Observations on the composition and behaviour of groups of female sperm whales near the Galapagos Islands

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During visual and acoustic tracking of sperm whales, *Physeter macrocephalus*, off the Galapagos Islands, observations were made on the composition and behaviour of the 13 photographically identified groups being followed. Observations of calves and the high incidence of animals with dorsal fin calluses suggested that the groups could be categorized as mixed groups, which contain females and their offspring. Animals recorded to be escorting calves were probably females. Individual calves were escorted by different individuals at different times, and known individuals were observed to escort more than one calf on different occasions. There was a significant difference in the proportion of open and closed fluke notches between groups, suggesting some relatedness of individuals within a group. Twenty-one percent of the identified individuals had tooth mark scars on their flukes, but there was no significant variation in this proportion between groups.

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Durant le suivi visuel et acoustique de Cachalots macrocéphales, *Physeter macrocephalus*, au large des Îles Galapagos, des observations ont été faites sur la composition et le comportement de 13 groupes identifiés par photographie. L'observation des baleineaux et la fréquence élevée d'animaux à cals sur la nageoire dorsale indiquent que les groupes peuvent être qualifiés de groupes mixtes contenant des femelles avec leur progéniture. Les animaux aperçus en train d'escorter des baleineaux étaient probablement des femelles. Chaque baleineau était escorté par différents individus à différents moments, et certains individus ont été aperçus plusieurs fois en train d'escorter plus d'un baleineau à la fois. Il y avait une différence significative d'un groupe à l'autre quant au nombre d'individus à encoche ouverte ou à encoche fermée sur la nageoire caudale ce qui semble indiquer l'existence d'un lien de parenté entre les individus d'un même groupe. Vingt-et-un pourcent des individus identifiés portaient des cicatrices de marques de dents à la nageoire caudale, mais il n'y avait pas de variation significative de ce pourcentage d'un groupe à l'autre.

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Introduction

Sperm whales (*Physeter macrocephalus*) are usually found in behaviourally cohesive groups. Of the different categories of sperm whale grouping described by Best (1979), the mixed group of about 20 females with their immature offspring has been of most interest to scientists. These mixed groups are the primary unit of sperm whale society, and there is evidence that they have stable composition over periods of years (Ohsumi 1971; Whitehead and Waters 1988). The age, sex, and social structures of these groups are of considerable significance both in attempts to model sperm whale population dynamics (e.g., Anonymous 1981; Cooke *et al.* 1983) and in studies of the function and evolution of the unusual form of social organization found in sperm whales (Best 1979).

Although there has been some investigation of the composition of groups of sperm whales using data collected during whaling (e.g., Best 1979; Ohsumi 1971), this work was hampered by the nature of the industry. In particular, selection by harpooners, size restrictions, and differential abilities of different types of animals to evade capture made it hard to obtain representative samples.

During studies off Sri Lanka, Whitehead and Gordon (1986) developed techniques of studying living sperm whales from a 10-m ocean-going boat. Gordon (1987) presents results on the social behaviour observed. Using the techniques described by Whitehead and Gordon (1986), we studied the social organization of sperm whales off the Galapagos Islands in early 1985. Statistical criteria allowed us to cluster individually identified females and immatures into groups, which appeared to have closed membership during the 2.5 months of our study (Whitehead and Arnbom 1987). Adult males were found to associate with particular groups of females and immatures for short periods, and to move between them. Here we present some results on the composition and behaviour of these groups.

Terminology, materials, and methods

The following terms have been adopted in this paper: calf, a whale less than 6.5 m in length and 1 year of age (Best *et al.* 1984); encounter, a 5-min observation period; escort, a whale swimming less than 2.5 m from a calf (an identified individual was scored only as an escort if the "escorting" was confirmed photographically); female/immature, a whale for which it was not known whether it was a mature female or an immature of either sex; group, an association of whales presumed to be closed over periods of weeks (see Whitehead and Arnbom 1987). Mature males could be distinguished from other sperm whales by their conspicuously larger sizes.

