Marbled Murrelet mortality due to gill-net fishing in Barkley Sound, British Columbia

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1. Abstract

Alcid mortality due to nearshore commercial fishing has been seldom examined. Little information is available on how it occurs and what effects it has on local populations. During studies of a breeding population of Marbled Murrelets (*Brachyramphus marmoratus*) in 1979 and 1980, in Barkley Sound, British Columbia, we obtained information on mainly Marbled Murrelet mortality due to a local, sockeye salmon (*Oncorhynchus nerka*) based, gill-net fishery. The fishing season coincided with the murrelets' nestling period and regular high-density aggregations of fishing boats and feeding murrelets overlapped. Most mortality occurred at night in the southern part of Trevor Channel. This mortality is significant because 7.8% of the fall population size is killed annually. Mortality has probably happened only recently, however, due to changes in fishing boundaries. Mortality could be effectively eliminated by excluding gill-net fishing from a small area where foraging Marbled Murrelets aggregate or by allowing "daylight" fishing only in this area.

2. Résumé

La mortalité des alcidés due à la pêche commerciale près des côtes a rarement été étudiée. On dispose de peu d'informations sur la façon dont elle survient et sur ses répercussions sur les populations locales. Au cours d'études réalisées sur une population nicheuse d'Alques marbrées (*Brachyramphus marmoratus*) en 1979 et en 1980, à Barkley Sound en Colombie Britannique, les auteurs ont recueilli des données sur la mortalité des alques résultant principalement de la pêche locale du saumon sockeye (*Oncorhynchus nerka*) au filet. La saison de pêche coïncidait avec la période de nidification des alques et régulièrement, de grandes quantités de bateaux de pêche venaient empiéter sur le territoire où se nourrissent ces espèces. La plupart des décès survenaient la nuit dans la partie sud du canal Trevor. Ce taux de mortalité est appréciable, car 7,8 % de la population d'automne est tuée chaque année. Toutefois, ces cas sont probablement récents, et seraient dus aux modifications des limites des zones de pêche. La mortalité dans les filets pourraient être éliminée en interdisant la pêche aux filets dans les petites zones où des groupes d'Alques marbrées viennent s'alimenter ou en n'autorisant dans cette région que la pêche pendant le jour.

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3. Introduction

Much concern has recently developed over the adverse effects that commercial fishing activities have on marine bird communities (Straty and Haight 1979). Considerable attention has been directed towards the incidental mortality of seabirds in offshore salmon gill-net fisheries (King *et al.* 1979, Ainley *et al.* 1981). Off Greenland, large numbers of murres (*Uria* spp.) were netted over several years (Tull *et al.* 1972, Christensen and Lear 1977). This mortality seemed to exceed the reproductive capacity of the breeding population and led to the closure of the fishery in some areas (Salomonsen 1979). Gill-net fishing in nearshore waters appeared to kill fewer seabirds and to be less significant. Large tolls, however, have been inflicted near large nesting colonies (King *et al.* 1979; Piatt *et al.*, this volume).

In this paper, we report the mortality of alcids, primarily Marbled Murrelets (*Brachyramphus marmoratus*), from a nearshore gill-net fishery in Barkley Sound, Vancouver Island, British Columbia. By examining dead alcids and the abundance and distribution of alcids and of gill-net boats, we discover factors that cause murrelets to become tangled in gill nets. We can then estimate the impact of gill-net mortality on the Barkley Sound breeding population. This localized mortality points to differences between nearshore and offshore net mortality. These differences need to be considered when determining the significance of this mortality.

4. Methods

Alcid mortality was determined during a study of Marbled Murrelet foraging ecology that was conducted from May through September (1979) and June to October (1980) in Barkley Sound, British Columbia (Fig. 1). All dead alcids, found floating or received from a Fisheries and Oceans Canada patrol boat, were salvaged. In 1980, a request for birds incidentally killed by commercial trolling, purse-seining, and gill-net fishing was posted on 7 June at three fish-delivery and packing plants in Bamfield. Fishery workers were asked to record, for each bird captured, the date, location, time of day, type of fishing gear used, and depth of capture, if known. Supplementary information on numbers and species of birds killed was obtained through casual discussions with fishermen and fishery officers. All specimens were deposited in the University of Manitoba Zoology Museum.

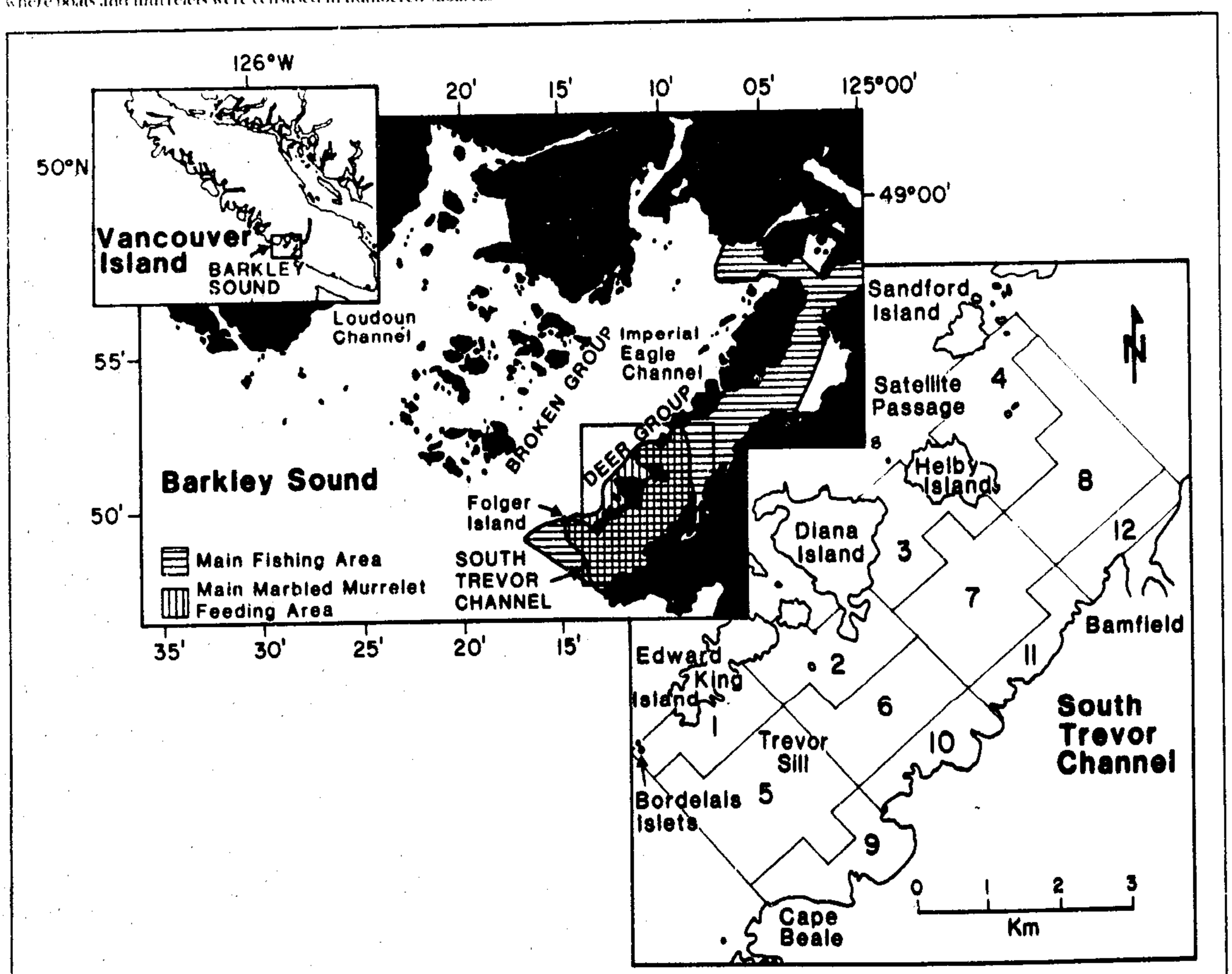
The abundance and distribution of alcids and gill-net boats were examined where aggregations of each overlapped in Trevor Channel (Fig. 1). In 1980, 37 censuses of alcids and boats were conducted on a 24-km^2 grid (later separated into 12 subareas) which we refer to as South Trevor Channel (Fig. 1). Censuses were made at four times of day (05:00, "dawn"; 10:00, "morning"; 15:00, "afternoon"; and 20:00, "dusk") and each census took 2–2.5 h. Censuses were conducted from a pneumatic boat with one observer between 16 June and 6 July. The numbers of all alcids were recorded but flying birds were not included in the calculation of bird densities. Gill-net boats were censused in 18 of the 37 censuses, during fishery openings. Boats were noted as "fishing" (if nets were set or being manipulated) or "not fishing." Visibility was adequate to record total numbers of boats for two adjacent areas in South Trevor Channel in 15 of 18 boat censuses.

