

## Chapter 23

# Marbled Murrelet At-Sea and Foraging Behavior

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**Abstract:** The behavior of Marbled Murrelets (*Brachyramphus marmoratus*) at sea while foraging for small fish and invertebrates is poorly known. This murrelet forages by pursuit diving in relatively shallow waters, usually between 20 and 80 meters in depth. We have also observed it diving in waters less than 1 meter and more than 100 meters deep. The majority of birds are found as pairs or as singles in a band about 300 to 2000 meters from shore. Pairs tend to dive simultaneously when foraging, and we suggest that pairing has some benefit to foraging efficiency. At times they are in small flocks and in aggregations. Larger aggregations are found in the northern part of its range, probably due to the denser population. Foraging dive times averaged about 16 seconds. Murrelets generally forage during the day, and are most actively in the morning and late afternoon hours. Some foraging occurs at night. Vocalizations during foraging occur after individuals of a pair surface apart from each other. The majority of the birds' surface time is spent loafing, preening, and wing stretching. We feel that adults holding fish are usually about to depart inland to feed a young, and are potentially a very useful measure of reproductive rate. Murrelets are not generally associated with interspecific feeding flocks, except in the northern part of its range.

The at-sea behavior of the Marbled Murrelet (*Brachyramphus marmoratus*) is relatively little known, with the exception of the work of Carter and Sealy (1990). Understanding the relationship between the species, its foraging habitat, and its prey species are important so that appropriate decisions are made concerning future recovery efforts. We have spent many thousands of hours observing murrelets on the ocean and this paper brings together these observations, contributions from colleagues, and the published literature, to give a perspective on the life history of the species in its marine environment.

## Foraging Range

Nearshore feeding—During the breeding season, the Marbled Murrelet tends to forage in well-defined areas along the coast in relatively shallow marine waters (Carter and Sealy 1990). Part of their distribution is related to availability of nesting habitat, as discussed in other chapters in this volume. Murrelets generally forage within 2 km of the shore in relatively shallow waters in Washington, Oregon, and

California. The species does occur farther offshore than 2 km (Carter, pers. comm.; Piatt and Naslund, this volume; Ralph and Miller, this volume; Sealy 1975a), but in much reduced numbers. Ainley and others (this volume) reported a few murrelets up to 24 km offshore in central California. Their offshore occurrence is probably related to current upwelling and plumes during certain times of the year (Hunt, this volume a). Off Alaska and British Columbia, the bird occurs more frequently further offshore; they occur quite regularly out 40 km in the Gulf of Alaska in the relatively shallow waters of that region (Piatt and Naslund, this volume; McAllister, unpubl. data). During the non-breeding season, murrelets disperse and can be found farther from shore, as is the case with some other alcids.

Murrelet prey species mostly include small inshore fish and invertebrate species such as sand lance (*Ammodytes hexapterus*), smelt (*Hypomesus* spp.), Pacific herring (*Clupea* spp.), capelin (*Mallotus* spp.), and various other fish (Burkett, this volume). Invertebrates such as *Euphausia pacifica* and *Thysanoessa spinifera* are also important prey (Sanger 1987b, Sealy 1975a).

