BREEDING PHENOLOGY AND CLUTCH SIZE IN THE MARBLED MURRELET

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THE Marbled Murrelet (*Brachyramphus marmoratus*) is the only species of bird considered to breed regularly in North America whose nest has not been found on this continent, despite recent publicity (Audubon Field Notes 1970). During a study of the feeding and breeding ecology of the Marbled and Ancient (*Synthliboramphus antiquus*) Murrelets (Sealy 1972) on and in the vicinity of Langara Island, Queen Charlotte Islands, British Columbia (Figure 1), I made observations and obtained information from collected specimens of Marbled Murrelets that indicate its clutch size and the pattern and timing of its breeding cycle there. Although I did not locate any Marbled Murrelet nests, the information contributes to our knowledge of its biology and provides dates between which certain events of its breeding cycle occur in that area. Such information may aid other workers in the ultimate discovery of its nest. A detailed account of the breeding biology of the Marbled and Ancient Murrelets is to be presented elsewhere (Sealy 1972, MS).

Several accounts of the many unsuccessful attempts to find the Marbled Murrelet's nest and speculations regarding its location are available (e.g. Young 1930; Guiguet 1950, 1956; Gabrielson and Lincoln 1959; Drent and Guiguet 1961). I do not intend to repeat all these observations but will utilize those from the Queen Charlotte Islands and those of particular interest.

The Marbled Murrelet has a disjunct distribution. Its range shows a gap bracing the Aleutian chain with subspecific differences on either side of this gap—*B. m. marmoratum* of the Northeastern Pacific coast, the race studied here, and *B. m. perdix* of the Northwestern Pacific coast (see Dement'ev and Gladkov 1951: 245–248; Udvardy 1963: 99).

STUDY AREA AND METHODS

Fieldwork was conducted on and in the vicinity of Langara Island and the northern shore of Graham Island, Queen Charlotte Islands, British Columbia (Figure 1), from 6 May to 10 July 1970 and 17 March to 10 August 1971.

Descriptions of the topography (Holland 1964), geology (Brown 1968), climatology (Williams *in* Calder and Taylor 1968), vegetation (Foster 1965, Calder and Taylor 1968, Schofield 1968), and mammalian fauna (Foster 1965) of the Queen Charlotte Islands, including Langara Island, are available. The avifauna of the Queen Charlotte Islands was first described in detail by Osgood (1901). Since that time several workers have visited the islands, usually in search of the Marbled Murrelet's nest,

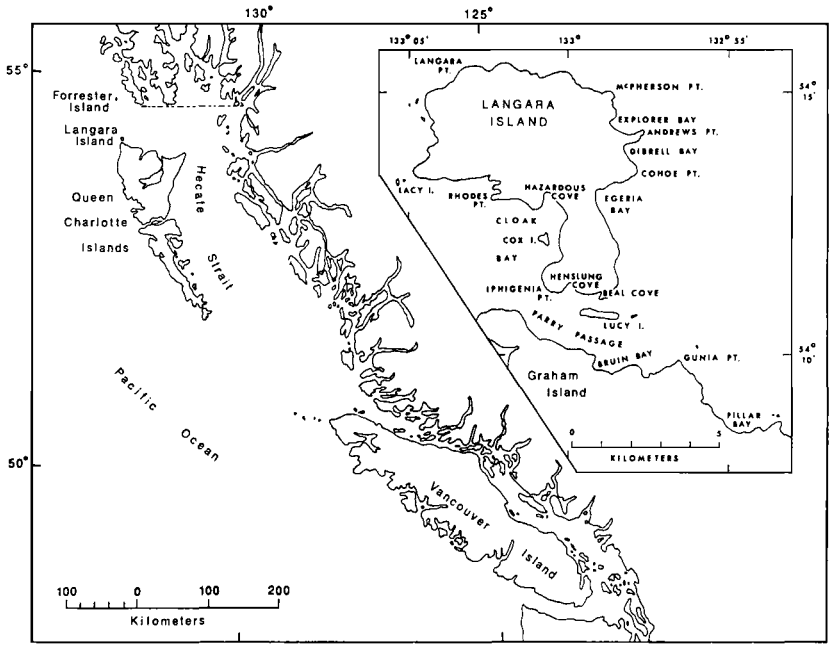

Figure 1. Map of the British Columbia coast. Inset shows Langara Island and portion of the northern shore of Graham Island where observations of Marbled Murrelets were made.

and have written about the birds they observed. Some of these papers concern the avifauna of Langara Island and immediate vicinity (e.g. Young 1927, Darcus 1930, Cumming 1931, Campbell 1969). Drent and Guiguet (1961) reported on the status of seabird colonies on the Queen Charlotte Islands, including Langara Island, as known up to 1960.