5. Results

5.1. Aspects of alcid gill-net mortality in Barkley Sound

Forty-four alcid carcasses were obtained during the fishing season in the two summers (12 in 1979 and 32 in 1980). Twenty-four carcasses were provided by five fishermen (1980), nine were received from a fisheries patrol boat, and 11 were found dead on the water. Thirty-three birds had been killed in gill nets. Six floating carcasses were fresh, had torn neck feathers and salmon scales on feathers, and resembled birds known to have been killed in gill nets. Five other floating carcasses were excluded because they were somewhat decomposed and appeared to have died from other causes. All birds were obtained between 11 June and 17 July. Birds were killed in multifilament nylon nets that were 135–375 m in length, less than 10 m in depth, with

Figure 1
Locations in Barkley Sound, British Columbia, that were used by fishing boats and Marbled Murrelets; and the location of South Trevor Channel where boats and murrelets were censused in numbered subareas



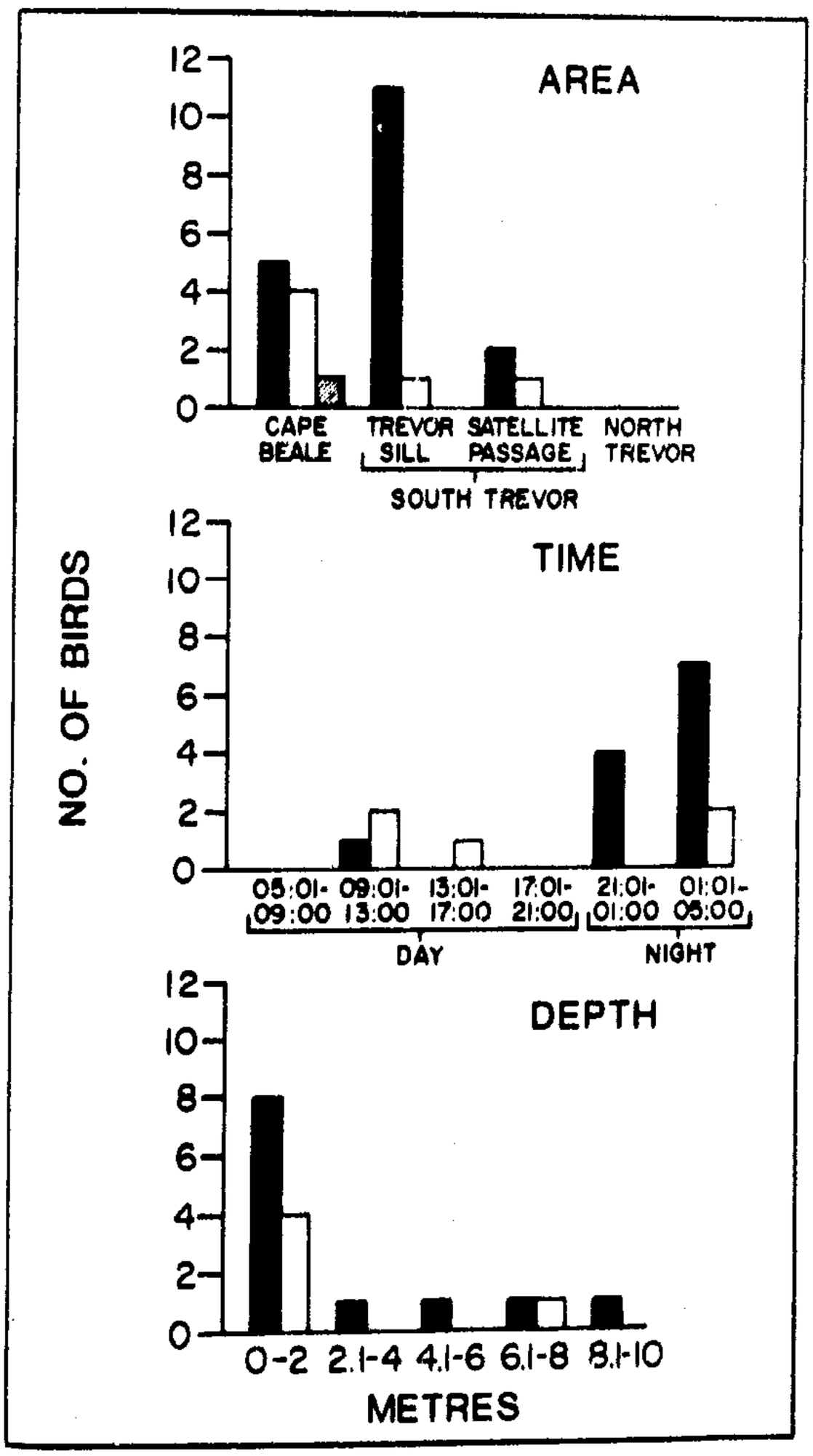
mesh sizes of 10–13 cm (see Pacific Commercial Salmon Fishery Regulations and BC Fishery (General) Regulations made under the 1978 Fisheries Act for other gill-net specifications).

The Marbled Murrelet was the most frequently killed alcid ($n = 28$), but Common Murres (*Uria aalge*) ($n = 10$) and Rhinoceros Auklets (*Cerorhinca monocerata*) ($n = 1$) were also killed. Most (93%) Marbled Murrelets were breeding (based on the presence of a brood patch) but one non-breeding and one hatching-year (HY) bird were also killed. One non-breeding Rhinoceros Auklet, and four breeding and six non-breeding Common Murres were killed. There were no obvious differences in the numbers of each sex in the sample of birds obtained.

Most birds were killed off Cape Beale and the Trevor Channel sill area, at the southern end of South Trevor Channel (Figs. 1, 2). More Marbled Murrelets were killed in the sill area, whereas more Common Murres were killed off Cape Beale. Marbled Murrelets were killed almost exclusively at night; however, Common Murres were killed at night and during the day (Fig. 2). Most birds were killed within 2 m of the surface. A few were taken deeper, at a maximum of 8.5 m (Fig. 2).

