

A study of the behavior of Dall's porpoise (*Phocoenoides dalli*) in the Johnstone Strait, British Columbia

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The behavior of Dall's porpoise was studied in the western Johnstone Strait, British Columbia, during the summer of 1984. Observations and theodolite trackings were made from a cliff-top observation point on West Cracroft Island. Dall's porpoise was the second most common marine mammal in the study area, being seen on 63% of the days, and it was reported to be a year-round resident of the Strait. Three types of surfacing behavior were observed, with slow rolling occurring in 97% of the sightings. Swimming speed of slow rolling porpoises was 5.1 ± 0.83 (SD) km/h ($n = 18$). Dives during travel averaged 35.9 ± 26.52 (SD) s ($n = 10$). Deep vertical dives lasted 2 to 4 min for adults and up to 2 min for calves, and were presumed to be associated with feeding. Westward movement predominated. Dall's porpoises usually showed no obvious reaction to resident killer whales, but apparently swimming speed increases when killer whales are within 2 km. Group sizes ranged from one to over five animals (mean size = 2.6 ± 1.05 (SD), $n = 68$). Groups that included calves tended to be larger than adult-only groups. Neither direction of travel nor time of day were significantly related to group size. The population appears to contain a high percentage of cow-calf pairs, and this suggests that the study area may be used as a calving area during the summer.

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Le comportement du Marsouin de Dall a fait l'objet d'une étude dans le détroit de Johnstone, Colombie-Britannique, au cours de l'été 1984. Un poste d'observation comportant un théodolite a été installé au sommet d'une falaise dans l'île de West Cracroft. Parmi les mammifères marins, le marsouin de Dall est le deuxième plus nombreux dans cette région, et des individus ont été observés au cours de 63% des jours d'étude; l'animal habite le détroit durant toute l'année. En surface, les marsouins utilisent trois types de comportement et les roulements lents ont été observés en 97% des cas. La vitesse de nage des marsouins au cours de ces roulements lents a été évaluée à $5,1 \pm 0,83$ (ÉT) km/h ($n = 18$). Les plongées au cours des déplacements duraient en moyenne $35,9 \pm 26,52$ (ÉT) s ($n = 10$). Les plongées verticales profondes pouvaient durer de 2 à 4 min chez les adultes et jusqu'à 2 min chez les petits; ces plongées semblaient associées à l'alimentation. Les déplacements se faisaient surtout en direction ouest. Les marsouins ne paraissaient pas particulièrement affectés par la présence d'Épaulards, mais il semble que la vitesse de nage augmente lorsque des Épaulards sont à moins de 2 km. Le nombre de marsouins dans un groupe variait de un à plus de cinq (moyenne = $2,6 \pm 1,05$ (ÉT), $n = 68$). Les groupes qui contenaient des petits avaient tendance à être plus grands que les groupes qui ne contenaient que des adultes. La direction des déplacements ou le moment de la journée n'étaient pas reliés au nombre de marsouins par groupe. La population semble comporter un important pourcentage de paires mère-petit, probablement parce que la région d'étude sert de territoire de reproduction au cours de l'été.

[Traduit par la revue]

Introduction

Dall's porpoise (*Phocoenoides dalli* True, 1885) is one of the lesser-known small cetaceans found in the North Pacific Ocean. Much has been learned about the behavior of other odontocete species by observations of them in captivity. This is not true for Dall's porpoise because of the difficulty associated with keeping these animals alive in the captive environment (see Norris and Prescott 1961; Ridgway 1966; Wood 1973; Walker 1975).

Little is known of the behavior of Dall's porpoises in the wild as well. Because of their relatively offshore distribution and inconspicuous nature, they have received little attention. Much of what is known comes from a long-term study of Dall's porpoises in Monterey Bay, California, by G. V. Morejohn and his associates (Loeb 1972; Morejohn *et al.* 1973; Morejohn 1979), and several studies of behavioral responses to survey vessels by G. C. Bouchet and his colleagues (Bouchet *et al.* 1983, 1984, 1985; Withrow *et al.* 1985).

Almost all information we have on Dall's porpoise behavior and social organization has been collected from boats. Unfor-

tunately, vessels often affect the animals' behavior, usually because the porpoises are attracted to the boat to ride the bow wave (Bouchet *et al.* 1983, 1984, 1985; Withrow *et al.* 1985). Social groupings observed from boats can be unrepresentative of natural situations, since mother-calf pairs may split off from groups that ride the bow wave (Kasuya and Jones 1984).