All my observations of Marbled Murrelets were made from a pneumatic boat with an outboard motor. From 4 June to 6 July 1970, I made nine trips between 09:00 and 23:00 (PST), each about 4 hours in duration, to observe and collect Marbled Murrelets for analysis of food habits. These trips as well as those in 1971 were along the northern shore of Graham Island to Pillar Bay and west to Cloak Bay and Parry Passage (see Figure 1). From 25 March to 10 August 1971, I made 56 such trips between 06:30 and 22:30, which varied from 1–7 hours with a mean duration of 4 hours, specifically to study the return of Marbled Murrelets in spring, foraging behavior, and foraging areas, to collect individuals for food habits analysis, and to census adults and, after 7 July, newly fledged juveniles.

Also while studying Ancient Murrelet nesting habits in 1971 I made almost daily trips, about one-half hour each way, from headquarters at Dadens up the east side of Langara Island to McPherson Point between 26 April and 5 July. I often saw Marbled Murrelets on these trips and twice collected two individuals in Egeria Bay.

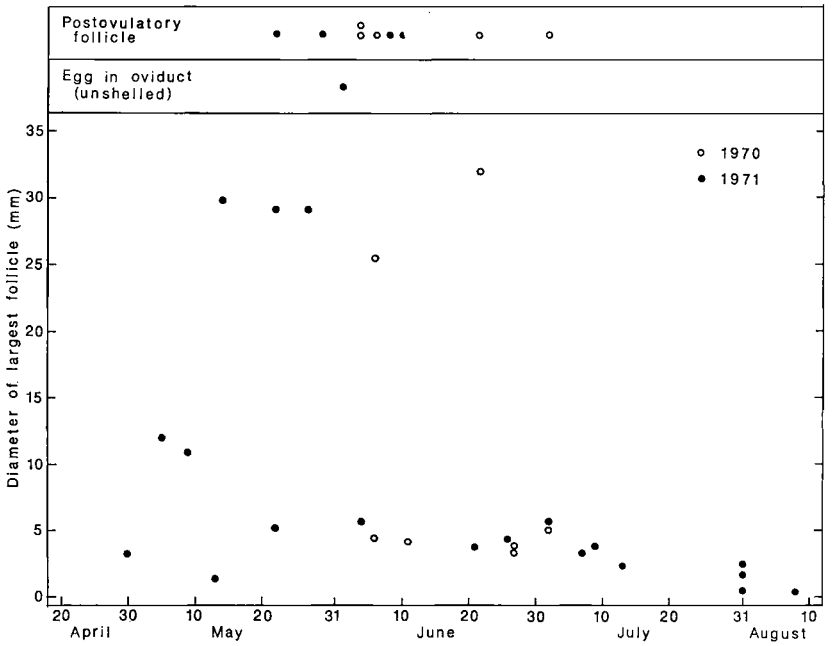

Figure 2. Follicular maturation in the Marbled Murrelet as indicated by the diameter in mm of the largest follicle or presence of a postovulatory follicle.

Birds were collected at weekly intervals, mainly in Cloak Bay, Hazardous Cove, Egeria Bay, and Pillar Bay (Figure 1). No nests were found and the information on the clutch size and timing of breeding in the Marbled Murrelet presented here was derived from observations of unmarked birds at sea and from examinations of collected specimens (see Sealy 1972 for details). The ovaries from females

TABLE 1

MARBLED MURRELET BROOD PATCH SCORES, LANGARA ISLAND, BRITISH COLUMBIA[1]

Period	Brood patch scores[2]							Mean score
	0	1	2	3	4	5	6	
15–31 March	1	—	—	—	—	—	—	0
1–15 April	—	—	—	—	—	—	—	—
16–30 April	5	—	—	—	—	—	—	0
1–15 May	8	1	1	—	—	—	—	0.3
16–31 May	4	2	3	2	—	—	—	1.3
1–15 June	—	1	4	6	—	—	—	2.5
16–30 June	2	—	3	9	—	—	—	2.4
1–15 July	—	—	1	8	3	2	—	3.4
16–31 July	—	—	—	—	1	7	—	4.9
1–15 August	—	—	—	—	1	2	—	4.7

[1] Scores of adults of both sexes collected in 1970 and 1971 are combined.
[2] For explanation see text.