As only a few fishermen provided birds, these data may be biased with regard to fishing time and location. However, the patterns were confirmed through casual discussions with fishermen, including fishermen who found birds dead in their nests but did not keep them. Many fishermen did not provide dead birds because they were suspicious or did not want to make labels.

Figure 2
Aspects of alcid gill-net mortality in Barkley Sound. Cape Beale and North Trevor areas are shown in Figure 6 and Trevor Sill and Satellite Passage areas are shown in Figure 1. Dark bars refer to Marbled Murrelets, open bars to Common Murres, and the striped bar to Rhinoceros Auklets



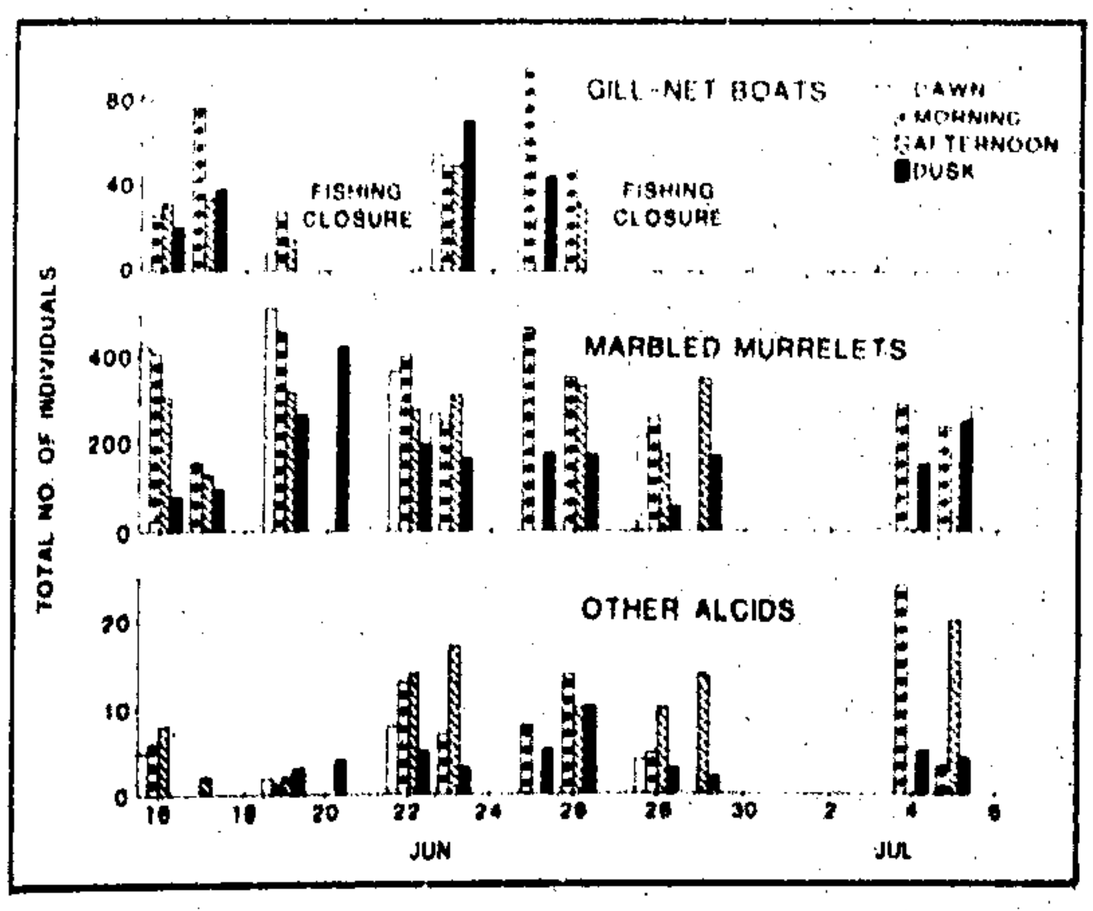
5.2. Alcid abundance and distribution in South Trevor Channel

During the count period, the Marbled Murrelet was the most abundant alcid in South Trevor Channel and averaged 265.8 ± 118.3 birds/census (Fig. 3). Pigeon Guillemots (*Cepphus columba*), Common Murres, and Rhinoceros Auklets averaged 4.6 ± 5.8, 1.5 ± 2.2, and 0.5 ± 0.9 birds/census, respectively. Therefore, murrelets were found in the highest mean densities (11.26 ± 4.95 birds/km^2) followed by Pigeon Guillemots (0.19 ± 0.25), Common Murres (0.06 ± 0.10), and Rhinoceros Auklets (0.02 ± 0.04).

Marbled Murrelets were unevenly distributed in South Trevor Channel; densities were higher in subareas along the shores, particularly of the Deer Group islands, and lower in mid channel except in subarea 5, which had moderate densities (Fig. 1). Very few murrelets occurred north of the count area in Trevor Channel at this time (Carter and Sealy, pers. obs.). Pigeon Guillemots were also unevenly distributed and found in subareas along the shore, while Common Murres and Rhinoceros Auklets were found more randomly but in the seaward half of South Trevor Channel (Fig. 1).

On average, Marbled Murrelets were more abundant during dawn and morning censuses (11.4 and 13.9

Figure 3
Total numbers of gill-net boats, Marbled Murrelets and three other alcid species for each census ($n = 37$) in South Trevor Channel. (Notes: Marbled Murrelets were seen on each of the 37 censuses whereas gill-net boats and other alcids were not; no other alcids were recorded on 16 June (dusk), 17 June (morning and dusk), 23 June (dawn), and 6 July (dawn).)