A total of 716 h were spent in visual or acoustic contact with aggregations of sperm whales in the waters west of the Galapagos Islands

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TABLE 1. Marks on flukes and dorsal fins used for individual identification of sperm whales

Small nicks	Small indentations in edge of fluke; only distinguished when the fluke was relatively close when photographed
Distinct nicks	Larger indentations that could be distinguished at relatively long ranges
Waves	Shallow depressions along the trailing edge of the flukes
Scallops	Almost semicircular depressions along the trailing edge of the flukes
Missing portions	Large parts of fluke missing
Holes	Perforations of the fluke only noticed when the fluke was perpendicular to the axis of the camera
Tooth mark scars	Often seen as parallel white lines
Calluses	Greyish deformities on the dorsal fin; the callus varies in colour, shape, and position on the dorsal fin

(1°S, 91°W) between 23 February and 20 April, 1985, aboard a 10-m sloop. Groups of sperm whales were tracked acoustically by means of a directional hydrophone (built by Dev-Tec Inc., Pasadena, CA). Whenever distance (usually less than 100 m) to whales and light conditions permitted, black and white photographs were taken of the flukes and dorsal fins of the whales. It is possible to identify individual sperm whales with certainty by means of natural marks on the fluke and the dorsal fin (Arnbom 1987*a*, 1987*b*; Gordon 1987; Whitehead and Gordon 1986).

Marks used for individual identification were small and distinct nicks, waves, scallops, tooth mark scars, missing portions, holes, the general shape of flukes, and the fluke notch (Fig. 1 and Table 1). Two catalogues were created: one for flukes and one for dorsal fins. The dorsal fin catalogue was divided into left and right dorsal fins depending on which side of the dorsal fin was photographed. Dorsal fin and flukes of the same identified individual were coupled when possible.

Kasuya and Ohsumi (1966) have estimated that 63% of females and 30% of the immature males have a callus on their dorsal fins and that no mature males have a callus (Fig. 2). Negatives of dorsal fins were examined and it was noted whether a callus was either present or not present, or if its presence was uncertain.

Veinger (1980) stated that the shape of the fluke notch can be used to distinguish different populations of sperm whales. He divided the shape of the fluke notch into three types but he did not define the different types. We divided fluke notches into two types: open and closed (Fig. 3). The type of fluke notch was noted for each identified whale with a certain individual identification from its flukes when photograph quality permitted.

Two hundred and ten females/immatures, 7 mature males, and 2 calves were individually identified with certainty from photographs of flukes (Arnbom 1987*a*). Thirty-eight females/immatures, 6 mature males, and 6 calves were individually identified from photographs of dorsal fins. Identifications from both dorsal fin and flukes were possible for eight females/immatures and six mature males. The 210 females/immatures identified from flukes were clustered, using statistical criteria, into groups (Whitehead and Arnbom 1987). The 13 primary groups, with more than six identified individuals in each group, are listed in Table 2. A recent reanalysis of these data suggests that groups G9 and G10 should be merged, and that a few other alterations in the allocations of identified whales to groups should be made, but these will not substantially change the results or conclusions of this paper (Whitehead and Waters 1988).

Results

Presence of calluses

There were 576 dorsal fin photographs (not individually identified whales; the same whale may have been photographed during several encounters but no animal was counted twice within the same encounter) from which it was possible to say whether or not a callus was present. Of the females/immatures, 84% (484 of 576) were recorded with a callus and 16% (92 of 576) without. As it is easier to say that a whale definitely possesses a callus than to say that it definitely does not, the true proportion of animals with a callus is less than indicated by these figures. None of the large males had a callus.

TABLE 2. Groups of whales, with the number of animals identified, a population estimate obtained by mark–recapture techniques, its estimated standard error, the number of days on which the grouping was identified, and the time span between its first and last sighting (from Whitehead and Arnbom 1987)

Group No.	No. of whales identified	Population estimate (SE)	No. of days group was identified	Time span of identifications, days
G1	14	14.1 (1.0)	7	46
G2	20	29.8 (6.9)	4	13
G3	18	18.3 (1.0)	6	43
G4	18	20.9 (2.8)	5	36
G5	20	22.5 (2.8)	7	40
G6	19	28.2 (6.9)	5	41
G7	17	20.7 (4.0)	2	14
G8	14	17.8 (3.5)	5	36
G9	9	10.6 (2.4)	4	48
G10	12	13.7 (2.6)	6	23
G11	10	—	1	1
G12	8	—	1	1
G13	7	—	1	1