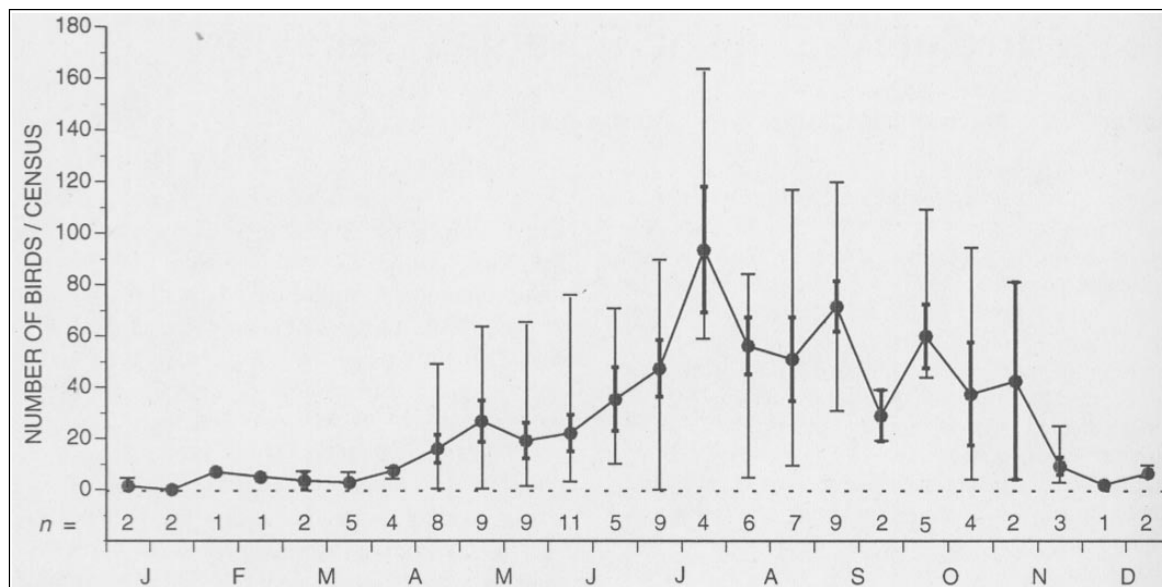
Winter distribution—In some locations, after the breeding season, birds appear to disperse, and are less concentrated in the immediate nearshore coastal waters. This has been observed in Año Nuevo Bay in central California (fig. 1), as birds move away from this protected bay from November through April. Similar movements have been observed in Clarence Strait in Southeast Alaska (McAllister, unpubl. data), where the birds are greatly reduced in numbers and probably have moved to the south. In the southern portion of their range, murrelets are reported in winter as far south in central California as San Luis Obispo County, and at times to the southern portion of the state. In many areas, however, individuals maintain an association with the inland nesting habitats during the winter months (Carter and Erickson 1988).

Fresh water lake use—Carter and Sealy (1986) found 67 records of birds on 33 fresh water lakes; 78.6 percent of those recorded were in British Columbia, 12.1 percent in Alaska, 6.1 percent in Washington, and 3 percent in Oregon. Foraging on lakes had been suspected because salmon fry, fingerlings, and yearlings that have been found in birds' stomachs (Carter and Sealy 1986). A few observations of birds presumably feeding in lakes have been recorded (Munro 1924, Carter and Sealy 1986). Carter and Sealy (1986) speculated that murrelets feed at night on these lakes when fish are available closer to the surface. Hobson (1990) found evidence, based on isotope analysis of murrelet muscle tissue, that birds collected on Johnston Lake, British Columbia, may feed in fresh water lakes for several weeks at a time.

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**Figure 1**—Average number of Marbled Murrelets/census by biweekly periods on Año Nuevo Bay during 1990. Figure shows the mean, standard error, and minimum and maximum values of from-shore censuses.  $n$  = number of censuses/time period.