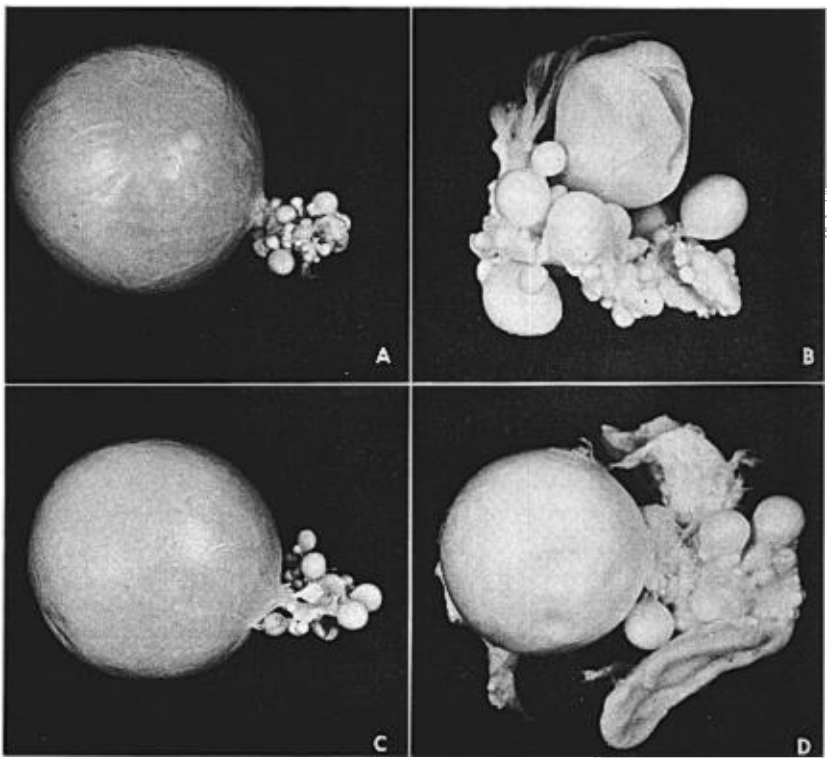

Figure 3. Gross structure of the ovaries of selected alcids. A, mature follicle of the Marbled Murrelet × 1.0. B, postovulatory follicle of the Marbled Murrelet × 2.4. C, mature follicle of the Least Auklet × 1.4. D, postovulatory follicle of the Ancient Murrelet with the second follicle about half developed (shelled egg was in the oviduct) × 1.9.

were removed and placed in Bouin's fixative for 24 hours before being stored in 70% ethanol. The diameter of the largest follicle in each ovary was measured to the nearest mm (Figure 2), also the diameters of the several smaller but somewhat developed follicles of each ovary, and the largest diameter of visible postovulatory follicles. The ovary of an egg-laying female Least Auklet (*Aethia pusilla*) shown in Figure 3 was obtained in 1967 during ecological studies of plankton-feeding alcids on St. Lawrence Island, Alaska (Sealy 1968).

Every adult bird examined (birds identified as subadults showed no brood patch development) was scored (see Tables 1 and 2) according to the developmental state of its brood patch as follows: class 0, no evidence of defeathering; class 1, loss of down and some contour feathers; class 2, almost complete loss of down and most contour feathers with vascularization beginning; class 3, complete loss of feathers with heavy vascularization (maximum development); class 4, regression beginning with down appearing, especially around the edges, and sheaths of new contour feathers appearing; class 5, most of area down-covered, contour

TABLE 2

BROOD PATCH SCORES OF ADULT MARBLED MURRELETS AT SELECTED PERIODS OF THE BREEDING CYCLE ON LANGARA ISLAND IN 1970 AND 1971

	Brood patch scores[1]							Mean score
	0	1	2	3	4	5	6	
Females with primary oocyte about one-half developed	2	—	—	—	—	—	—	0
Females with fully developed ovum still in follicle	—	2	3	—	—	—	—	1.6
Female with unshelled egg in oviduct	—	—	1	—	—	—	—	2.0
Females with one recently ovulated follicle	—	—	1	9	—	—	—	2.9
Males and females at time of first appearance of young on the sea	—	—	1	4	3	2	—	4.6

[1] See text for details of scoring method.

feathers beginning to break out of sheaths; class 6, complete regression, appearance as in class 0.