Calves and escorts

Records of visual observations and inspection of photographs suggested the 13 groups possessed between 0 and 3 calves per group (Table 3). If we assume that the proportion of mature females in mixed groups is 0.59 and that the calving interval is 6 years (Best 1979; Best *et al.* 1984), the expected number of 1st-year calves for each group, given in Table 3, was calculated as follows: estimated number of individuals in group × proportion of mature females in mixed groups (0.59)/calving interval (6 years). The observed number of calves for the mixed groups was lower than expected (Table 3), but not significantly so (χ^2 tests, $P > 0.1$).

The identities of the escorts of the calves were examined. All seven females/immatures that escorted calves, and for which the presence or absence of a callus could be determined, possessed a callus on the dorsal fin. Four of the individually identified females/immatures were observed with calves on 3 different occasions and one female/immature on 11 occasions. However, an examination of the ratio of the number of observations with a calf to the total number of observations (calf identification ratio) showed that none of the escorting females/immatures was identified exclusively with calves. The calf identification ratio for these females/immatures varied between 0.48 and 0.75. Two particular females/immatures were identified escorting different calves on different occasions. One identified calf was recorded as escorted by three different individually identified females/immatures on different occasions.

Marks and notches on flukes

The analysis of flukes showed that 21% (39 of 190) of the

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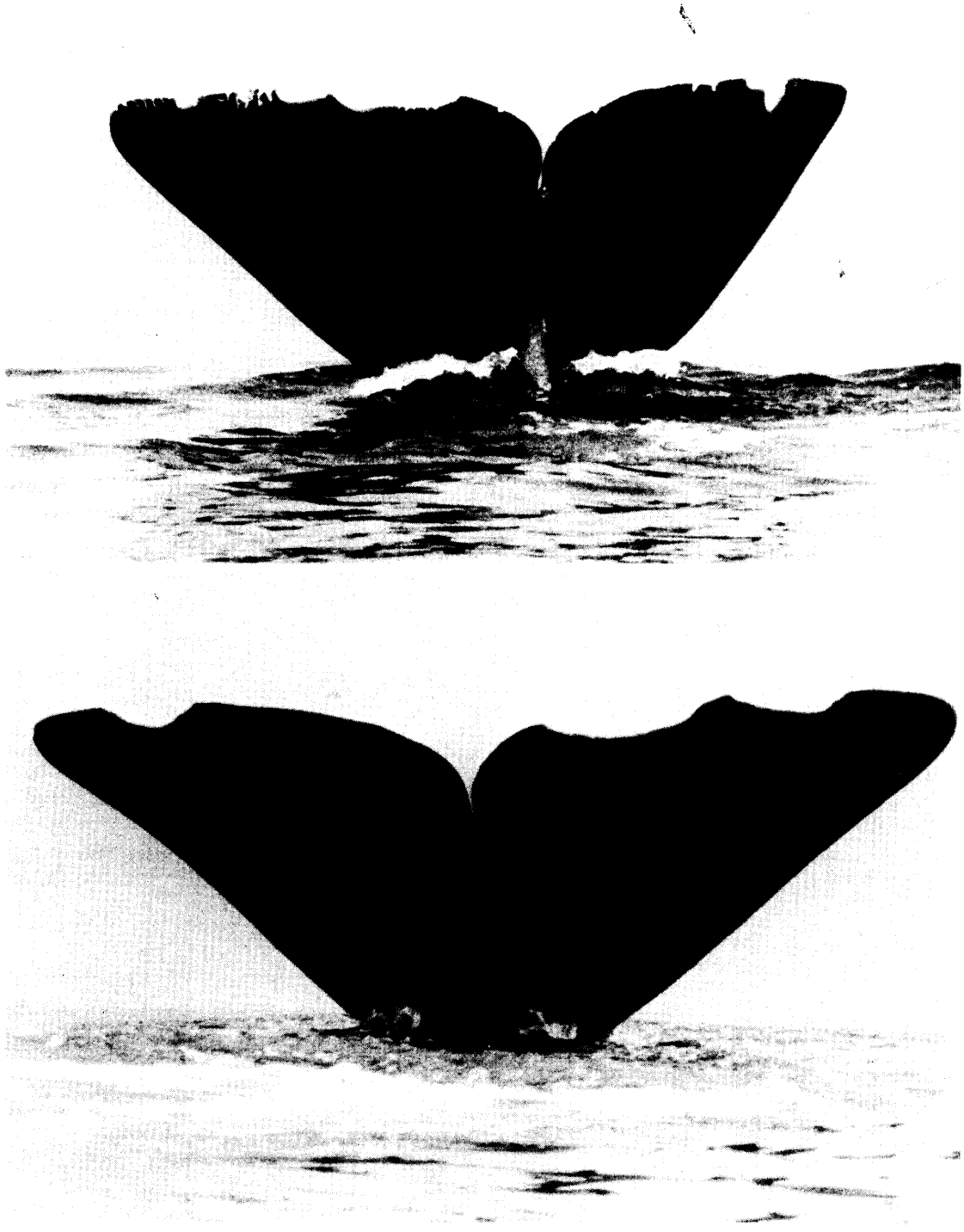

