when tidal flows are clearly evident. The locations of tidal activity covered by data that are presented here (*figs. 5* and *6*) are well known and particularly prominent places of tidal activity. However, tidal activity is observable throughout Puget Sound and is likely the single dominant and persistent physical process there. We suggest that analysis of our data at the level of individual censuses may give insight into the relative importance of tidal activity in determining the movements and foraging areas of Marbled Murrelets.

As recognized previously, there are seasonal regional patterns in the distribution and abundance of murrelets in

Table 3—Yearly rates of occurrence of Marbled Murrelets in nearshore habitats off Grays Harbor, Washington

Year	Grays Harbor Channel			Grays Harbor Channel to 20 m			20 to 50 m depth		
	No. birds	No. km	Birds/ km	No. birds	No. km	Birds/ km	No. birds	No. km	Birds/ km
1971	6	27.7	0.22	0	20.3	0	0	53.4	0
1972	51	98.6	0.52	0	66.3	0	0	108.0	0
1973	15	109.4	0.14	0	39.6	0	0	93.8	0
1974	7	40.0	0.18	0	51.2	0	0	88.7	0
1975	16	69.8	0.23	9	56.0	0.16	0	81.1	0
1976	11	36.8	0.30	7	88.6	0.08	0	117.1	0
1977	35	76.9	0.46	15	148.9	0.10	1	206.9	0
1978	10	90.2	0.11	10	81.8	0.12	0	150.7	0
1979	26	88.4	0.29	0	54.7	0	0	155.9	0
1980	7	75.6	0.09	51	77.7	0.66	0	100.1	0
1981	24	60.8	0.39	20	125.1	0.16	18	168.8	0.11
1982	88	111.1	0.79	16	128.2	0.12	2	202.5	0.01
1983	23	101.2	0.23	16	75.4	0.21	4	158.8	0.03
1984	24	128.4	0.19	7	100.8	0.07	11	213.4	0.05
1985	74	137.9	0.54	102	140.5	0.73	0	227.2	0
1986	24	81.8	0.29	7	73.5	0.10	0	136.1	0
1987	27	129.3	0.21	16	115.2	0.14	3	191.0	0.02
1988	69	112.6	0.61	50	104.6	0.48	2	179.5	0.01
1989	8	104.0	0.08	2	86.0	0.02	0	120.0	0
1990	11	111.5	0.10	13	140.0	0.09	2	173.0	0.01
1991	25	131.5	0.19	21	148.5	0.14	0	172.0	0
1992	13	141.5	0.09	22	126.5	0.17	2	165.5	0.01
1993	5	125.0	0.04	2	142.5	0.01	0	172.5	0
Total	599	2190		386	2191.9		45	3436	

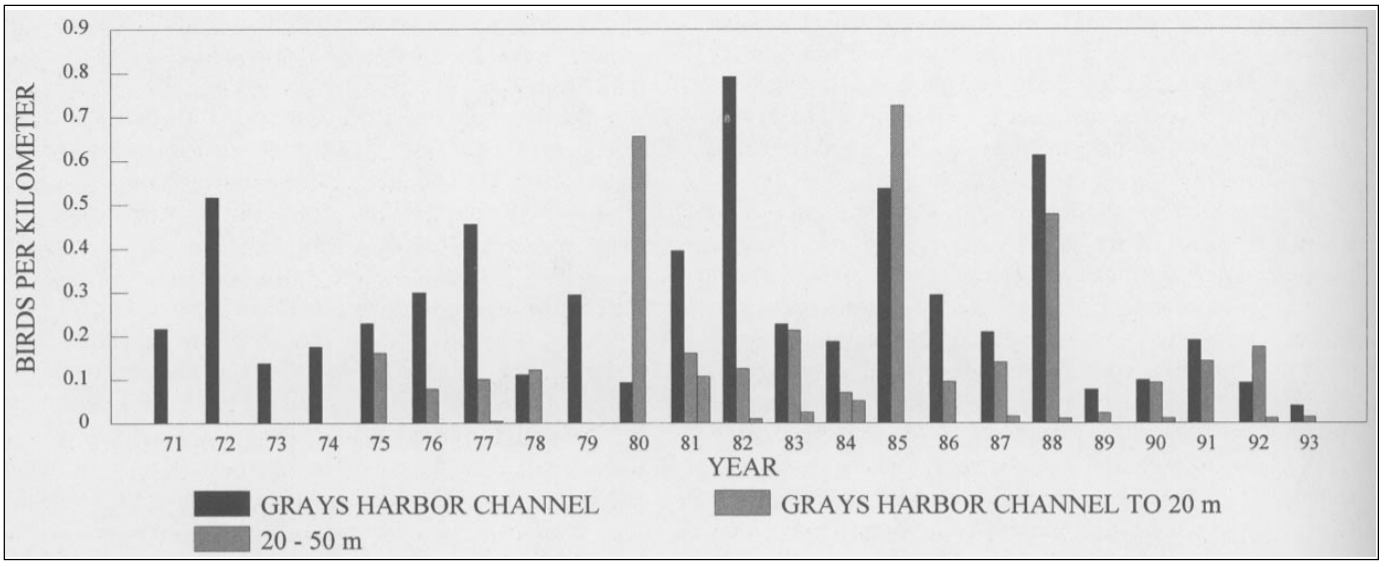

Figure 12—Yearly abundance of Marbled Murrelets in Grays Harbor habitats, 1971 through 1993. See *table 3* for sample parameters.