PRE-EGG STAGE

Most students (e.g. Munro and Cowan 1947, Gabrielson and Lincoln 1959, Guiguet 1971a) have considered the Marbled Murrelet to be a permanent resident throughout its range, and indeed it is present in waters along much of the Pacific coast in winter. Between 20 March and 24 April 1971 I saw only one Marbled Murrelet near Langara Island, on 29 March; on 25 April about 30 individuals appeared in Pillar Bay and from that day on they were prevalent in the area.

The birds were not gregarious during the first half of their breeding season—they returned in spring paired, and the individual pairs were maintained, usually aloof from other pairs, until at least late June. From this time on I encountered mixed flocks of adult males and females and subadults, which usually consisted of 4–11 individuals (mean = 7, N = 75 flocks counted). In late July and early August these groups frequently included newly fledged young.

As the next section shows, egg-laying commenced about 15 May in 1971 and thus the pre-egg stage lasted only about 3 weeks after the birds returned to the Langara Island vicinity on 25 April.

THE NEST SITE

Many field parties hunting for the Marbled Murrelet's nest (see Young 1930; Guiguet 1956; Gabrielson and Lincoln 1959: 488–490; Drent and Guiguet 1961: 79–83) have searched the Queen Charlotte Islands, particularly Langara Island and neighboring islets. Young (ibid.)

and Drent and Guiguet (ibid.) discussed the several eggs of questionable identity these parties produced.

According to Young (1930: 19) C. F. Newcomb collected the first known egg, allegedly of this species, on the "Queen Charlotte Islands" in 1901. Drent and Guiguet (1961) later traced this egg to the Royal Ontario Museum but were unable to uncover additional data. A second egg (apparently no longer extant) was collected by C. de B. Green from a burrow on Cox Island near Langara Island (not Banks Island near Prince Rupert as stated by Young) on 22 July 1920. Two more eggs brought from Cox Island were considered by Young to be from another species, possibly the Ancient Murrelet although he gave no reasons, i.e. coloration, size, etc., for his decision (Young 1930).

Darcus (1927, 1930) reported finding a breeding colony of 20 pairs of Marbled Murrelets on Cox Island on 14 May 1927. He collected one egg from each of three burrows and a fourth egg on 15 May, but as in the above records, he collected no adults with the eggs to prove their source unequivocally. Drent and Guiguet (1961) believed these eggs were probably Ancient Murrelets' because they were collected from burrows on Cox Island which was then known to support a large Ancient Murrelet colony. Evidence obtained in the present study supports Drent and Guiguet. The Marbled Murrelet does not start to lay near Langara Island until about mid-May, and laying peaks toward the end of May or early June (Figure 2). Ancient Murrelets begin laying their two-egg clutches on Langara Island in late April and leave their first eggs unattended in the burrow before returning to lay their second eggs (Sealy 1972). The four eggs Darcus collected on 14, 15 May 1927 were probably unattended Ancient Murrelet eggs.

Such information remained all that was available concerning the nest site of the Marbled Murrelet on the Queen Charlotte Islands (see Bent 1919: 143; Dement'ev and Gladkov 1951: 247–248; Gabrielson and Lincoln 1959: 488; Drent and Guiguet 1961: 79–81, for details of disputed nest sites elsewhere) until the early 1950s. On 4 June 1953 W. Feyer and another man felled a large hemlock near Masset on Graham Island; from the debris they removed a dazed but living adult Marbled Murrelet and eggshells that contained blood. The adult was not preserved and it was not ascertained whether the nest site was actually in the tree or in its path when it fell (Drent and Guiguet 1961). Further evidence of tree nesting in this species comes from Holberg on northern Vancouver Island where Harris (1971) reported that on 24 August 1967 two young Marbled Murrelets dropped out of a tree being felled by loggers. The nest was apparently some 50 feet up in a cedar about 5 km inland. In Russia, Kuzyakin (1963) found a nest

(of the race *perdix*) on 17 June 1961 about 7 m above the ground in a taiga larch tree, some 6–7 km from the sea.