Though commonly regarded as a pelagic species, Dall's porpoise can be seen in many of the straits, channels, bays, fjords, and sounds of southern Alaska, British Columbia, and Washington (Leatherwood *et al.* 1982). In some of these areas, porpoises can be observed from shore.

Recently, land-based observations have begun to reveal a great deal about the behavior and group organization of many delphinid species (Condy *et al.* 1978; Saayman *et al.* 1972, 1973; Saayman and Tayler 1973, 1979; Tayler and Saayman 1972; Norris 1974; Norris and Dohl 1980; Norris *et al.* 1985; Shane 1980; Würsig 1978; Würsig and Würsig 1977, 1979, 1980). Among the phocoenids, only the harbor porpoise (*Phocoena phocoena*) has been studied from shore-based stations (Amundin and Amundin 1974; Watson 1976; Taylor and Dawson 1984). The present study represents the first time that a cliff has been used as an observation platform to study Dall's porpoise behavior. A cliff-top observation point allows

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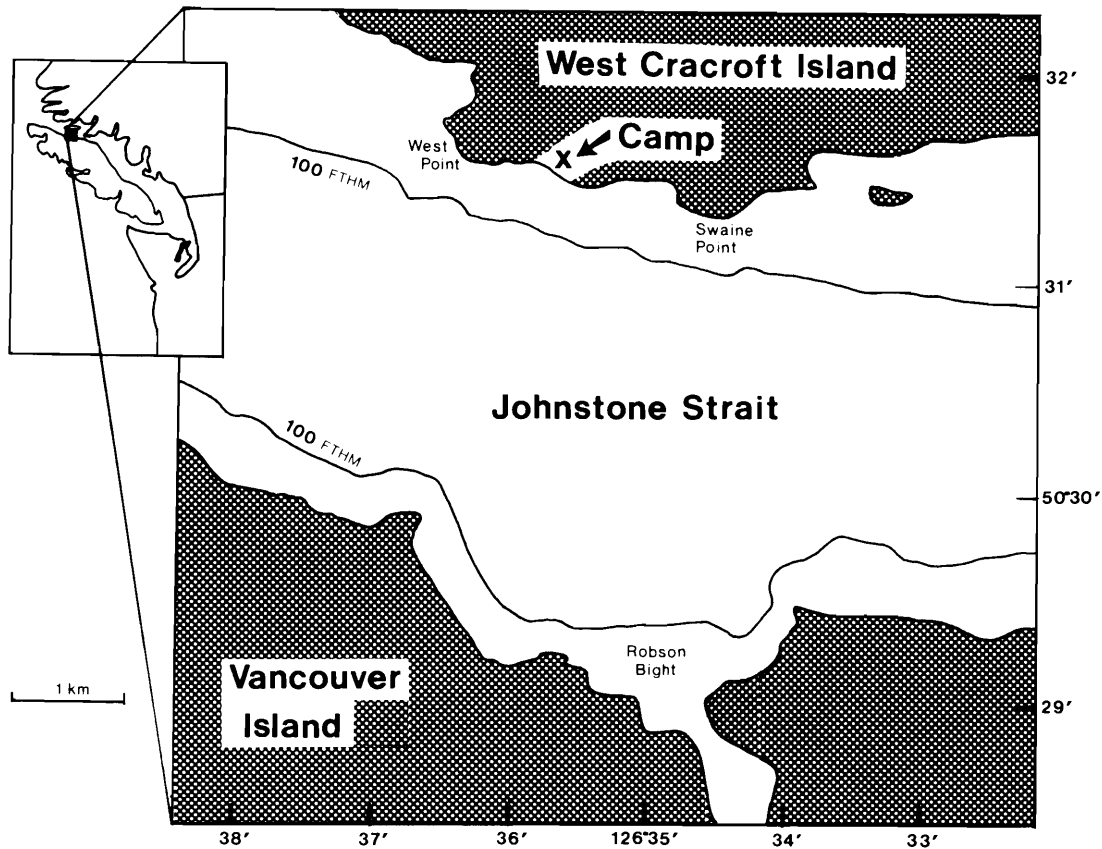


FIG. 1. A map of the study area. Inset shows location of the study area off northern Vancouver Island, British Columbia, Canada. Unless otherwise stated, all observations and theodolite trackings were made from camp.

the observer to see the animals' natural behavior and groupings, unaltered by vessels, and it allows the use of a surveyor's theodolite to track movements.

Methods and study area

Observations of Dall's porpoises were made in the western Johnstone Strait, British Columbia, Canada, between 6 July and 3 September 1984. During the 60 days of the study, there were 76 sightings of Dall's porpoises. In addition to these, there were several sightings outside the study area, before or during the study period. These additional sightings were not used in statistical analyses, but supplemental information from them is presented where appropriate.