FIG. 1. Photographs showing marks on flukes of sperm whales from the Galapagos.

identified individuals had tooth mark scars. It was possible to record the presence or absence of tooth mark scars for only 190 of the 210 individually identified female/immature flukes. Photograph quality was not sufficient to distinguish tooth marks on the fluke for the other 20 individually identified females/immatures. There were no tooth mark scars on the flukes of the mature males (Arnbom 1987*a*). There was no significant difference in the proportion of individuals with tooth mark scars for the different groups (Table 3, $\chi^2 = 14.34$, $df = 12$, $P > 0.10$). Apart from the tooth mark scars there were small round holes, missing pieces, and scallops that could have been made by sharks or other animals. The total number of each different kind of mark was divided by the number of individuals from which it was possible to record the presence of the mark. Holes and missing pieces were found on 8 and 19% of the flukes, respectively, and 1.7 scallops were recorded per individual whale (Table 4). The mean number of marks on the flukes of animals from different groups varied

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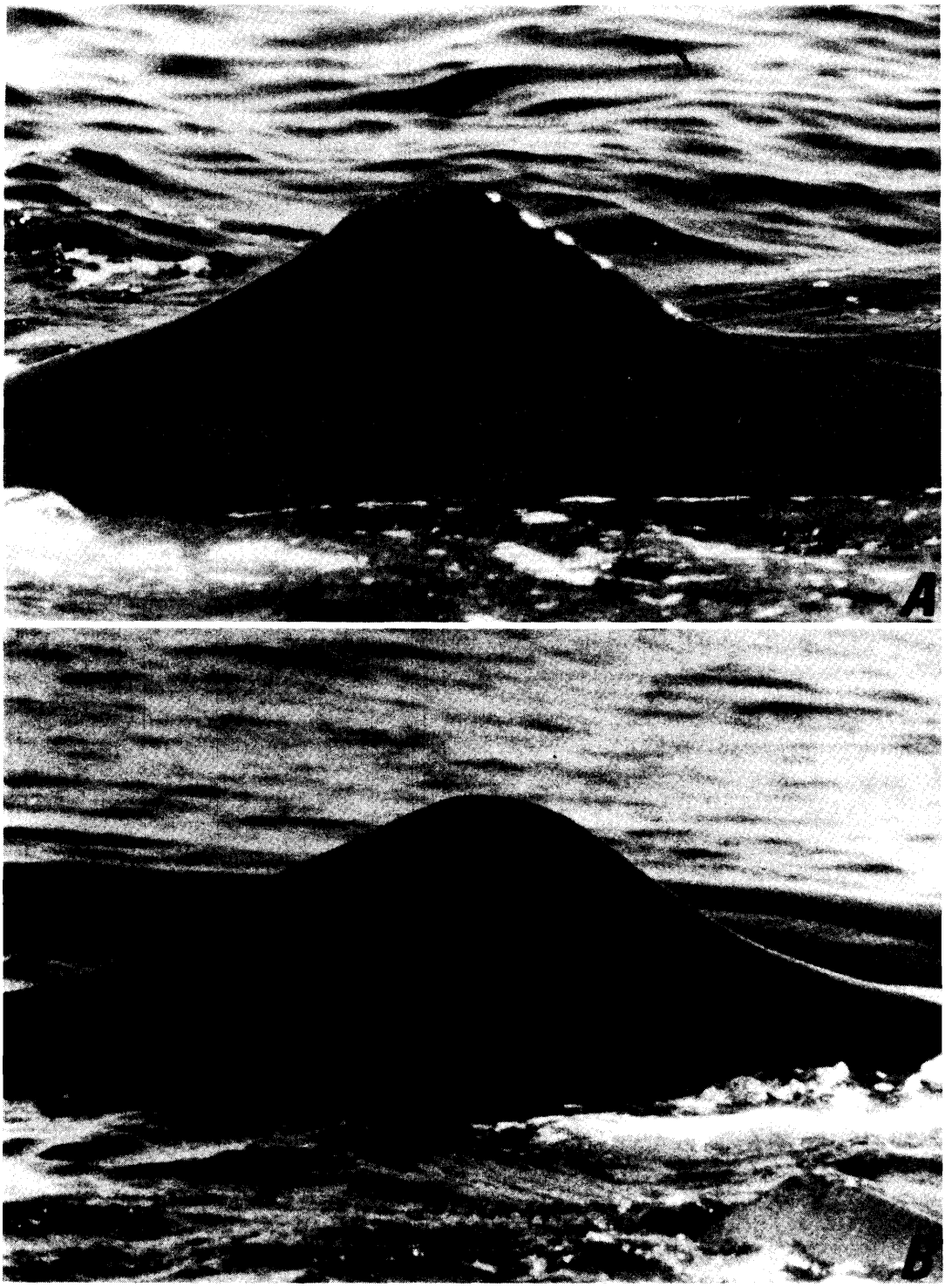

FIG. 2. Photographs of dorsal fins of sperm whales from the Galapagos: (A) with callus, (B) without callus.

from 5.9 to 10.8 with a mean of 8.2 (Table 3).

The ratio of animals with open rather than closed fluke notches was 105:79. There was an overall significant difference in the proportion of open and closed fluke notches between the groups ($\chi^2 = 27.03$, df = 12, $P < 0.01$). Two groups (G3 and G11) were significantly different from the overall ratio ($\chi^2 = 5.33$ and 6.00, df = 1, $P < 0.05$). Group G3 had more closed and G11 had more open fluke notches.

Discussion

The predominance of whales 7–12 m in length (Whitehead and Arnbom 1987), observations of calves, and the high frequency of calluses on the dorsal fins strongly suggest that most of the whales encountered were mature females and immatures from mixed groups.

There was an overall difference between the groups when comparing the shape of the fluke notch, which suggests that