Puget Sound. Of particular note, are the nearshore subregions along western portion of the Strait of Juan de Fuca where they are found less often during the winter period. This area, particular in Puget Sound, is exposed to winter storm activity, as it opens directly to the Pacific Ocean, while those Strait of Juan de Fuca subregions to the east of Dungeness Spit are relatively protected from western approaching winter storms. The densities in these subregions also suggest a shift of birds from the Strait of Juan de Fuca during the spring and summer periods, to areas in the San Juan Islands and the eastern bays during the fall and winter periods. In addition, as demonstrated in Speich and others (1992), there is apparently an additional influx of Marbled Murrelets into the latter areas from the north, presumably British Columbia. A shift in Marbled Murrelets from the Strait of Juan de Fuca alone cannot account for the increases in numbers in these areas. Similar patterns, though on a lesser scale, are likely present in other areas of Puget Sound.

An estimate of the size of the Marbled Murrelet population found in the marine waters of Washington during the spring-summer breeding period has been made by Speich and others (1992), calculated at approximately 5,000 birds. Estimates were made for each of four marine regions: southern outer coast, <500 birds; northern outer coast, 1,900; southern Puget Sound, 480; and northern Puget Sound, 2,100. Except for the southern outer coast figure, in reality an educated guess, estimates of breeding populations were based on data from censuses that sampled specific areas, calculated projected numbers for sub-regions (see Wahl and others 1981), then adjusted for the proportions of non-breeding birds and those not present on the water during censuses but incubating and brooding at inland nest sites (Speich and others 1992). We consider these only approximations of the numbers of breeding Marbled Murrelets, requiring a better defined baseline for detecting and appraising potential changes in the future.

There may be several factors that could explain the observed apparent decrease in murrelet abundance in the Grays Harbor study area in the nearshore continental shelf waters. Some may suggest that the population has been reduced by the accumulative removal of terrestrial nesting habitat areas. Such action has the potential to affect Marbled Murrelet populations and may have in particular locations. However, such an evaluation is beyond this paper (see Ralph 1994). In our paper, in the time period presented (1971–1993), there are recent indications of changes in the marine carrying capacity of waters over the continental shelf and slope, off Grays Harbor and beyond. This is reflected in the recent record low abundances reported for several species of marine birds, birds representing several different foraging techniques and positions in marine food changes, and of various geographic affinity. On a slightly larger scale, the reduced abundance of Common Murres in the study areas since 1989 suggests that marine food chains have been reduced, or have otherwise become unavailable to Common Murres for several years, because breeding colonies as far south as Oregon have experienced depressed reproduction rates (Varoujean, pers. comm.). The study area numbers in part reflect the abundance of murres moving north from Oregon breeding colonies after the breeding period. Additionally, the Common Murre breeding population in Washington has declined over the past decade (Ainley and others 1994; Wilson 1991). Although the Marbled Murrelet is not as oceanic a species as other species reported on here, the documented declines in abundance and local breeding success suggest that fundamental changes in marine systems have occurred, likely expressed by the reduced availability of prey. Considering the temporal and geographic scale of reported effects it is perhaps not surprising that Marbled Murrelet abundance in the Grays Harbor study area was lower the past two years in particular, or even for the past several years.

The patterns of abundance and occurrence presented herein are descriptive in nature, and represent the "what" stage of the continuing investigation of the Marbled Murrelet in the marine waters of Washington, in this case, Puget Sound. There is certainly the need to advance our understanding of the marine biology of the Marbled Murrelet beyond the descriptive phases of investigation. We need to address, as we have started to do here, "why" Marbled Murrelets are found distributed as they are. However, such *post priori* explanations are limited by their nature in their potential to allow understanding of the causes of Marbled Murrelet distribution and abundance patterns. Clearly, the development and testing of *a priori* questions, hypotheses, and the development of models are appropriate and necessary steps for meaningful advancement of our understanding of Marbled Murrelet biology. However, as necessary and desirable as these last steps are, a sound and basic knowledge of the natural history of the species is necessary for the interpretation and evaluation of study and test results and for our understanding of the factors influencing and controlling Marbled Murrelets (see interesting discussion in Oreskes and others [1994]).

Puget Sound is by its very nature a complex system of bays, estuaries, channels, passages and straits, greatly influenced by tidal and wind patterns, by the influx of fresh water and nutrients from several river systems, and by its connections to the Pacific Ocean. Perhaps a better understanding of, and precision in predicting, the temporal and spatial variable distribution and abundance of the Marbled Murrelet in Puget Sound and along the Pacific Ocean coast would result from an increased understanding of marine physical and biological processes and how they link with Marbled Murrelets.

Acknowledgments

This paper is the result of combining the data from several different projects. Consequently, the list of persons and organizations who contributed in many different ways is long. Specific acknowledgments are found in documents cited herein as are the many sources of support (see also

Speich and others 1992). Data from the Grays Harbor area were made largely possible through the long interest and efforts of bird watchers and other naturalists that supported vessel time. William Tweit and Dennis Paulson, by their interest and participation, contributed in no small way to the success of the Grays Harbor effort. We especially appreciate the professionalism of Deborah Kristan, as reflected in her review, and her manipulating and editing of the Puget Sound data set. The review and comments of C. John Ralph and S. Kim Nelson were particularly helpful, as was the technical assistance of Linda Long.

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