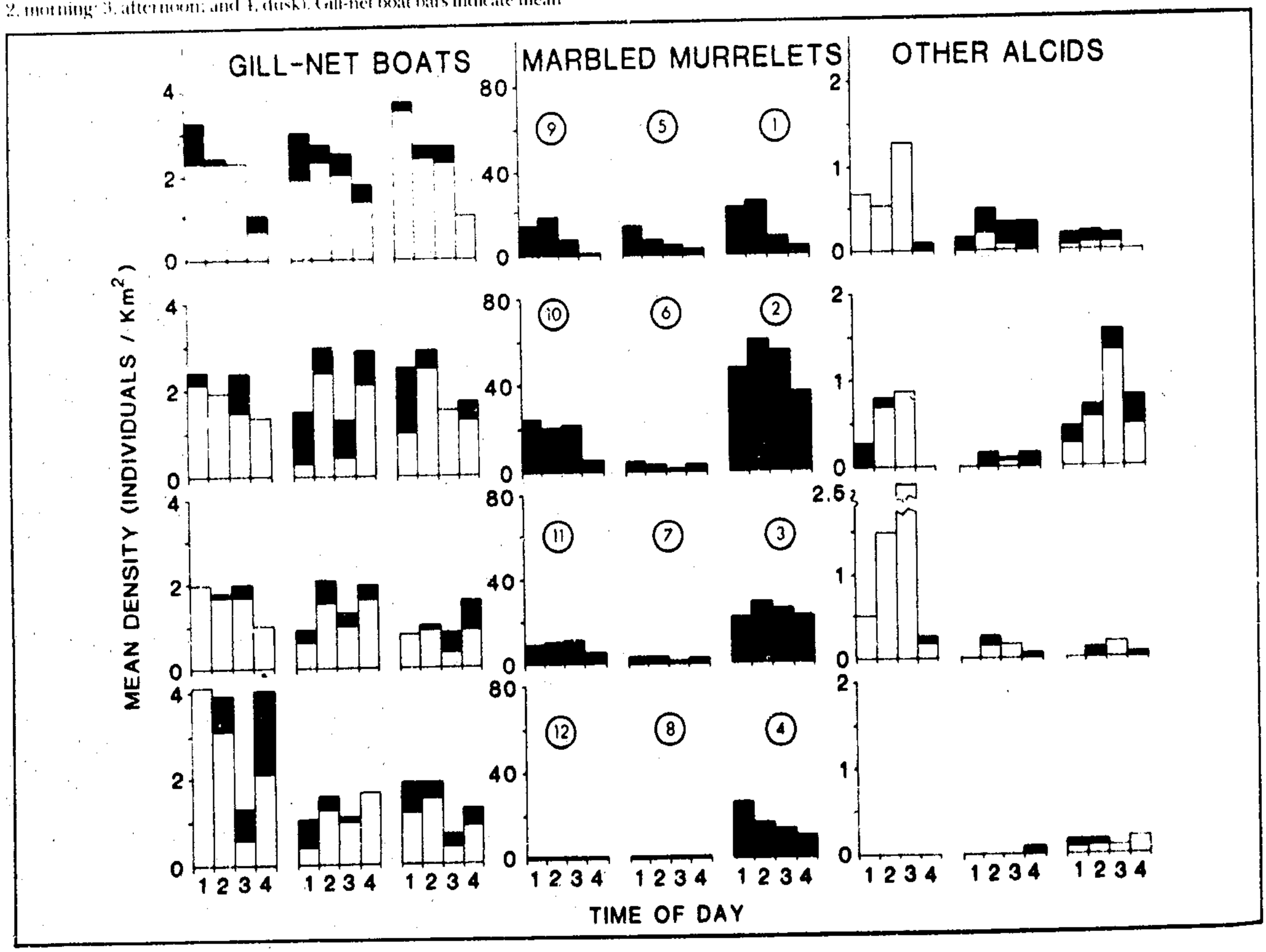
birds/km^2, respectively) becoming less abundant in afternoon (11.0 birds/km^2) and dusk (7.7 birds/km^2). Murrelets were clumped throughout the day particularly in subareas 2 and 3 (Fig. 4). Smaller numbers remained in all areas throughout the day. Pigeon Guillemots were more abundant during morning and afternoon censuses (0.24 and 0.39 birds/km^2, respectively) and were clumped in subareas 2, 9, 10, and 11 at these times. Common Murres and Rhinoceros Auklets were too uncommon to identify any diurnal patterns (Fig. 4).

Marbled Murrelets regularly formed large gatherings in South Trevor Channel from late May to early August in 1979 and 1980, presumably in response to a localized food resource (Carter and Sealy 1980). The nesting location of these murrelets, however, was not determined. They probably nest solitarily along heavily forested coasts and adjacent inland areas of Barkley Sound (Sealy and Carter, in press). Non-breeding murrelets also occur in the aggregation (borne out by collecting; also see Sealy 1974, 1975). A few small colonies of other alcids near South Trevor Channel are probable sources of breeding birds observed during counts. Seabird Rocks supports 150 nesting pairs of Rhinoceros Auklets and 50 pairs of Pigeon Guillemots; a few scattered pairs of Pigeon Guillemots also nest in the Deer and Broken Group islands (Guiguet 1971, Hatler *et al.* 1978). The nearest Common Murre colony is at Tatoosh Island, Washington, where 100 pairs nest (Wahl *et al.* 1981). Based on the number of birds present at sea, the Marbled Murrelet is the most abundant breeding seabird in Barkley Sound (Guiguet 1971; Hatler *et al.* 1978; Sealy and Carter, in press).

5.3. The gill-net fishing season in Barkley Sound

The fishing season in Barkley Sound (statistical area 23 defined in Pacific Commercial Salmon Fishery Regulations; see map in British Columbia Commercial Fishing Guide [1981:79]) is presently regulated through four phases: (1) February to May; (2) early June; (3) late June to late July; and (4) short openings in fall (Fig. 5). Gill-net fishing is permitted in phase 1, but little fishing occurs due to mesh-size restrictions. Starting in phase 2, an influx of boats occurs (in 1979, 62 gill-net boats were present at opening). By phase 3, the peak influx of boats occurs (in

Figure 4
Mean densities of gill-net boats, Marbled Murrelets, and three other alcid species in each subarea (shown in Figure 1) in South Trevor Channel (indicated by circled numbers) and for each time of day (coded as 1, dawn; 2, morning; 3, afternoon; and 4, dusk). Gill-net boat bars indicate mean densities of boats fishing (open) and not fishing (dark). Other alcid bars represent Pigeon Guillemots (open), and Common Murres and Rhinoceros Auklets (dark)



1979, 215 gill-net boats; 1975–79, 207 boats average). At the end of phase 3, gill-net fishing is shifted into Alberni Inlet, to control the harvest of salmon from specific spawning rivers. Barkley Sound proper is closed to gill-net fishing from late July to February, except for occasional short openings that may occur in phase 4.

5.4. Abundance and distribution of gill-net boats in South Trevor Channel

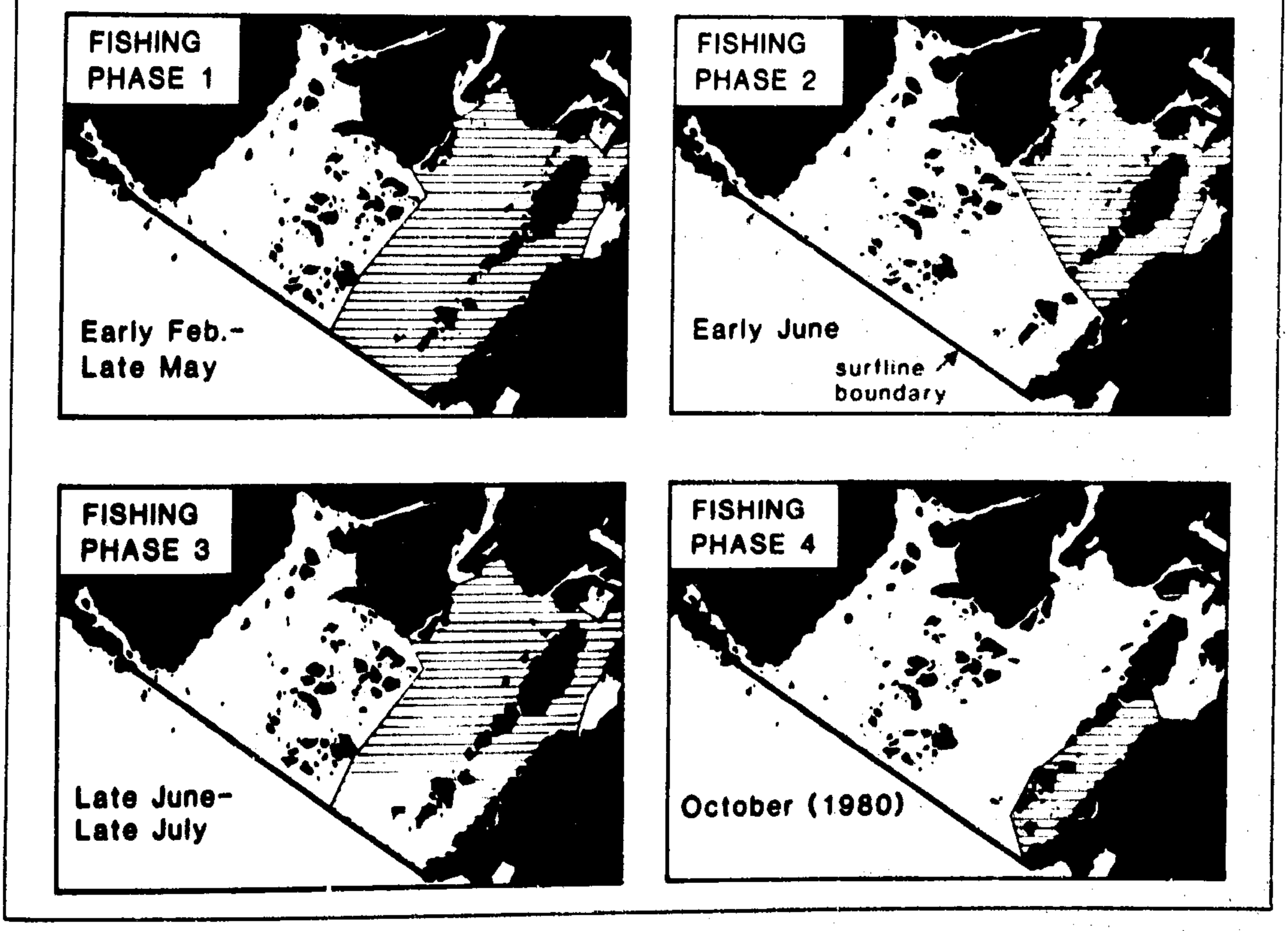
Gill-net boats were censused during phase 3 of the fishing season: South Trevor Channel contained an average of 44.4 ± 23.8 boats/census; the Cape Beale and North Trevor Channel areas contained only 28.1 ± 15.1 and 15.3 ± 19.9 boats/census, respectively (Fig. 6). Densities of gill-net boats averaged 2.00 ± 1.00 boats/km^2, in South Trevor Channel. Densities could not be calculated for the two adjacent areas because the area censused was not measured. Boats may have been in higher densities off Cape Beale than in South Trevor Channel for this area is smaller (Fig. 6).