## Foraging Behavior

### Pairing and Group Size

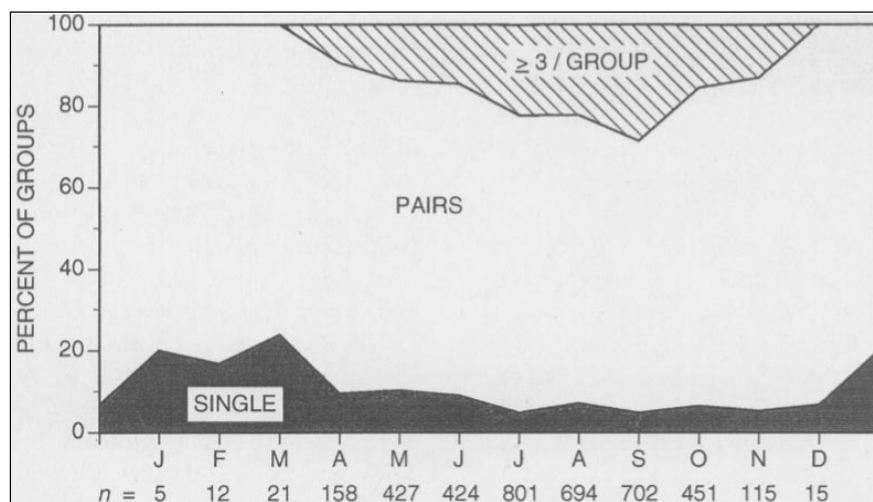
Frequency of pairs—Murrelets forage mostly in pairs throughout the year. This is an important aspect of their life at sea, as we have often observed murrelets vocalizing on the water while foraging, apparently attempting to locate the other member of a pair when coming to the surface, or after a disturbance. The call usually used is the typical “keer” in rapid succession or singly. The percentage of birds in an area that are foraging or loafing in pairs varies, but not greatly. Mean group size from Oregon was 1.8 birds, with about 70 to 80 percent of the birds observed in pairs (Nelson 1990). Along the central Oregon coast, Strong and others (1993) observed that murrelets almost always occurred as single birds or pairs. In Alaska, pairs made up 45 percent of the population (Kuletz, pers. comm.). Carter and Sealy (1990) found in Trevor Channel, Alaska, that pairs were 40 percent of the birds seen. During the summer of 1993, Ralph and Long (this volume) reported 63 percent of groups were pairs and 27 percent were single birds in northern California.

In central California, 75 to 80 percent of birds foraged as pairs during the breeding season (*fig. 2*). Single birds are more common in the winter, when the populations are low at this location (*fig. 2*). Sealy (1975c) suggested that, during the incubation period, a daily pairing of birds occurred as birds flew around in the forested nesting area after an incubation exchange. We have observed many single birds circling and calling at inland sites until joined by a second bird, when both headed west to the ocean. We have also observed at times many hundreds of birds arriving at the ocean in the morning from inland nesting sites, usually in

pairs, threes, or fours. Observations at the nest would suggest that the birds should arrive singly (Naslund 1993a; Nelson and Hamer, this volume a), as pair members are rarely at the nest simultaneously, which might suggest that the birds pair with non-mates enroute to the sea.

Composition of pairs—In British Columbia, Sealy (1975c) found that 11 out of 13 pairs collected in late April were composed of an adult male and adult female. After egg laying occurred, more single “off duty” birds were encountered at sea. He surmised that both adults stay together during the day and returned to the nest site at night to feed their chick. The subadults (birds one or two years old who have not yet bred, as determined by collecting) also returned in late April, but were encountered only as single individuals until late June and early July when mixed groups of “off duty” adults and subadults, were observed. During late July newly fledged young were frequently seen in these groups.

Reason for foraging in pairs—Sealy (1975c) stated “I believe that the occurrence of these pairs can be adequately explained on the basis of pair bond maintenance and that an advantage to feeding need not be involved.” Possible evidence of pair bonding is found in observations of pairs separated by boats. Ralph (unpubl. data) and Miller (pers. comm.) have noted that about two-thirds of these pairs call and attempt to reunite, while the remaining birds simply disperse. However, we feel that foraging plays the major role in pairing, and probably involves some sort of cooperative foraging technique. Evidence of this includes the observation that the vast majority of actively foraging paired murrelets consistently dive together (Carter and Sealy 1990). Laing (1925) stated that the “birds of this genus work in winter and summer in pairs, but not as a defensive measure, for



**Figure 2**—Group size of Marbled Murrelets by month on Año Nuevo Bay during 1990, detailing percentage of groups observed consisting of single birds, pairs, or groups of >3 birds. *n*= number of groups observed.

they dive almost together”. Carter and Sealy (1990) reported that pairs were often seen swimming towards each other before diving, and that three or more birds never dove together in a coordinated fashion. They also stated that foraging by singles and pairs may prevent foraging interference, competition, and kleptoparasitism that would be more likely in foraging flocks.