Savile (1972) pointed out that in 1957 while he was traveling throughout the Queen Charlotte Islands, Marbled Murrelets were numerous along shorelines bordering heavy stands of timber, but were scarce in waters adjoining cliffs and scrub forest. He reported that along the north shore of Graham Island on 17 July 1957, his vessel flushed from the water two Marbled Murrelets carrying fish in their bills; they flew directly to the shore where they rose "to near tree-top height before being lost in haze at a distance of a mile or more." Although the evidence for tree nesting in the Marbled Murrelet is mounting, Savile's observations are at best only circumstantial evidence of it.

The first hint of possible tree nesting in the Marbled Murrelet came from Cantwell (1898) who reported that Indians of the Prince of Wales Archipelago told him the species nests in hollow trees high up in the mountains. Although Bent (1919: 142) considered the tree nesting hypothesis unlikely, Storer (1945) presented additional evidence, mostly morphological, to support it. Storer cited Cantwell's statement and mentioned that G. Willett had told him of seeing an Indian painting of a Marbled Murrelet perched on a tree limb. Storer's (1945) statement that the Marbled Murrelet's "summer plumage is not unlike the bark of several conifers in colour" deserves elaboration. The breeding plumage of this species basically consists of mottled brown underparts and rufous-colored back and rump (see Bent 1919: 143; Kozlova 1957: 86–87). Prevalent in the forests on Langara Island and vicinity are large evergreens, both hemlock and cedar which, in addition to having many large crotches suitable for a nest, frequently have large accumulations of moss on horizontal branches. Such moss "beds" often measure up to a meter across and would surely support a nest, but the murrelets' rufous-colored back would certainly not afford the incubating bird concealing coloration. Also prevalent in these forests are freshly broken hemlock and cedar trunks, the inner wood of which, to my eyes, matches perfectly the rufous of the adult Marbled Murrelets' backs. If indeed the Marbled Murrelet does nest in trees, as the number of potentially suitable nest sites in the coastal forests is almost infinite, some method of locating their nests other than chance sightings is desirable. As the species is nocturnal in its movements to and from the nest site, it is impossible to follow its flights directly inland to the nest except possibly by radiotelemetry.

TIMING OF EGG-LAYING

Judging by gonadal development in adult female Marbled Murrelets during the breeding season in North America (see Table 1 of Drent and

Guiguet 1961), eggs have been laid from 23 April 1920 at Wrangell, Alaska (Bailey 1927), to as late as 13 July 1941 near Glacier Bay, Alaska (Jewett 1942). From the Queen Charlotte Islands, Feyer's record near Masset indicated advanced incubation in one egg on 4 June 1953.

The species' egg-laying period near Langara Island can be deduced to within a few days from Figure 2. The diameter of the largest follicle was used to illustrate seasonal changes in the females reproductive tract. The presence of postovulatory follicles, the unshelled egg in the oviduct, and mature follicles are probably within 1 to 3 days from an actual egg-laying date (Sturkie 1965: 468). Figure 2 also shows that egg-laying in the 2 years spanned a 6- to 7-week period from about 15 May to late June or early July.

Clutch Size

Although the nest site of the Marbled Murrelet has never been found in North America, examinations of ovaries from 20 adult females collected during the egg-laying period in 1970 and 1971 (Appendix 3 of Sealy 1972) indicate that Marbled Murrelets lay a one-egg clutch. In summarizing similar information from specimens collected throughout its apparent North American breeding range, Drent and Guiguet (1961: 82) also concluded that this species generally lays one-egg clutches.

Drent's and Guiguet's summary indicates that certain workers have noted more than one ovum developing in Marbled Murrelet females. As these workers did not provide follicle measurements their data, as discussed below, do not show unequivocally that the species ever produces two eggs.

Brooks (1926) reported an adult female R. M. Stewart collected on Harrison Lake, British Columbia, that proved upon dissection "to have two well formed eggs in her. One was almost perfect and over an inch in length, the other less than half formed." The second follicle Brooks referred to was possibly one of several additional enlarged ones (see Figure 3B) and without its measurement, it is not strong evidence that this individual produced two eggs. Bailey (1927: 14) took a female near Wrangell, Alaska, on 23 April 1920 "which had evidently laid an egg, and had another ready for the shell; another specimen with an egg nearly ready to be laid was taken in Glacier Bay on July 12." Bailey did not state whether a postovulatory follicle was present or just how he ascertained that it had "evidently laid an egg."