The camp was situated on a cliff 49 m above water level at midtide, on West Cracroft Island (50°31' N, 126°36' W), off northern Vancouver Island (Fig. 1). The camp overlooked the western section of the Johnstone Strait, an east-west running inland waterway between Vancouver Island and mainland British Columbia. The Johnstone Strait is deep, dropping off to about 430 m (235 fthm) less than a kilometre from shore, and wide (about 4 km across). It is characterized by high tidal fluctuations (up to 5 m) and strong currents (about 3 kn; 1 kn = 1.852 km/h).

When weather permitted, surveys were conducted approximately every 30 min, during daylight hours. Each time a Dall's porpoise group was sighted, date, time, direction of travel, group size and composition, surfacing activity, behavior, and comments (such as location of group, sighting conditions, and color variations) were noted. When possible, Dall's porpoise groups were tracked with a Nikon NT-2A (30X) theodolite. This allowed the movements of the animals to be plotted, and swimming speeds to be calculated. Other groups were observed with Bushnell 7 × 50 and 10 × 50 binoculars. A few observations outside the study area were made from a 5.2-m outboard motor boat.

To get a general idea of the animals' activities at night, an observer stayed awake on several nights. Dall's porpoise groups that passed relatively close to the camp could be heard, and distinguished from other animals by the unique sound of their respiration. Surfacing activity and direction of travel (if the animals surfaced several times within hearing range) could be reliably determined based on sound. There were 17 such night-time observations of Dall's porpoises in the study.

Results

Occurrence

Dall's porpoises were present throughout the summer study period, and discussions with year-round residents of the area indicated that they are also present in all other seasons. It is unknown, however, if these animals are resident, or if different individuals migrate through the area.

Dall's porpoise is the second most common marine mammal in the study area, after the killer whale (*Orcinus orca*). Porpoises were seen on 38 of 60 days (63.3%) during the study period. There were sightings on almost all days when conditions were good and surveys were conducted throughout the day.

Swimming behavior

Three types of surfacing behavior were distinguished in this study: (i) slow rolling, (ii) rooster tailing, and (iii) fast surfacing. By far the most common type was the slow roll. Slow rolling porpoises spent a short amount of time at the surface, exposing only the back, dorsal fin, and dorsal part of the peduncle. The animals generally swam at a leisurely pace, and they often rolled on their longitudinal axes and changed orientation between surfacings. This type of surfacing created

TABLE 1. Frequencies of various surfacing behaviors observed in day versus night

	Slow roll	Slow roll – rooster tail	Fast surface	Total
Daylight	73	2	1	76
Night	17	—	—	17
Total	90	2	1	93

only slight ripples on the surface, and the breath was heard as a quiet puff. Sometimes, both the exhalation and the inhalation could be distinctly heard. The appearance of the deepened caudal peduncle above the surface just before the porpoise submerges is a unique feature of slow rolling in this species. Brown and Norris (1956, p. 323) describe it as looking "something like a large black and white square rolling over."

Rooster tailing is a type of surfacing behavior often seen when Dall's porpoises are sighted from a boat in pelagic waters. This behavior is unique to Dall's porpoise, although "pop-splashing" harbor porpoises may be mistaken for rooster tailing Dall's porpoises (see Taylor and Dawson 1984). When rooster tailing, the animals surfaced very quickly, slicing along the surface of the water. This activity produced a V-shaped splash which obscured most of the porpoise from view. Respiration was explosive. High-speed photographs of rooster tailing Dall's porpoises reveal that the exhalation actually begins before the porpoise's blowhole is at the surface, and inhalation continues inside an air cavity under the surface caused by the animal's head. This sequence has been described in detail for the Hawaiian spinner dolphin (*Stenella longirostris*) by Norris *et al.* (1985). Both rooster tailing and slow rolling are illustrated in Morejohn (1979).

The third type of surfacing activity was termed fast surfacing, and resembled the "porpoising" of most delphinids. Fast surfacing porpoises were moving relatively quickly, and in a straight line. The animal brought most of its body out of the water, and created a much smaller splash than in rooster tailing. The breath was quick and explosive.

Table 1 shows the frequencies of different surfacing behaviors observed. The night data were based on the fact that slow rolling sounded very different from either rooster tailing or fast surfacing. The exhalation was quiet, and there was little or no sound of a splash when porpoises slow rolled.