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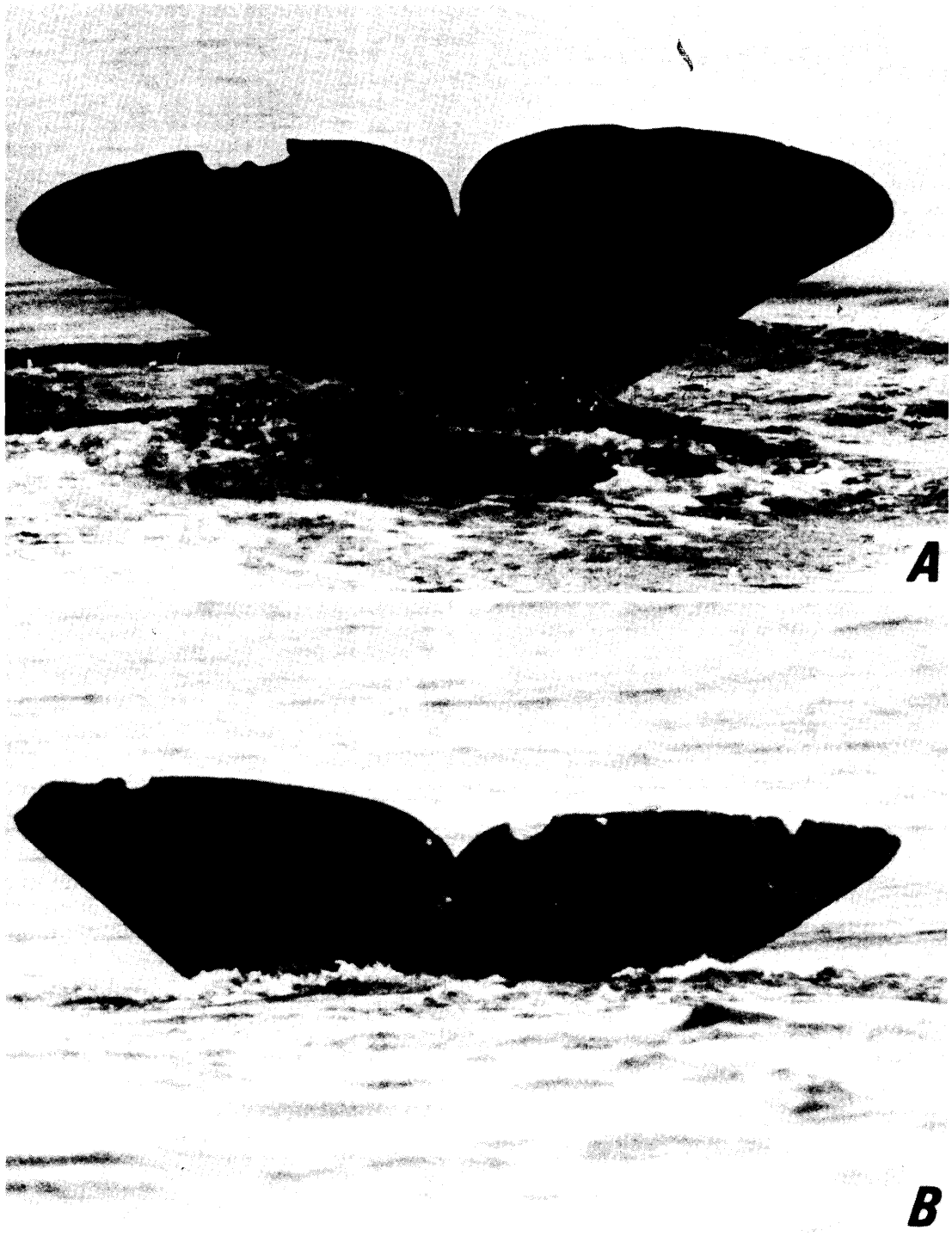

FIG. 3. Photographs of flukes of sperm whales from the Galapagos: (A) with open fluke notch, (B) with closed fluke notch.

there are morphological differences between groups and may imply that these groups are to a certain extent genetically discrete.

It is likely that many of the marks on sperm whale flukes, in addition to the obvious tooth mark scars, are due to predators of sperm whales. There were tooth mark scars on approximately 21% of the identified flukes. Both killer whales, *Orcinus orca*, and sperm whales leave parallel tooth mark scars on their victims (Best *et al.* 1984). Other possible sources for the tooth mark scars on the whale flukes off the Galapagos are sharks and cephalopods, although it is probably impossible for cephalopods to make several parallel lines several centimetres apart on the free edge of a sperm whale fluke (Arnbom 1987*a*).

There are differences in tooth mark scars on the flukes of sperm and humpback whales, *Megaptera novaeangliae*. Photographs of humpback flukes (Katona *et al.* 1980; Mayo *et al.* 1985) show that the entire surface area of some flukes

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TABLE 3. Summary of attributes of groups: mean number of marks per individual, percentage of individuals in each group with tooth mark scars, number of identified individuals that definitely did and did not possess a dorsal fin callus, number of individuals with open and closed fluke notches, and the observed (maximum of visual and photographic records) and expected number of calves per group