Taylor (1921) stated that G. Cantwell collected three female Marbled Murrelets at the mouth of the Columbia River between 10 and 18 May 1918, two of which "contained two eggs each, and one bird one, in the

oviduct. The egg in the last named case was about 1½ inches in diameter, and the breast of the bird showed a bare area, as if she had been sitting." As will be seen later, the brood patch has only just begun to defeather at the time of ovum maturation. The so-called "second" but unmeasured eggs reported are not conclusive evidence for two-egg clutches.

Figure 3 shows ovaries of the Marbled Murrelet (A, mature follicle; B, with postovulatory follicle), Least Auklet (C, mature follicle), and Ancient Murrelet (D, one postovulatory follicle and second follicle developing). As in the Least Auklet, which lays only one-egg clutches (Sealy 1968), only one ovum and follicle appear to develop to maturity in the Marbled Murrelet. Also as in the Least Auklet, each ovary of the Marbled Murrelet examined during egg-laying (Appendix 3 of Sealy 1972; Figure 3 of this study) has 3 to 10 additional slightly enlarged follicles that measured up to 5 mm in diameter. If the Marbled Murrelet usually or even frequently lays two eggs, the secondary follicle would probably be larger when the primary follicle has reached maturity, as in the Ancient Murrelet, which habitually lays two eggs (Sealy 1972).

Two possible nest discoveries of the Marbled Murrelet discussed by Drent and Guiguet (1961: 79–83) indicate that only one egg was present in both nests. The case Harris (1971) reported of two flightless chicks that fell out of a tree felled by loggers on Vancouver Island suggests a two-egg clutch, but whether the two chicks were in the same nest or the tree contained two nests is not known. The nest Kuzyakin (1963) discovered in Russia contained only a single egg. The congeneric Kittlitz's Murrelet (*B. brevirostre*) appears definitely to lay only one-egg clutches (see Thayer 1914, Bailey 1943, Gabrielson and Lincoln 1959, Murie 1959, Thompson et al. 1966).

BROOD PATCHES

During the breeding season, both male and female Marbled Murrelets develop a single brood patch, which is centrally located back of the sternum. The brood patch is bare and has loose and greatly vascularized skin. The average dimensions of the fully developed patch (stage 3) in 14 adults were 37.5 mm by 28.3 mm.

Table 1 summarizes the stages in brood patch development by biweekly peroids for June and early July of 1970 and the entire summer of 1971. The sexes are lumped because in pairs collected the brood patches of both sexes exhibited equal development. Brood patches have not begun to develop when the adults return in spring to the Langara Island vicinity, but develop rapidly to near completion by the time the eggs are laid (Table 2). Development was maximal by mid-July; refeather-

ing had begun in some individuals in early July, when the first newly fledged young were beginning to appear at sea (Table 2). Refeathering was not complete on any individual examined up to mid-August when collections ceased.

Incubation

The incubation period of the Marbled Murrelet, extrapolated indirectly, is approximately 30 days. In 1971 the first eggs were laid about 15 May (Figure 2) and the first adults carrying fish in their bills at dusk before flying in to feed their young were seen 13 June 1970 in Hazardous Cove and 16 June 1971 in Pillar Bay. Drent and Guiguet (1961: 86) predicted the incubation period of this species to be 1 month, based on comparison with the relatively long incubation periods of other alcid species.

Flightless Young

To date only one flightless young Marbled Murrelet has been discovered on the Queen Charlotte Islands (see Drent and Guiguet 1961: 83–90). R. M. Stewart reported to Guiguet that a girl picked up a flightless murrelet near Masset about 2 miles from salt water on 15 July 1947. The bird was completely feathered with an egg tooth present and some down adherent.

Appearance of Fledged Young at Sea

In 1970 R. W. Nelson and I saw the first young Marbled Murrelet on 6 July near Iphigenia Point. In 1971 the first young (accompanied by 2 adults) was observed in Egeria Bay on 7 July. Young Marbleds were seen daily near Langara Island and along the northern shore of Graham Island from 7 July until 10 August 1971 when observations ceased. Apparently young Marbled Murrelets assume an independent existence once they reach the sea. Although I often saw single young accompanied by one or more adults (parents?), young were more frequently encountered alone or in groups of two (Table 3). Guiguet (1971b) frequently observed similar mixed groups of young and adults in Barkley Sound on Vancouver Island.