Speeds between surfacings of slow rolling porpoises were determined from theodolite trackings. Slow rolling porpoises travelled at an average speed of 5.1 ± 0.83 (SD) km/h, with a range of 2.4 to 8.3 km/h ($n = 18$ surface intervals among six total groups). This is probably a slight underestimate of the true speed, since it assumes straight-line travel between surfacings. Würsig and Würsig (1979, 1980), also using theodolite tracking, found average swimming speeds of 6.1 km/h for bottlenose dolphins (*Tursiops truncatus*), and 7.7 km/h for dusky dolphins (*Lagenorhynchus obscurus*) in the South Atlantic. Gaskin *et al.* (1975), using radiotelemetry, found a mean swimming speed of about 2 km/h for slow surfacing harbor porpoises in the Bay of Fundy, New Brunswick.

Loeb (1972) and Morejohn (1979) have interpreted slow rolling as sleeping or resting. Some of their observations of slow rolling may have been of resting porpoises, but animals in the Johnstone Strait also appear to slow roll when travelling slowly and diving deeply to feed (see Diving, below).

Each time that rooster tailing was observed, the group also slow rolled in the same sighting. As Morejohn (1979) suggests, rooster tailing may be associated with play behavior. The first time that it was seen, the porpoises appeared to be playing and chasing each other. In another instance (outside the study area), they were rooster tailing around a boat, and in a third they surfaced around a group of killer whales.

Interestingly, no bow-riding behavior was observed in the study area, despite the presence of many fast-moving boats and ships. One boat was determined to be moving at 31.8 km/h (17 kn) by theodolite tracking, and there were many other vessels that matched or exceeded this speed. In other parts of their range, Dall's porpoises are known for their propensity to ride bow waves of boats. Morejohn (1979) states that animals in Monterey Bay often come to the bow of vessels travelling at 14 to 16 kn or faster. Leatherwood *et al.* (1982) report that speeds of 9 kn are often required to attract Dall's porpoises to the bow. Thus it appears that the absence of bow-riding was not due to a lack of vessels travelling at the proper speed. Apparently, porpoises in the study area chose not to ride bow waves.

No breaching or other aerial behavior was observed. Dall's porpoise is known to be a nonaerial species, and the few reports of animals leaping clear of the water (Yokum 1946; Lustig 1948; Tomilin 1967) may be descriptions of rooster tailing or fast surfacing, rather than breaching.

Diving

The amount of time spent below the surface for slow rolling adult porpoises travelling through the strait was highly variable (mean = 35.9 ± 26.52 (SD) s, range = 3 to 74 s, $n = 10$). The number of actual timed dives is small, but my subjective impressions agree with the high degree of variability. Calves usually surfaced more often than adults.

What were presumed to be feeding dives generally lasted from 2 to 4 min for adults. Upon surfacing from a long dive, the animal slow rolled in a circle or in a straight line, generally staying under for less than 15 s between breaths. About 10 to 15 of these short dives were followed by another long dive. Porpoises usually surfaced within a few metres of where they went down for a long dive. This cycle of a long dive followed by a series of short dives sometimes continued for more than an hour, suggesting that these may have been feeding bouts. Similar deep-diving behavior has been reported by Bouchet *et al.* (1983) in Prince William Sound, Alaska. The longest sustained periods of observation of groups of porpoises were during these bouts of deep diving.

When a calf accompanied deep-diving adults, the calf's dives were shorter, ranging up to 2 min. Very small, possibly newborn, calves didn't perform deep dives; but were left unattended at the surface while the adults did their 2- to 4-min dives. The adults almost invariably surfaced from their deep dives in the general vicinity of the calf. Amundin and Amundin (1974) and Gaskin and Watson (1985) have also observed the temporary separation of a mother from her calf during feeding activities in harbor porpoises.

Movements

In 69 of 76 sightings (90.8%), the direction of movement of the porpoises was east and (or) west (parallel to the direction of the strait), rather than north or south. During the remaining seven sightings direction of travel was not determined.

Figure 2 shows frequencies of directions of travel for different periods of the day, and Table 2 gives results of chi-square tests on the differences between east and west travel

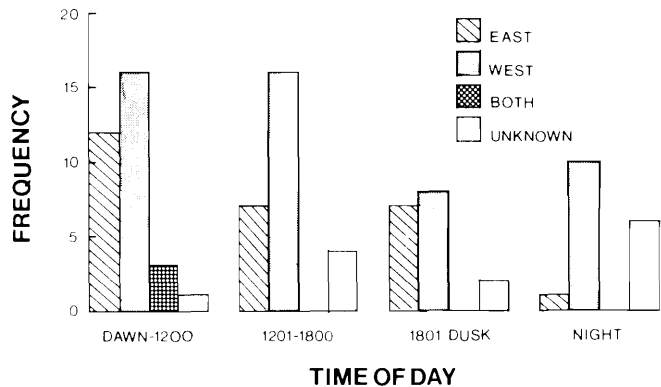


FIG. 2. Frequency distributions of various directions of travel for different time periods. Night data are based on animals that surfaced several times within hearing range of the observer.

for different time periods. The predominance of westward movement may indicate that the porpoises tend to travel westward near the Cracroft Island shore, and eastward closer to the Vancouver Island shore.