Gill-net boats were almost evenly distributed in South Trevor Channel although, on average, more boats were found near the sill (subareas 1, 5, 9) (Fig. 4). The highest mean density, however, occurred in subarea 12, adjacent to Bamfield Inlet (2.71 ± 1.88 boats/km^2). Densities of boats "fishing" averaged 1.57 ± 0.88 boats/km^2.

In South Trevor Channel, mean numbers of boats were fairly consistent between times of day, whereas at Cape Beale, numbers were higher in the morning (39.8 boats/census) and at North Trevor, higher at dusk (29.8 boats/census) (Fig. 6). With all three areas combined, mean numbers were highest in morning (103.7 boats/census) and lowest in the afternoon (56.8 boats/census). Within South Trevor Channel, the highest mean densities (2.27 boats/km^2 occurred in the morning (when 84% of the boats were fishing) and the lowest mean densities (1.60 boats km^2) in the afternoon (when 78% of the boats were fishing). At dawn and dusk, 69% and 76% of the boats were fishing, respectively.

During phase 3, gill-net boats tended to fish in Trevor Channel (particularly South Trevor Channel). Most

Figure 5
Gill-net fishing boundaries by phase in Barkley Sound in 1979–80. Areas open to fishing are striped



of Imperial Eagle Channel, which was open to fishing, was not used. Regulations restricted fishing to usually 3–4 days and nights a week and this probably accounted for the regular presence of large numbers of boats throughout the permitted days. Gill-net boats were small (about 10 m in length) and each boat set out one net in a straight line (often perpendicular to shore) for varying periods of time. This allowed for high densities of boats. Boats were spaced apart to prevent interference and were thus evenly distributed in South Trevor Channel. Generally, fishermen delivered fish once a day and often moved to Bamfield to dock, if they were not fishing at night. These movements accounted for the number of boats not fishing during counts. Fewer boats fished at night, judging by the number of lights that were visible from Bamfield.

6. Discussion

6.1. Tangling of Marbled Murrelets in gill nets

Alcids are highly susceptible to being killed in gill nets because they dive to obtain food (Ainley *et al.* 1981). The number of birds that are killed is related to the number, density, and variability of nets and birds where they co-occur. However, the relationship between bird-net encounters, and birds diving and becoming tangled in nets is obscure and may involve feeding and/or escape behaviour.

6.1.1. *Co-occurrence of murrelets and gill nets* — Large mean numbers of Marbled Murrelets and gill-net boats were present in Barkley Sound during phase 3 of the fishing season (Fig. 7). The clumped dispersion patterns of murrelets and boats promoted murrelet mortality where high-density aggregations overlapped in South Trevor Channel. Other alcids which occurred in lower densities were caught less often. If fishing occurred later in the summer or more intensively in phase 4 (Fig. 5), fewer birds would have been killed because murrelets were distributed in small and widely scattered flocks while moulting (Fig. 7).

Murrelets were present in high densities throughout the day (and probably at night) whereas gill-net boats were present in high densities only during openings. The alternation of closings and openings may have reduced the numbers of birds killed but probably intensified fishing effort, and thus boat densities, during each opening.

6.1.2. *Attraction of murrelets to gill nets* — Murrelets were often observed in small flocks landing near or sitting beside nets during the day. Birds may have been attracted to nets to feed on small schooling fish that collected at the net interface (e.g. herring [*Clupea* spp.], Parrish 1969). Birds were observed "surface seizing" and diving, probably to obtain fish near nets. M. E. "Pete" Isleib (*in litt.*) also believed that the presence of small fish attracted Marbled Murrelets to nets in Prince William Sound, Alaska. He recorded murrelets "usually in singles or pairs swimming along nets and diving, often surfacing on one side and then the other." Birds may recognize nets by the styrofoam floats that line their tops (Melville 1973). Most murrelets, however, were not observed near nets in the day. Birds may have been opportunistic and attracted to nets from a short distance or some avoidance may have occurred. Thus, during the day, fewer murrelets may have encountered nets than might be expected at random from observed densities.

6.1.3. *Night mortality and murrelet distribution* — All murrelets that were killed in gill nets at night (Fig. 2) were breeding. Based on brood-patch scores (Sealy 1974), birds were either incubating or feeding nestlings. A few birds had food in their stomachs, indicating that at least some birds were feeding themselves at night. As most murrelets were killed near the top of nets, birds may have been foraging near the surface. Isleib (*in litt.*) also noted that murrelets were caught within 3–5 m of the surface. Simons (1980) suggested, however, that murrelets may make many nocturnal,