Drent and Guiguet (1961: 88–89) summarized dates and localities where newly fledged young Marbled Murrelets were reported at sea in North America. On 22 July 1920 Allan Brooks and C. de B. Green collected a juvenile "with the bases of its quills still in sheath. . .some 200 yards out to sea from [Cox Island]" (Brooks 1926). C. J. Guiguet (*in* Drent and Guiguet 1961: 89) collected two juvenile females both with egg tooth intact on 28 June 1947 in Peril Bay, directly east of

TABLE 3

SIGHTINGS OF YOUNG MARBLED MURRELETS NEAR LANGARA ISLAND BETWEEN 7 JULY AND 10 AUGUST 1971

Sightings[1]	Number	Percent
Single young	102	62.2
1 young and 1 adult	7	4.3
1 young and 2 adults	15	9.1
1 young and > 2 adults	6	3.7
2 young and 1 adult	1	0.6
2 young and 2 adults	4	2.4
2 young	23	14.1
3 young	3	1.8
4 young	1	0.6
5 young	1	0.6
6 young	1	0.6
TOTAL	164	

[1] It is possible that many young and/or adults were seen repeatedly.

Frederick Island; the previous day he saw the first young Marbled Murrelets of that year at sea. The same year Guiguet saw three juveniles in Tian Bay on 7 July, one in Nesto Inlet on 9 July, and one in Rennell Sound on 13 July (all localities along the west coast of Graham Island).

Near Forrester Island, Alaska, some 70 km north of Langara Island, Willett (1926) stated that "During six summer seasons. . .on Forrester Island, probably the greatest seabird rookery on the Pacific Coast, this murrelet was never observed at all until late July, when they appeared in small numbers accompanied by their young, who were then full grown." He gave one early date for the appearance of young near Forrester Island—26 June 1921.

Several workers (e.g. Willett 1926, Guiguet 1950, Cantwell *in* Jewett et al. 1953) reported adult Marbled Murrelets accompanied at sea in late summer by one young and have assumed, possibly correctly, that such are indeed family groups, but it is evident from Guiguet (1971b) and Table 3 that no such assumption can be made. Nor can such observations be used as indicators of brood size.

TIMING OF BREEDING

The data on the breeding cycle of the Marbled Murrelet near Langara Island permit outlining the timing of the major events of its breeding season there (see Figure 4). Such information is essential for planning an expedition, especially one limited by time, to search for a nest site. Figures 2 and 4 suggest the most productive period to search for a nest is during the last 2 weeks of June and the first week of July. This is the period when most pairs have laid their eggs and are incubating, and the young hatched in early nests have not yet fledged. As the

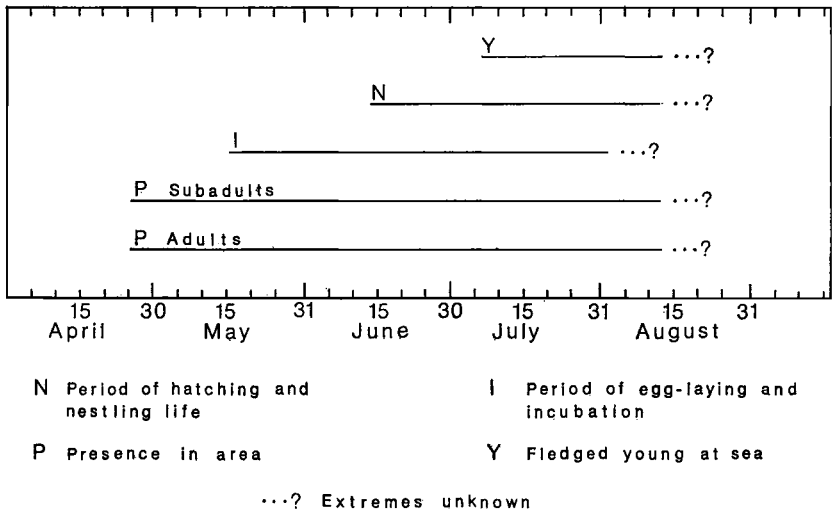

Figure 4. Diagram of the breeding phenology of the Marbled Murrelet near Langara Island. The line ends show the extremes I observed in 1970 and 1971. Question marks indicate that the extreme dates may have extended beyond the observation period.

maximum number of nests are active here during this period, a worker's chances of locating one would then be best.

Acknowledgments

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