**Flock size and frequency**—Carter and Sealy (1990) suggested that murrelets are most aggregated during the nesting period. Aggregations of large numbers have been reported in the northern range (Carter 1984; Carter and Sealy 1990; Hunt, pers. comm.; McAllister, unpubl. data). Foraging aggregations were probably related to concentrations of prey. McAllister (unpubl. data) observed an aggregation of 4,000 to 6,000 individuals at Point Adolphus on Icy Strait, in southeast Alaska, on 3 May 1991.

Observers have noted great variation in size of flocks (defined as three or more birds in close proximity and maintaining that formation when moving). In southeast Alaska, Quinlan and Hughes (1984) reported flock sizes up to 50 birds in Kelp Bay. Kuletz (1991a) found in another Alaskan population that flock sizes greater than three birds made up about 8 percent of the birds, 7 percent of the birds were found in groups of four birds, 3 percent of the birds in groups of five, and 1 percent were found in groups larger than five. The largest number in a concentrated flock was 22 birds. In British Columbia, Carter (1984) found larger, non-feeding flocks of up to 55 birds. The larger flocks usually occur during the later part of the breeding season, and may be made up of juveniles and subadults. Sealy (1975c) found that flocks would feed together at Langara Island, British Columbia, with the mean flock size of eight.

Flock sizes in the southern populations of California, Oregon, and Washington, rarely number more than 10,

according to our and others’ observations. Nelson (pers. comm.) recorded groups greater than 3 as very uncommon in Oregon, with a maximum of 10 birds in a flock. Also in Oregon, Strong (pers. comm.), found similar flock sizes during his 1992 study. The largest flock that he observed was 15 birds. In California, Ralph and Long (this volume) found two was the most frequent group size (63 percent), while less than 10 percent of flocks contained more than three birds. The largest flock seen was 12 birds at Santa Cruz. At Año Nuevo Bay, in central California, flocks are similar in size (fig. 2). Here, at the southern end of the species’ range, during late summer and early fall, flocks of over three would often contain juvenile birds. Groups of three or more were found during the summer, when the population is highest (fig. 1), and may be a function of density, rather than flocking.

**Behavior in flocks**—Sealy (1975c) observed that the flocks would tend to dive against the current, and soon become spaced in a linear fashion with the main axis of the flocks paralleling the direction of the current. Carter and Sealy (1990) observed that larger flocks do not appear to be foraging. Sealy (1975a) stated that birds foraging during the breeding season “invariably occur in pairs or as single individuals.” Early in spring adults feed in pairs while the subadults feed singly, but in early July, when pairs are still feeding young at the nest, mixed flocks of adults and subadults begin to form.

### Foraging of Juveniles

When the first juveniles reach the water during the breeding season, usually by early July (Hamer and Nelson, this volume a), they are distinctive in plumage from adults, making identification of individuals in a small flock possible (Carter and Stein, this volume). From this we can learn

about the need for foraging in groups. McAllister (unpubl. data) found in Alaska, between mid-July and mid-August, that more than 80 percent of the young were observed without adults present. By contrast, in California, Ralph and Long (this volume) observed that half of the juveniles observed were accompanied by one or more adults, while the remaining juveniles occurred alone.

By mid-August, it becomes difficult to differentiate juvenal plumage from molting adults. In our observations of juveniles on the water, we found that juveniles foraged without the assistance of the adults. They were seen as single birds, in pairs, and in small flocks. The largest flock was one of 12 young seen together in Peril Strait (McAllister, unpubl. data). Juveniles were most common within 100 m of shorelines, particularly where bull kelp (*Nereocystis* spp.) is present (McAllister, unpubl. data). At this time of year, adults were generally farther from shore in this area, at the sharp tidal interfaces, e.g. rips. However, in a 1993 study, Ralph and Long (this volume) found no difference between the distribution of adults versus juveniles in California.

Behaviorally, the fledglings are generally less wary, more curious, and much more approachable by boat. In flight, they are weak and slow (McAllister, unpubl. data), as compared to adults.