Most Dall's porpoise sightings were between shore and the 100-fthm (183-m) contour. This sample is biased, however, since the closer to shore the group was, the more likely it was to be detected, either by sight or sound. The degree to which this bias affected sightings is unknown, but I am under the subjective impression that Dall's porpoises in this area tend to follow the shoreline relatively close to shore.

With the exception of deep-diving bouts, porpoises in the study area appeared to be systematically travelling from place to place in the Strait. Even after diving bouts, the animals usually continued in the same direction that they had previously been moving. Perhaps they were travelling to and from major feeding areas outside the study area. Gaskin (1977), and Gaskin and Watson (1985) report that movements of New Brunswick harbor porpoises correlate mainly with the distribution of herring and mackerel, their major food items.

Interactions with killer whales

Killer whales are the most abundant marine mammal in the study area, and are sighted almost every day during the summer. Killer whales were sighted in the vicinity of Dall's porpoises on 12 occasions. The reaction of the porpoises ranged from attraction to apparent avoidance. During 10 of the 12 incidents, however, there was no obvious response by either species (Fig. 3).

On 29 July, an interesting interaction was observed. At 0824, a lone adult Dall's porpoise swam slowly west about 100 to 200 m offshore. At the same time, four resident killer whales were moving slowly east about 300 to 400 m from shore. The porpoise suddenly picked up speed, moved toward shore, circled less than 30 m from land, and then proceeded quickly to the east very close to shore. There was no apparent change in the behavior of the whales. At 0902, a lone adult Dall's porpoise (possibly the same individual) passed the cliff, going west unusually close to shore. Movements into shallow nearshore waters, apparently to avoid killer whale predation, have been reported for humpback dolphins (*Sousa* sp.) by Saayman and Tayler (1979) and dusky dolphins by Würsig and Würsig (1980).

In contrast to the above event was an incident in which a group of porpoises appeared to seek out and play with a group of killer whales on 29 August. At least five Dall's porpoises were seen slow rolling near West Point at 1900 (see Fig. 1). A

TABLE 2. Results of chi-square tests of significance between eastward and westward travel for different times of day (in all cases, $df = 1^a$)

Time period	East	West	χ^2	Level of significance
Dawn-1200	12	16	3.214	NS ^b
1201-1800	7	16	2.783	NS
1801-Dusk	7	8	0	NS
Night	1	10	5.818	$p < 0.05$

^aBecause $df = 1$, a Yates' correction for continuity was used (see Zar 1984).

^bNS, not significant.

group of resident killer whales was sighted just below the cliff, travelling slowly west. At 1915, the porpoises started to rooster tail, and move east towards the whales under the cliff. The porpoises began to rooster tail around the whales. As the killer whales moved west (showing no apparent reaction to the porpoises), the Dall's porpoises continued to surface around them, some less than about 3 m away from the whales, and moved west with them. The entire group of animals disappeared beyond West Point at 1920.

Although based on a very small sample size, the theodolite data show an interesting possible "response" to killer whales. Mean Dall's porpoise swimming speed when killer whales were not sighted in the study area was 4.4 ± 0.90 (SD) km/h (range = 2.4 to 5.7 km/h, $n = 14$). When killer whale pods were sighted within 2 km of Dall's porpoise groups, mean swimming speed was 7.4 ± 0.52 (SD) km/h (range = 7.2 to 8.3 km/h, $n = 4$). The difference is highly statistically significant (Mann-Whitney $U = 56.0$, $p < 0.001$). An increase in swimming speed may be indicative of disturbance. Kruse (1985) found that killer whales in the study area swim significantly faster when boats are within 400 m, and Bauer *et al.* (1985) found a significant correlation between several vessel variables and humpback whale (*Megaptera novaeangliae*) swimming speed.

Group size and composition

Each porpoise observed was placed into one of three categories: (i) adult, (ii) calf, or (iii) unknown. Adult Dall's porpoises were characterized by their size and the existence of white frosting on the flukes and dorsal fin. Calves were distinguished by their much smaller size (one-half to two-thirds the size of adults), and lack of frosting. Animals classified as calves were probably less than 1 year of age, and were always accompanied by one or more adults. The unknown category was reserved for those individuals that could not be seen well enough to determine their growth stage, and I suspect that many juveniles and subadults were in this category as well (although some may have been counted as adults).