Figure 6
Mean numbers of gill-net boats by area and time of day

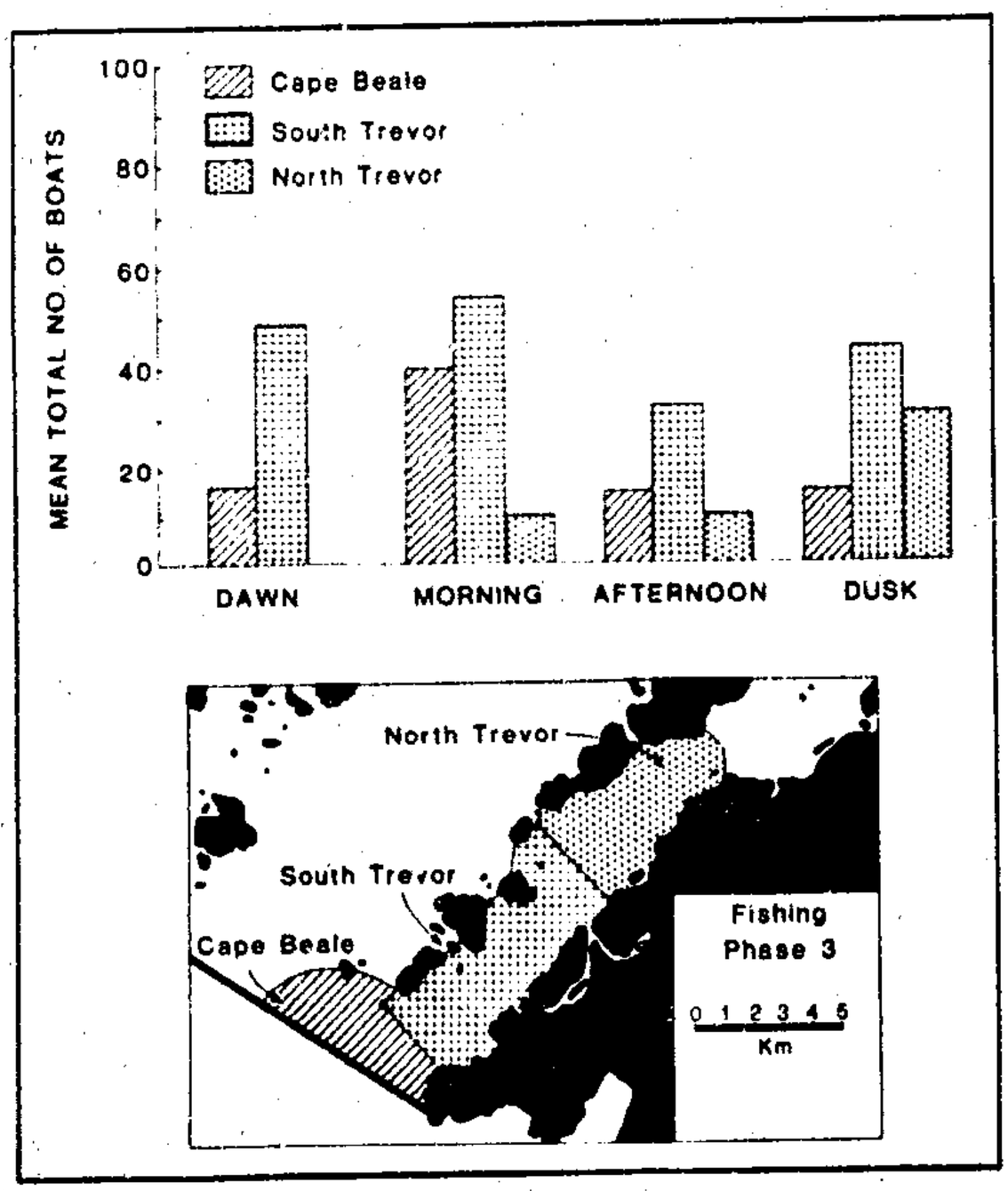
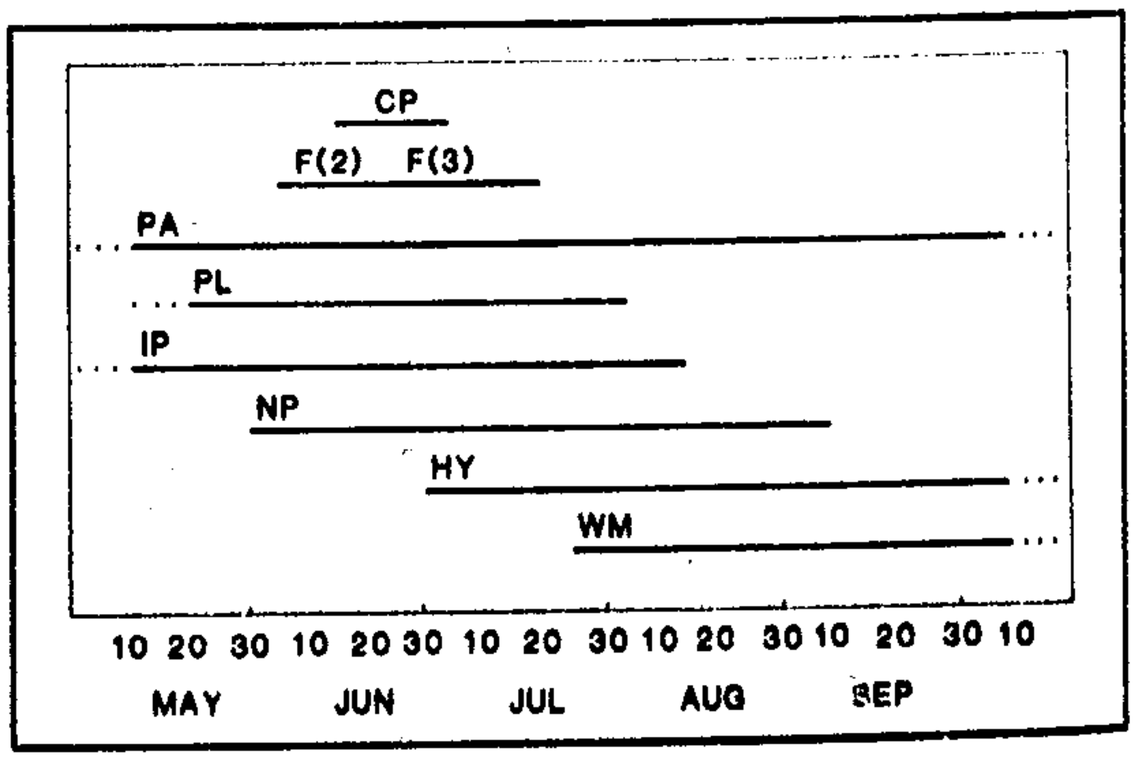


Figure 7
Breeding phenology of the Marbled Murrelet in relation to the gill-net fishing season in Barkley Sound, 1979–80. Phenology designations, in part, follow Sealy (1974): CP, census period; F, fishing season phase; PA, presence of adults, PL, presence of large numbers of murrelets in South Trevor Channel; IP, incubation period; NP, nestling period; HY, fledged young at sea; WM, wing moult period; and . . . ., extremes unknown



nestling-feeding trips. Thus, some birds (that were killed with empty stomachs) may have been foraging for their young. Night foraging by Marbled Murrelets has been previously suggested by observations of birds flying inland throughout the night (Carter and Sealy, unpubl. data) and is supported by birds being killed throughout the night in South Trevor Channel (Fig. 2). Bailey (1977) also suspected that murrelets were feeding at night near the Kenai Peninsula, Alaska, and Isleib (*in litt.*) indicated that most (>80%) murrelets were killed at night in Prince William Sound, Alaska. Christensen and Lear (1974) demonstrated that murres were also killed mainly at night off Greenland and suggested that individuals were better able to "evade" nets during the day. Nylon nets may have been less visible to murrelets at night (Bibby 1973), as has been shown for some fish (Hamley 1975). This may account for more bird kills at night, although foraging occurs during the day and night.