### Interspecific Relations During Foraging

In the southern part of the range, from Washington south, murrelets rarely forage in mixed seabird flocks. Pairs or small flocks will usually forage away from other species. In California and Oregon, murrelets have been reported foraging close to Pigeon Guillemots (*Cephus columba*) and Common Murres (*Uria aalge*), but seldom within any major mixed species flocks. Murrelets have been observed by Strong and others (1993) to avoid large feeding flocks of murres, cormorants (*Phalacrocorax* spp.), and other species in Oregon. He presumed that the small size of the murrelet may render them vulnerable to kleptoparasitism or predation in mixed species flocks. In addition, if the murrelets forage in some cooperative effort, the confusion of a large flock of birds might reduce foraging efficiency.

In the northern part of the range of the murrelet, from Puget Sound north, the literature has more records of the bird mixing with other seabirds when foraging (e.g., Hunt, this volume b). In this region, Marbled Murrelets were less common than the other species in the flocks, and rarely initiated the feeding flock (Porter and Sealy 1981; Chilton and Sealy 1987). Porter and Sealy (1981) found in Barkley Sound, British Columbia, that the murrelet had the lowest flocking tendency (0.2 percent) of the birds seen participating in multispecies feeding flocks, although there they did appear to initiate feeding flocks. Mahon and others (1992) observed that murrelets participate frequently in mixed species feeding flocks in the Strait of Georgia, British Columbia. They found a correlation between the number of feeding flocks observed in the area and the number of murrelets present. Chilton and Sealy (1987) suspected that

murrelets enter small flocks to minimize disturbance from larger, more numerous, and aggressive individuals of other species that would find single birds easy to intimidate. Mixed flocks would occur after murrelets drove a school of sand lance to the surface. Other species participating in these feeding flocks in order of relative occurrence were Glaucous-winged Gulls (*Larus glaucescens*), Bonaparte's Gulls (*Larus philadelphia*), Common Mergansers (*Mergus merganser*), Pigeon Guillemots, Mew Gulls (*Larus canus*), and Pelagic Cormorants (*Phalacrocorax pelagicus*). They felt that several factors encouraged a higher level of interspecific flocking behavior by murrelets: (1) larger and more aggressive alcids, such as Common Murres were absent; (2) the area had a high density of Marbled Murrelets; and (3) prey were locally concentrated, as the fish balled up at the surface when attacked, likely facilitating flock formation.

In Alaska, the foraging flock of 4,000-6,000 Marbled Murrelets on 3 May 1991 in Icy Strait contained an equal number of Bonaparte's Gulls (McAllister, unpubl. data). Both species were feeding actively on what was suspected to be the hatch from a recent herring spawn. In southeast Alaska, McAllister (unpubl. data) found that Marbled Murrelets were rare in the areas where Common Murres and Rhinoceros Auklets (*Cerorhinca monocerata*) from the Forrester Island colony foraged around Prince of Wales Island. This area contains much suitable nesting habitat for murrelets, including large, contiguous stands of old-growth trees, but murrelets apparently avoid the region. He has also observed this at colonies near Saint Lazaria Island, in Sitka Sound, and Hazy Islands group.

In the Gulf of Alaska, where the range of the Kittlitz's Murrelet (*Brachyramphus brevirostris*) overlaps with that of the Marbled Murrelet, the two species often share common foraging areas (McAllister, unpubl. data). However, the two species were not found to interact as pairs or in flocks.

### Diving

Marbled Murrelet foraging is by pursuit diving (Ashmole 1971). Depth and time of murrelet dives are little known.

Dive times—We have recorded dive times of birds using birds with transmitters that were monitored by an observer on shore. When birds are underwater, the transmitter can no longer be heard. We also present some data from birds observed from shore through telescopes.

Dive times were obtained from six birds fitted with transmitters in studies in 1989 and 1991 in northern California. The birds were followed on 13 occasions by a monitor on shore. The median dive times averaged 14 seconds, with the longest at 69 seconds. The mean length of pauses between dives averaged 17 seconds in each year. Rest times were naturally more variable, with as long as 18 minutes between dives.