Very little is known of the structure of Dall's porpoise schools, so this word is avoided in referring to their apparent groupings. A group was defined as one or more porpoises moving in the same general direction at the same rate. Most animals in a group were within three body lengths of another, although some groups temporarily separated (for example, when one or more individuals performed a long dive while others remained near the surface). There was only one instance in which group size changed during the sighting. This occurred when two animals were joined by two others, and then all four moved off as a single group.

For groups sizes that were recorded as ranges, the midpoint



FIG. 3. A peaceful interaction between a Dall's porpoise and killer whales. Photograph by D. Bain, Long Marine Laboratory, University of California, Santa Cruz, CA.

was used in computing the mean (for example, four was used when the range was three to five). Sightings in which only a minimum number of animals could be recorded were omitted from analysis of group size. There is a slight bias in the data, since most of the five discarded group sizes were larger groups of at least four animals (it can be said, however, that none of these groups consisted of more than 10 animals). Thus, the mean group size is a slight underestimate.

Sixty-eight of the 76 sightings in the study produced useful group size estimates (either a single number or a discrete range). Useful group size estimates ranged from one to five or more (Fig. 4). Mean group size was 2.6 ± 1.05 (SD). Two was the most common group size, making up 30 of 68 (44.1%) of all useful group size estimates. Pike and MacAskie (1969) found that a large percentage of Dall's porpoise groups in inshore British Columbia waters consisted of more than five individuals. The much smaller group sizes found in this study cannot be explained at present.

There appears to be a difference in size between groups of different composition. Mean size of adult-only groups was 2.0 ± 0.89 (SD) (range = 1 to 4, $n = 23$). Groups that included both adults and calves tended to be larger, and had a mean size of 3.1 ± 1.13 (SD) (range = 2 to 5.5, $n = 29$). The difference between these means is highly significant ($t = 3.863$, $df = 50$, $p < 0.001$). This difference is also evident in Fig. 4, in which the

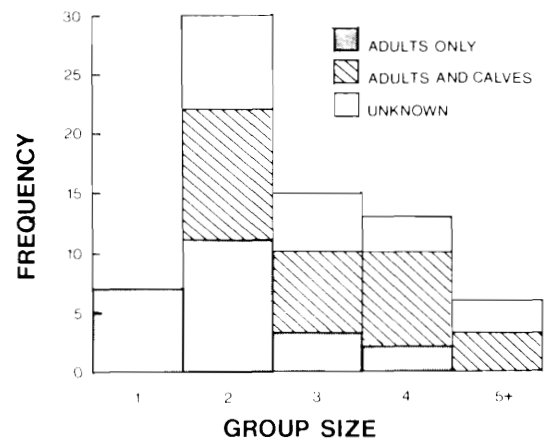


FIG. 4. Group size frequencies observed in the study, further broken down into group composition types.

frequencies of adult-only groups and mixed groups are shown as a function of group size.

Group size did not significantly change throughout the study period (Fig. 5), nor in relation to time of day (Fig. 6). Similarly, group size did not appear to be related to direction of travel. Groups travelling west (mean size = 2.7 ± 1.07 (SD), range = 1 to 5.5, $n = 40$) were not significantly larger than those

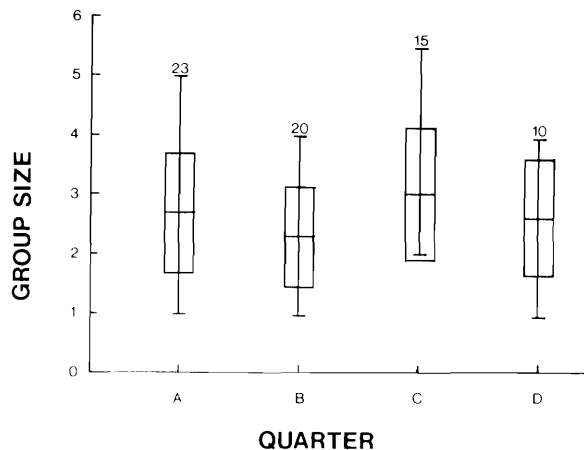


FIG. 5. Group sizes observed in each 15-day quarter of the study. Vertical bars represent range, boxes represent \pm one standard deviation, horizontal bars represent mean, and numbers represent sample sizes. Quarter A is 6 to 20 July, B is 21 July to 4 August, C is 5 to 19 August, and D is 20 August to 3 September. ANOVA: $F = 1.459$, $df = 67$, NS).