Marbled Murrelets in South Trevor Channel may have different distribution patterns at night, which further increased their susceptibility to becoming tangled. In subareas, 1, 5, 9, and 10, a dramatic increase in mean numbers occurred between dusk and dawn censuses (Fig. 4). Most mortality was reported from this area (Trevor Sill); yet these areas did not have the largest daytime murrelet densities. More murrelets, more gill-net boats, and/or more foraging may have occurred there at night. Thus, the frequency of bird-net encounters and numbers of birds killed may have been greater. If true, this factor would greatly reduce the value of daytime counts of abundance and distribution. Similarly, McMahan and Fritz (1967) noted that Redheads (*Aythya americana*) were distributed differently at night, depending on weather, and on certain nights were more susceptible to being hooked on trotlines. Breeding Pigeon Guillemots, in South Trevor Channel, may have reduced their susceptibility at night by staying at the nest site; large numbers were observed only on morning and afternoon censuses (Fig. 4) and none were obtained or reported killed.

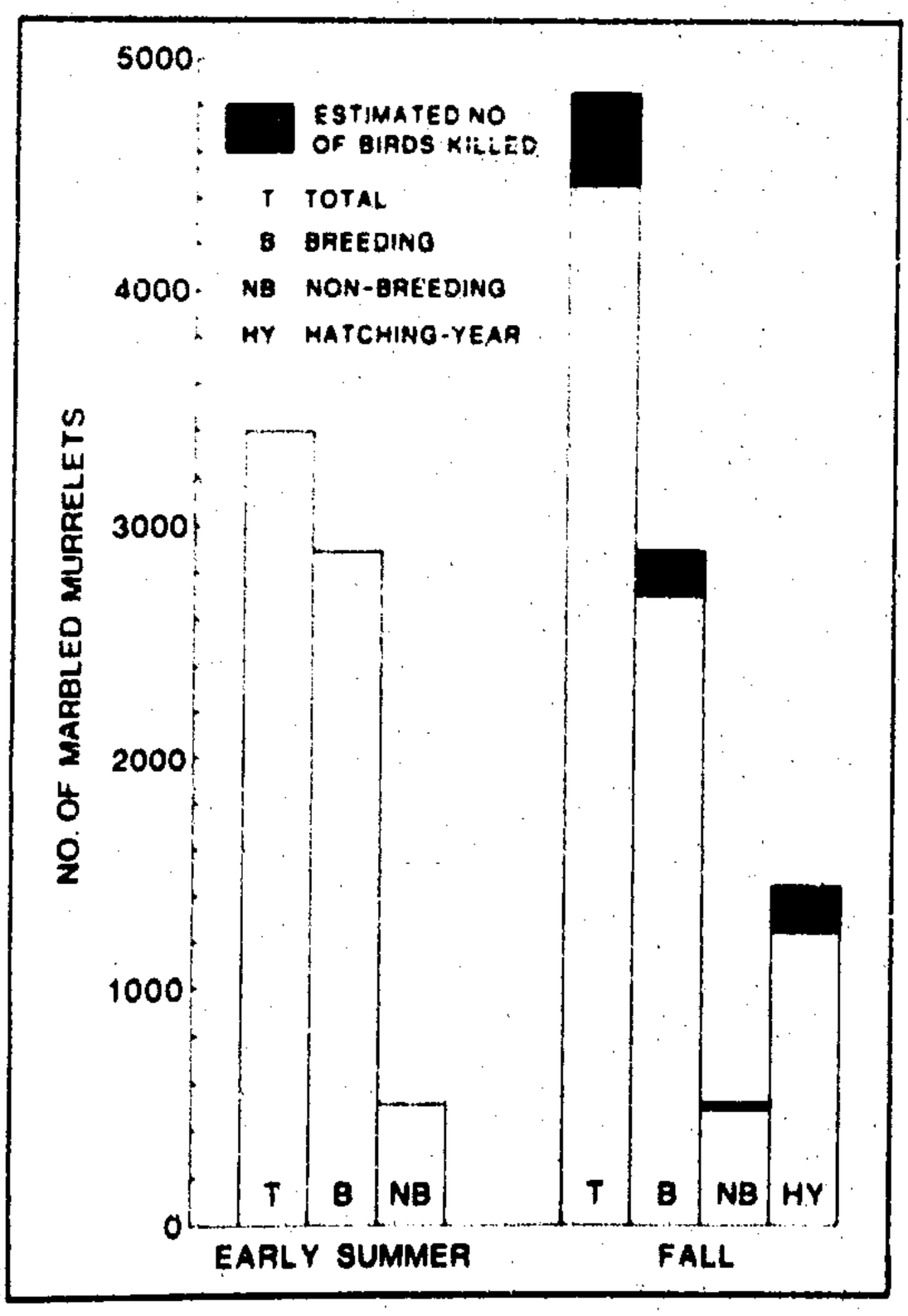
6.2. Impact of gill-net mortality on the local Marbled Murrelet population

The dispersed solitary nests of Marbled Murrelets could make the species less susceptible to gill-net mortality (King *et al.* 1979). However, the aggregative behaviour of murrelets at sea during the nesting period makes them susceptible where aggregations co-occur with gill-net fishing areas. Since specific murrelet nesting areas are not known, it is not possible to directly determine whether numbers of nesting individuals are declining due to gill-net mortality. Thus, to determine the impact of gill-net mortality on Marbled Murrelets in Barkley Sound requires some speculation.

It was difficult to estimate how many murrelets were killed annually in Barkley Sound from the small sample of dead birds obtained. Since 17 murrelets were obtained from five fishermen in 1980 and on average about 70 gill-net boats were present in areas where most birds were killed, possibly as many as 250 murrelets were killed. Fishermen that were interviewed also indicated that they caught "some" (or "many") murrelets each season, including in 1980. However, most birds were killed at night when less fishing occurred. We believe that between 175 and 250 murrelets were killed in 1980.

In Barkley Sound, there are an estimated 3400 murrelets (Sealy and Carter, in press). About 15% of the birds were probably non-breeding (Sealy 1974). Therefore, the breeding population consisted of 2890 birds or 1445 pairs. By extrapolating from the sample of dead birds obtained, we estimated that breeding, non-breeding, and HY individuals constituted 90%, 5%, and 5% of the total number of murrelets killed in gill nets, respectively. Using a conservative estimate of 200 birds killed in gill nets/year, 180 breeding, 10 non-breeding and 10 HY birds were therefore killed. By adding 180 nestlings that did not fledge (because 180 breeding birds were killed in gill nets), to the number of HY birds killed in gill nets, we determined the total impact on the population of HY birds in the fall (Fig. 8). We estimated that a total of 380 murrelets were killed in 1980, of which 47%, 3%, and 50% were breeding, non-breeding and HY birds, respectively (Fig. 8). Thus, an estimated 6.2% of the breeding individuals were killed. Additionally, 13.1% of potential young were not raised to fledging (assuming one nest attempt per year, one parent cannot raise the young, and both members of the pair were not killed), or were killed in nets. Also, 2% of the non-breeding birds were estimated to have been killed. If no gill-net mortality had occurred and excluding natural mortality, the fall population size would have been 4845 birds. With gill-net mortality, the fall population size was estimated to be 4465 birds. Thus, 7.8% of the potential fall population died in gill nets in 1980.