From-shore observations at Año Nuevo Bay in California, birds were observed with dive times ranging from 7 to 42 seconds. The depth of water for the 7-second dive was 1-2

meters, in a rocky substrate, and the longer dives were observed in about 40 meters of water. Over a 4-year observation period, Strachan (unpubl. data), observed dive times in 20 to 50 meters deep water averaging about 31 seconds. Also at Año Nuevo, Strachan (unpubl. data) observed four birds, with a combined average dive time of 17 seconds, ranging from 6-39 seconds. The shortest average time (11.2 seconds) was a pair of possible juveniles in shallow waters of 2 to 5 m depth, up against the edge of a cliff. Those dives in the deepest water (40-45 m) were also the longest, and averaged 20.0 seconds.

Pairs of birds resurface together on most dives, suggesting that they likely keep in visual contact underwater. Carter and Sealy (1990) found that dive times of individual birds averaged 27.8 seconds. Thoresen (1989), in a Washington study, observed the mean time for a dive was 44 seconds (range 15-115).

Dive depths—Carter and Sealy (1984) found that murrelets killed in gill nets at night were probably feeding near the surface, as they were caught within 3 to 5 meters of the surface. Sealy (1974) stated that they usually foraged in areas that were sheltered from the prevailing winds and were relatively shallow (<30 m in depth). In southeast Alaska, Quinlan and Hughes (1984) found them most often in water less than 100 meters in depth and along steep, rocky coastline. In Prince William Sound, Alaska, Kuletz (1991a) found the highest densities of foraging birds in waters less than 80 meters deep. Also in Alaska, Sanger (1987b) collected birds in January and estimated that most birds had been feeding in water of 18 to 45 meters deep. The birds had apparently foraged from the mid depths, to occasionally at or near the bottom, based on the prey species found in their stomachs. In Año Nuevo Bay, California, Strachan (unpubl. data) found the murrelets generally foraged in waters that ranged from 20-30 meters.

### **Fish Holding**

Few observations have been published of birds on the water holding fish. Carter and Sealy (1990) observed that most murrelets seen holding fish were observed near dusk, just before they fly to their nest to feed nestlings. A few birds were observed holding fish at dawn and later in the morning. They inferred that some individuals may feed chicks during the day because they felt that adults holding fish can not usually capture more fish. Carter and Sealy (1990) felt that increased fish holding by birds toward dusk coincided with the decrease in overall numbers of birds in the foraging area. Larger flocks sometimes included birds holding fish that were not feeding, although most birds that held fish were alone or in pairs. McAllister (unpubl. data) has recorded pre-dusk flyways where hundreds of fish-holding murrelets are counted as they leave foraging areas in Icy Strait, Sumner Strait, and in Frederick Sound in Southeast Alaska, heading towards their presumed nesting areas. At numerous locations, McAllister (unpubl. data) has recorded continuous flyway activity (averaging more than 20 birds per minute), with the majority of birds holding fish.

On a few occasions, birds have been reported holding more than one fish in their bill. Thoresen (1989) observed a bird with two fish and a bird with three fish held crosswise, both on the water's surface and flying. Other observations of multiple fish in the bill include Carter (pers. comm.), Cody (1973), Fortna (pers. comm.), and Savile (1972).

### **Foraging Influences**

Adjacent inland habitat—Densities of the Marbled Murrelet in specific geographic areas during the breeding season appear to be related to the adjacent nesting habitat (Carter and Sealy 1990; Ralph and Miller, this volume). It is also very probable that foraging locations are dependent upon prey habitat or availability, but no research has been conducted on this subject to date.

Weather—Throughout their range, murrelets have been observed foraging in all weather conditions normal for that habitat. They have also been seen foraging in extreme weather conditions. McAllister (unpubl. data) has recorded foraging at night in sub-freezing conditions, with 40-60 knot easterly winds blowing out from the Taku River Valley. The birds were foraging on the herring schools that were feeding in the interface between marine and fresh water. Due to the topography, nearby waters within 4 km were relatively calm, yet the birds chose to be active at night in the rough weather and seas.