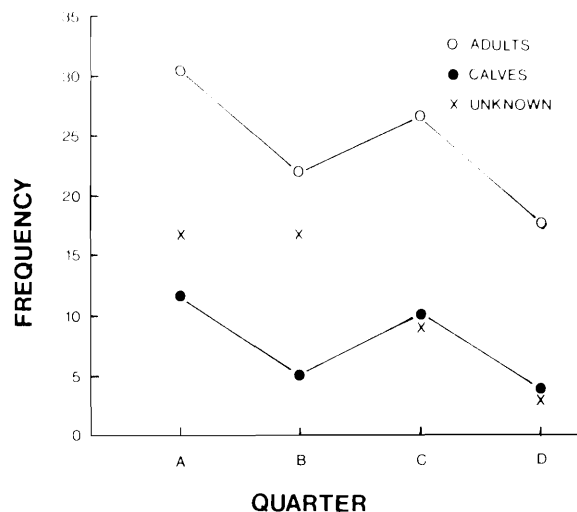


FIG. 7. The number of adults, calves, and unknown animals observed during each 15-day quarter of the study period. Quarters as in caption for Fig. 5.

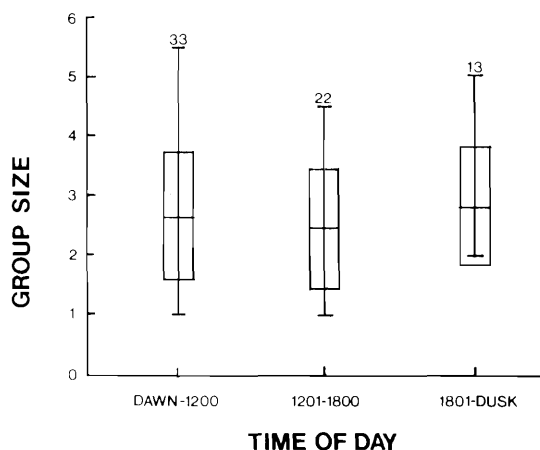


FIG. 6. Group sizes in relation to time of day. Display as in Fig. 5. ANOVA: $F = 0.540$, $df = 67$, NS.

travelling east (mean size = 2.5 ± 0.97 (SD), range = 1 to 4.5, $n = 22$) ($t = 0.584$, $df = 60$).

Calving

Of the 131 animals that could be placed into an age-class, 31 (23.7%) were calves. Since each calf was accompanied by at least one adult (presumably its mother), 62 (47.3%) of all known individuals were involved in cow-calf pairs.

This high percentage of cow-calf pairs suggests that the study area may be used as a calving area (an area of segregation of lactating females and possibly females about to give birth) during the summer. Kasuya and Jones (1984) have found that the area south of the western Aleutian Islands in the northwestern North Pacific is an area of segregation of Dall's porpoise mother-calf pairs and pregnant females. Little bow-riding behavior was observed in this area, because mother-calf pairs almost never ride the bow wave. The fact that no bow-riding behavior was observed in the present study area further supports the suggestion that it is used as a calving area in the summer. Kasuya and Jones (1984) also found that the area of segregation of mother-calf pairs generally had water temperatures of less than 11°C . The modal surface water temperature in this study was 10.5°C (T. R. Kieckhefer, personal communication).

An alternative explanation must be considered. Perhaps parturition occurs offshore, and then females bring their calves into the area. This is apparently the case for harbor porpoises in the Deer Island area of New Brunswick (Watson 1976; Gaskin 1977).

Calves were seen as early as 10 July, when three were observed in three separate sightings. As Fig. 7 shows, there is no clear change in the proportion of calves throughout the study period. This may indicate that the calving peak is before mid-July in this area. This is in agreement with the conclusion of Ridgway and Green (1967) that, in the eastern North Pacific, Dall's porpoises give birth mainly in late spring to early summer.

Morejohn's (1979) contention that parturition takes place year-round in the eastern North Pacific is based on a small number of fetuses, neonates, and juveniles. A spring to summer calving peak seems likely, however, based on the apparent unimodal summer calving peaks for this species in the northwestern North Pacific (Newby 1982; Jones *et al.* 1984, 1985) and off the Pacific coast of Japan (Kasuya 1978), and the high number of calves observed and collected in spring and summer in North American waters (Ridgway and Green 1967; Hall 1981; Dohl *et al.* 1983; Bouchet *et al.* 1984; this study).

Fisheries interactions

Despite extensive gillnetting and purse-seining operations in the Johnstone Strait, no Dall's porpoises were observed to become entangled in fishing gear. John Lewis (Department of Fisheries, Alert Bay, British Columbia; personal communication) reported that he knew of only one Dall's porpoise becoming entangled in a gillnet during the summer of 1984. It was released alive.