Figure 8
Estimated impact of gill-net mortality on Marbled Murrelet numbers in Barkley Sound in 1980



The possible long-term effects of mortality caused by nearshore fishing have not been widely recognized. Because the numbers of birds found killed are generally low (often in the low hundreds [Bibby 1971, 1973; Melville 1973]), nearshore mortality has not been considered to be as significant as larger offshore mortality (King *et al.* 1979). Since nearshore mortality is probably sustained annually on the same population, the cumulative effect could be great. Cobb (1976) has demonstrated that the continuous toll inflicted on murres by nearshore fishing was important and vastly outweighed numbers killed by oil spillage near St. Andrew's Bay, England. Murrelet (and other inshore seabird) populations are sensitive to additional unnatural mortality caused by gill-net fishing because of their lower numbers compared to offshore feeding seabirds (Diamond 1978, Sowls *et al.* 1980, Wahl *et al.* 1981). Whether reductions occur in Barkley Sound will depend on murrelet immigration, emigration, and recruitment; the permanence of South Trevor Channel as the main feeding area for murrelets; and, the persistance of high-density gill-net fishing, over the long term.

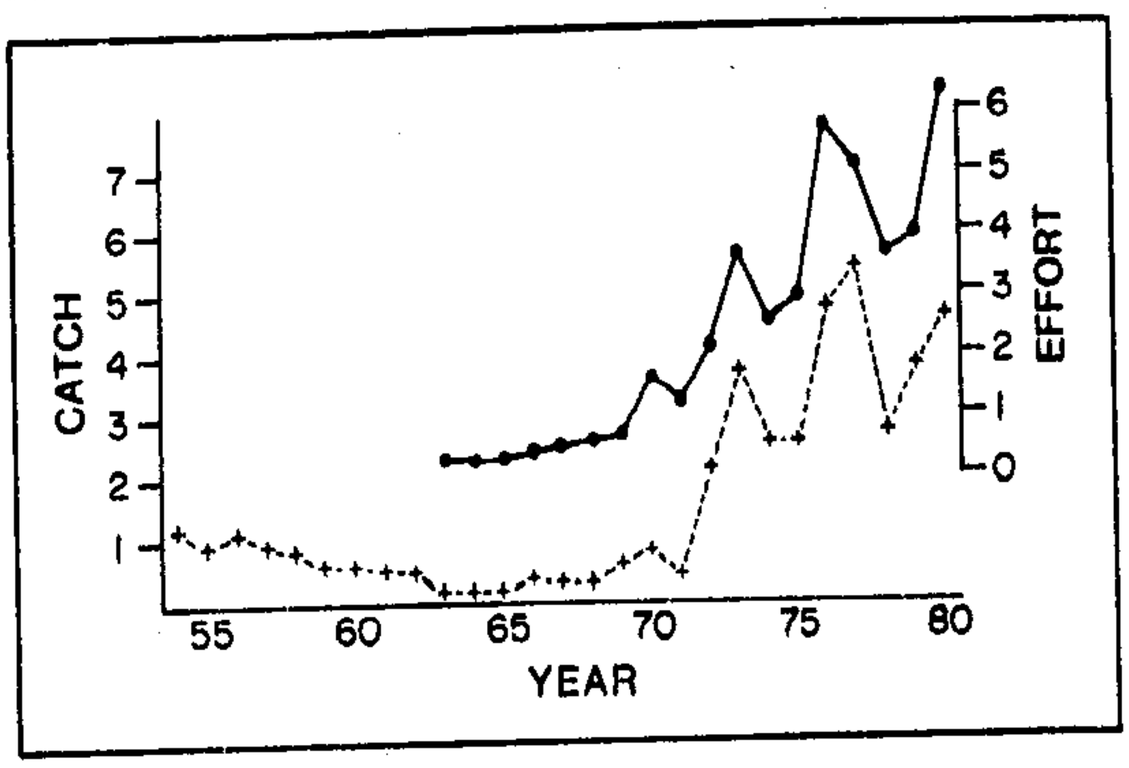
6.3. Gill-net fishing trends

The movement of the fishing boundary out to "surfline" in phase 3 (Fig. 5) has produced the overlap of gill-net boats and feeding murrelets in South Trevor Channel and near Cape Beale. However, fishing has only been allowed out to the "surfline" since 1978. Earlier, the phase 2 boundary remained in effect until the late summer closure of the Barkley Sound fishery. The fishing season has also been shortened since 1978. In 1975–77, gill-net fishing started in mid May and ended in late August (Salmon Expectations and Proposed Fishing Patterns 1975–1980). Within each season from 1975 to 1980, openings were 4 days per week but, in 1980, they were reduced to 3 days per week. Also, phase 2 was reduced to one opening in 1980.

In relation to these regulation changes, fishing effort was lower in 1978 and 1979. In 1980, however, the largest annual gill-net fishing effort (number of days fishing) occurred (Fig. 9). Since openings were shorter in 1980 (and the length of the fishing season was much the same as in 1979), probably more gill-net boats fished in South Trevor Channel in 1980 than in previous years. However, because gill-net fishing only began in that area in 1978 and bird mortality was only measured in a year when fishing effort was high, the estimated kill of Marbled Murrelets in 1980 probably reflects a higher than average mortality than elsewhere in the Barkley Sound fishing area.

The size of fishing catches in future years will largely determine the persistance of high-density gill-net fishing in Barkley Sound. The fishery is presently based on sockeye salmon (*Oncorhynchus nerka*) stocks which have been successfully enhanced (Robinson and Barraclough 1978). How long these stocks can withstand the steadily increasing fishing pressure (Fig. 9) is not known. However, Barkley Sound has an early and annually consistent fishery that has attracted many boats from other fishing areas. Long-term gill-net fishing in Barkley Sound can be expected, as can long-term gill-net mortality of murrelets.

Figure 9
Salmon catch and gill-net fishing effort (1954–80) in Barkley Sound. The broken line refers to catch (total number of salmon caught, in thousands) and the solid line to effort (total number of days fishing, in thousands). Data from BC Catch Stat. Dep. Fish. Oceans Canada, Pac. Reg. Vancouver.



6.4. Conservation measures

We believe that the mortality of Marbled Murrelets in gill nets in Barkley Sound is significant and suggest that it be further examined. This nearshore mortality could have immediate consequences because it is directed on a small population and occurs annually. At present, the geographic extent of the gill-net mortality of murrelets is not known, although it occurs in Prince William Sound, Alaska, and is suspected to occur throughout southeastern Alaska (Isleib, *in litt.*). It has also been recorded in Monterey Bay, California, in winter (D. Croll, *in litt.*). Susceptible populations of Marbled Murrelets may be identified by censuses at sea and monitored regularly over the long term to detect changes (see Sealy and Carter, in press).

In Barkley Sound, two measures would reduce the mortality of murrelets in gill nets. First, if salmon catches were unaffected, the exclusion of gill-net fishing (perhaps by maintaining the phase 2 fishing boundary (Fig. 5) during phase 3) in South Trevor Channel and off Cape Beale only, would eliminate the overlap of aggregations of murrelets and gill-net boats (Fig. 1). A similar measure has been considered in Monterey Bay, California, where a rapid growth in the gill-net fishery has caused a drastic increase in nearshore seabird mortality (Heneman 1981). Also, Bartonek (1965) suggested that certain areas of Lake Winnipegosis, Manitoba, could be closed to commercial fishing if reductions of Redheads continued to occur. Second, gill-net fishing could be prohibited at night, when most murrelet mortality occurs. Daylight fishing could be extended through longer openings and salmon catches probably would not be affected. This measure has been previously enforced in other fishing areas in British Columbia, although not for conservation reasons (S. A. Benoit, pers. comm.).

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