Times of day—Birds appear to forage at all times of the day, and in some cases during night hours, presumably when there is enough ambient light to capture prey. Some observers have hypothesized that murrelets move from one feeding area to another during the early morning and late afternoon periods (Carter 1984, Carter and Sealy 1984, Prestash and others 1992). On the other hand, they may be staging in an area in the early morning near the nesting area, then moving out into foraging areas. Off the California coast, six birds with radio transmitters did not forage during the night in June or July (Ralph, unpubl. data), rather, the foraging was confined to the daylight hours.

Topography—We have observed consistent densities of birds utilizing the lee of protected headlands in California, as has Kuletz (pers. comm.) in Alaska. We have noticed, but not quantified, that the wind conditions could be a factor for greater bird densities in the lee of headlands. Carter and Sealy (1990) speculated that prey also concentrates in sheltered waters. Certainly concentrations of birds are likely due to the availability of prey at the rip-current lines and in the tidal eddies that are established to the downwind of such features. In Oregon, Strong and others (1993) found that the highest densities of murrelets were found adjacent to beaches or mixed beach and rocky shore areas.

## **Non-Foraging Behavior**

### **Coalescence**

An interesting phenomena that has been noted by a few researchers is that during the breeding season, about an hour

before dusk, birds that are both loafing or foraging will coalesce into loose aggregations with much preening and wing stretching (Carter and Sealy 1990; Nelson, pers. comm.; O'Donnell, pers. comm.). We and Sealy (1975) have noted that specific sites are consistently used for these gatherings. Carter (pers. comm.), Kuletz (pers. comm.), and we have observed many times that a few minutes before dark the birds will begin to take off and fly inland in pairs or singly. In southeast Alaska, McAllister (unpubl. data) has found that these loose aggregations most often occurred offshore of forests, and in waters where foraging is rarely, if ever, observed. He found that birds begin landing at these locations in the late afternoon. The rate of arrival increased steadily until the hour before dusk, as birds were commonly seen flying in and landing, with most holding fish. He observed this commonly along the west shore of Admiralty Island where birds arrive on flyway routes from foraging areas in Icy Strait. The birds holding fish were found in a band between 1-2 km from the shoreline. At dusk these birds fly from the water, often climbing steeply before heading inland. Simons (1980) and Hirsch and others (1981) also observed murrelets holding fish just before flying inland at dusk.

### Loafing Activities

Loafing in the murrelets involves resting on the water, perhaps sleeping, along with preening and other activities. During loafing, we have observed that birds appear to drift with the currents, or move about without direction. We have also observed vocalizations during loafing periods, especially during the mid-morning and late afternoon. There are no data available on the frequency of wing stretches and flutters during the day, nor the function of the vocalizations.

### Flyways

In regions of high murrelet populations in coastal British Columbia and Alaska, what we refer to as "flyways" of Marbled Murrelets occur. Here, hundreds to thousands of birds commute between foraging and nesting areas. The birds are moving distances up to 60 km (McAllister, unpubl. data). McAllister has observed throughout the breeding season that birds moving along these routes are most numerous in the two hours following sunrise, as birds returned to foraging areas. During the chick-feeding period, the same flyways are again active in the night just before dawn (taking fish to their young) and just after dusk (returning to foraging areas).