Discussion

The relationship between killer whales and Dall's porpoises is an interesting one. Killer whales are known to prey on Dall's porpoises at times (Nishiwaki and Handa 1958; Rice 1968; Pike and MacAskie 1969; Barr and Barr 1972; Morejohn 1979; Matkin 1981; Newby 1982; Hall *et al.* 1985; Jacobsen 1986). There have also been several observations of peaceful interactions between the two species (Scheffer 1949; Brown and Norris

1956; Spong *et al.* 1970; Matkin 1981; Braham and Dahlheim 1982; Jacobsen 1986; this study).

Killer whales in British Columbia appear to pursue one of two different lifestyles: (i) resident or (ii) transient (Bigg 1982). Residents seem to be primarily fish eaters, at least during the summer (when most of the observations have been made). Balcomb *et al.* (1980) have observed the southern residents (those in Greater Puget Sound) to attack only one marine mammal, a harbor porpoise, in 700 h of observation. The northern resident killer whales (those inhabiting Johnstone Strait and surrounding waters) have never been seen to attack a marine mammal, despite extensive observations by many researchers.

Transient killer whales travel through the ranges of the residents, covering much larger distances than residents do, and marine mammals appear to make up a significant part of their diet. Both Dall's porpoise attacks observed in the Johnstone Strait involved transient whales (J. K. Jacobsen, personal communication).

It seems that Dall's porpoises have little to fear from resident killer whales, and it would obviously be adaptive for them to be able to distinguish transients from residents. Possibly, they can do this by sound. Ford and Fisher (1982) report the existence of dialects in British Columbia killer whale vocalizations. Transients produce completely different calls than resident whales do. Also, transients are much less vocal, tending to be silent even during active periods (when residents are generally vocal). Dall's porpoises may be able to detect and use these differences to avoid predation by transient killer whales.

When one considers the serious problem that gillnets pose to Dall's porpoises in various parts of their range, especially in the northwestern North Pacific and Bering Sea, the situation in British Columbia is especially interesting. Why is it that porpoises suffer little gillnet-caused mortality in the Johnstone Strait? On several occasions, when fishing was heavy, porpoise groups appeared to actively avoid gillnets in their path by swimming unusually close to shore. Thus it would seem that they can detect the nets, either by vision, echolocation, or possibly passive hearing.

Several important differences exist between the salmon fishery in British Columbia and that in the northwestern North Pacific and Bering Sea (this fishery is hereafter referred to as the mother-ship fishery). First, the nets used in the Johnstone Strait are much smaller. By Pacific Commercial Salmon Fishery Regulations (Government of Canada, Fisheries and Oceans), they must be between 135 and 375 m long. The nets used in the mother-ship fishery are 16.5 km long. Also, the gillnets in British Columbia are set both day and night, whereas in the mothership fishery they are only set at night. Possibly the most important difference is that many of the nets used in the Johnstone Strait are made of multifilament line, which may trap air bubbles. The monofilament line used in the mothership fishery may be harder for the porpoises to detect, since the reflected acoustic energy is smaller (Awbrey *et al.* 1979). Also, the mother-ship fishery nets are weighted by a leadline which does not rattle. The lead weights used in British Columbia can often be heard through hydrophones (D. Bain, personal communication).

Other possible differences are in the animals themselves. It is very likely that the animals involved in the two fisheries are from separate, reproductively isolated populations (although this has not yet been confirmed by morphological studies). The northwestern North Pacific Ocean and Bering Sea Dall's

porpoises are pelagic animals with distinct migrations (Kasuya 1982). The animals in the Johnstone Strait are likely to be seasonal residents, and possibly are present year-round. These inshore porpoises may be familiar with the area and its fishing activities. Young animals may learn at an early age how to avoid nets, and they may have experienced walls (in the form of steep underwater cliffs). All or some of these differences may explain why Dall's porpoise entanglement in gillnets is not as serious a problem in British Columbia as it is in the mother-ship fishing area.

The information gathered in this study suggests that some of our past knowledge of Dall's porpoise behavior may have been biased by the use of vessels as the sole observation platform. Where possible, cliff-top observation, along with detailed study using boats, will provide a better picture of the natural behavior of Dall's porpoises.

Although this study is based on only one field season of data collection, I feel it is important because of the dearth of knowledge on the behavior of this species. This study has provided some basic information on Dall's porpoise in a very restricted portion of its range during summer. Future research in other areas, during all seasons, is needed to better understand this species and to aid in reducing losses from entanglement in gillnets.

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