Group No.	Marks per individual	% with tooth marks	Callus		Notch		No. of calves	
			Yes	No	Open	Closed	Obs.	Exp.
G1	8.6	11.8	2	0	9	4	3	1.4
G2	7.6	38.1	2	1	11	5	1	2.9
G3	10.8	23.5	4	0	5	12	2	1.8
G4	7.1	11.1	4	0	7	8	2	2.0
G5	8.0	16.7	0	0	14	4	1	2.2
G6	7.6	13.3	0	2	7	7	1	2.8
G7	7.5	6.7	3	1	5	8	1	2.0
G8	8.5	41.7	4	0	4	8	2	1.7
G9	9.3	16.7	3	0	3	3	0	1.0
G10	7.7	28.6	4	0	4	1	1	1.3
G11	10.0	37.5	2	0	6	0	0	—
G12	5.9	12.5	0	0	5	3	1	—
G13	8.7	0.0	1	0	5	1	1	—

TABLE 4. Incidence of marks on sperm whale flukes (for each type of mark this table gives the mean number of marks per individual (with SD), the maximum number on any individual, and the number of individuals with sufficiently clear fluke photographs so that the presence of marks could be determined)

Type of mark	Mean no. per individual (SD)	Max. no. per individual	Sample size
Small nicks	3.1 (2.6)	15	201
Distinct nicks	1.4 (1.3)	6	214
Waves	1.1 (1.3)	7	214
Scallops	1.7 (1.4)	7	216
Missing portions	0.19 (0.48)	2	213
Holes	0.08 (0.31)	2	208
Tooth mark scars[a]	0.21 —	—	190

[a]Tooth mark scars were only scored as either present or absent.

is covered with tooth mark scars, while on sperm whale flukes these were only found along the trailing edges. Most tooth mark scars on the flukes of humpbacks are from killer whales (Katona *et al.* 1980). This suggests that most of the tooth mark scars on sperm whale flukes are either from a different source or from killer whales that bite only along the trailing edge of the sperm whale's flukes. Arnbom *et al.* (1987) observed that, when attacked by killer whales, sperm whales formed tight groups and appeared principally to use their powerful jaws to defend themselves; in contrast humpbacks, in much smaller groups, defended themselves by thrashing back with their flukes (Whitehead and Glass 1985). These differences in defensive behaviour might have led to the more extensive scarring on humpback flukes.

Arnbom (1987*a*) notes that sharks associate with sperm whales, and that tooth mark scars, possibly from a shark, in a photograph of a sperm whale calf shown in Best *et al.* (1984) are similar to those found on eight of the flukes photographed off Galapagos. A comparison of the scallop shapes on the flukes with photographs (in Lineaweaver and Backus 1970) of a blue shark (*Prionace glauca*) attacking a dead dolphin suggests that scallops are made by sharks. The results from the Galapagos presented in this paper seem to strengthen the assumption that sharks attack sperm whales.

Different individual females/immatures were observed to escort the same calf on different occasions. Further, identified females/immatures were observed with several different calves on different occasions. These findings are very similar to Gordon's (1987) results from Sri Lanka. All of our escorts had calluses, as did many of Gordon's (although at least one of his escorts was an immature male). These observations suggest that females may accompany several calves at different times, and also confirm Ash's (1962) speculation that different females accompany a particular calf at different times.

The escorting of calves by several, or even all, adult members of a mixed group may be significant for the females in the group, as well as for the evolution of stable mixed groups. As sperm whales feed at considerable depth and a calf probably cannot follow its mother for several consecutive deep dives (Best 1979; Gordon 1987), calves are potentially vulnerable to predators such as killer whales and large sharks. Members of a group almost always stagger their feeding dives, leaving some adults at or near the surface at all times (H. Whitehead, unpublished data). If females, and possibly immature animals as well, escort calves that are not their own, and therefore protect the calf from predators while the mother is feeding, each female may expect lower infant mortality of its offspring, as well as possibly greater feeding success (Best 1979). If females in a mixed group are closely related genetically, as suggested by the fluke notch data, kin selection could allow the evolution of this apparently altruistic behaviour. The benefits of reciprocal escorting of calves might have been a significant factor in the evolution of stable, behaviourally cohesive, and possibly genetically related, groups of female sperm whales.

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