### Courtship Behavior

Courtship behavior at sea has been rarely reported in Marbled Murrelets. Quinlan (1984) described courtship behavior involving both birds of a pair extending their necks vertically and pointing their bills skyward while slowly swimming towards each other. The birds maintained this posture, then swam together for 15 to 30 seconds. McAllister (unpubl. data) has observed courtship behavior in March and April in southeast Alaska, most often in the early morning, soon after birds land following dawn flights. He has recognized

two distinct behaviors: heads-up posturing, and pursuit flight-diving. The most common, *heads-up posturing*, involves two birds taking an erect posture, necks fully extended upwards, and heads tipped back, so that bills are directed upward. Pairs will draw very close to one another and either circle or swim forward rapidly. They may dive and then resurface in the heads-up posture. If separated while diving, the pair will rapidly swim towards each other in the heads-up posture. Heads-up posturing may change into *pursuit flight-diving* behavior, as one bird flies low across the water pursued by the other bird. The lead bird then makes a flying dive, the other following into the water and pursuing the lead bird underwater until they resurface into flight again, without a hesitation in wing beats. The pair may take flight and dive repeatedly, as many as four times consecutively.

Copulation has been observed only rarely on the water, and may primarily occur in forests before egg laying. Quinlan (1984) observed copulation at sea once on 16 May 1984. Prestash (pers. comm.), recorded copulation on May 29, 1990 at Muscle Inlet, British Columbia. In California, copulation on the water has been observed only 3 times in approximately 3,000 hours of observations, mostly during the breeding season (Ralph, unpubl. data).

### Disturbances

The effects of human disturbance on murrelets at sea is not well documented. Strong (in press) felt that birds were very sensitive to his passing vessel. Almost all responses occurred at less than 50 m from the boat. Of 4721 behaviors recorded, in apparent response to passage of the boat, 1103 birds dived (23.4 percent), and 725 (15.4 percent) flew. McAllister (unpubl. data) observed that in Gastineau Channel, near Juneau, Alaska, murrelets apparently habituate to heavy levels of boat traffic. Ralph (unpubl. data) has noted that birds in the San Juan Islands, Washington, allowed much closer approach in boats, as contrasted to birds in waters of offshore California, where boat traffic is much lighter.

## Discussion

Documentation of the species' at-sea behavior is important to the full understanding of the ecology of the species. Our overview demonstrates how few data have been gathered on the behavior of the bird on the ocean. Knowledge of the timing and extent of different behaviors is also essential to the design and implementation of at-sea monitoring protocols. For instance, the response of birds to boats and airplanes would greatly influence the ability of observers to count birds. Also, knowledge of the percent of time spent underwater is also important in determining the ability of observers to detect birds from boats.

Various observations during the breeding season suggest that the birds may forage in some areas at night, and probably more often at or near dawn and dusk, to procure food for their chicks. Some observations of nocturnal feeding are possibly related to prey tending to be closer to the surface at

night. Certainly murrelets must be able to locate prey species where or when there is little ambient light.

Many observations of fish holding occur at dusk. At nests, observations of nestlings being fed whole fish have almost always been during first light at dawn (Nelson and Hamer, this volume a). Foraging for nestlings therefore would probably occur during the early morning periods when there is enough light for the murrelets to catch prey. We feel that observations of adults holding fish are strong indicators of a bird about to depart inland to feed a young. As such, this may be a sensitive measure of birds with young on the nest, potentially a very useful measure of reproductive rate in this species.

The majority of birds on the water are in pairs. We do not know what proportion of these are mated birds, or what proportion are birds temporarily paired for foraging. Observations of murrelets in groups of more than four are rarely foraging, and appear to be largely loafing. In most cases, pairs on the water dive simultaneously, strongly suggesting to us an apparent benefit to foraging. We can find no evidence that pairs on the water during the breeding season are actually mates involved in breeding. By the same token, we do not know if single birds belong to a pair of

incubating birds. We feel that it is likely that the species has evolved a yet-undescribed feeding strategy that involves cooperative herding of schools of small fish.

Flock size appears to be related to the size of the regional populations, prey availability, and possibly juvenile behavior. The largest flocks are in areas with the largest populations of birds. There are no obvious behaviors related to flocking, other than loafing, that have been reported.

We very much need more work in several areas relating to offshore behavior. Since it is possible to completely census birds on the water, and much of the adult mortality probably takes place here, it is vital that we have a fuller understanding of the factors involving the distribution, abundance, feeding behavior, juvenile behavior and survivorship, at-sea social behavior, as well as many other factors, of these interesting birds.

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