

Evidence of Sex Segregation in Hector's Dolphin (*Cephalorhynchus hectori*)

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Abstract

Segregation by sex is evident at a variety of levels in many birds, fishes, and mammals. Segregation has been observed in marine mammals to varying degrees, but it was previously undocumented in Hector's dolphin (*Cephalorhynchus hectori*). Forty-three groups (of group size ≤ 5) were sexed using an underwater pole-camera; 91% of groups consisting of two to five individuals ($n = 32$) were either all male or all female. Sexes were obtained from an additional seven groups containing calves. All of the adults associating with mothers and their young were female. This research suggests that Hector's dolphin groups are highly segregated by sex. Sex segregation might have implications for reproduction in Hector's dolphins, including difficulty in finding a mate as local populations decline.

Key Words: sex segregation, group composition, Hector's dolphin, *Cephalorhynchus hectori*

Introduction

Determination of sex is important for modeling mammal populations (Slooten et al., 2000; Hall et al., 2001) and for defining social structure (Main et al., 1996; Michaud, 2005). Group composition is well-studied in many terrestrial mammals—for example, western lowland gorillas (*Gorilla gorilla gorilla*) (Magliocca et al., 1999; Parnell, 2002), African elephants (*Loxodonta africana*) (Wittemyer et al., 2005), and ungulates (Kie, 1999)—but is much more difficult to study in cetaceans, which spend prolonged periods of time underwater. Groups may form for a variety of reasons, including avoidance of predation and intraspecific competition, enhancement of foraging (i.e., targeting and catching prey), and facilitation of reproduction (Connor, 2000; Acevedo-Gutiérrez, 2002). Group size, stability, and sex all influence group composition, which is highly variable between and even within species

(Würsig et al., 2007). Knowledge of the composition of these groups provides information about the social system and hence the potential reasons for formation of particular groups.

Segregation by sex is well-known in many species of terrestrial mammal (Weilgus & Bunnell, 1995; Conradt, 1999; Loe et al., 2006; Smit et al., 2007), birds (Clarke et al., 1998; Gonzales-Solis et al., 2000), and fish (Croft et al., 2006). Sex segregation has also been observed in a variety of marine mammals, including pinnipeds (Wolf et al., 2005; Breed et al., 2006), odontocetes (Amano & Kuramochi, 1992; Whitehead, 2003; Martin & Da Silva, 2004; Loseto et al., 2006), and mysticetes (Stevick et al., 2003). Differences in morphology and reproductive condition resulting in different energy requirements and survival strategies influence segregation. Extreme size dimorphism is linked to sex segregation (Myrsterud, 2000) and is particularly evident in species such as elephant seals (*Mirounga angustirostris*) (Stewart, 1997; Le Boeuf et al., 2000) and sperm whales (Lyrholm et al., 1999). In sperm whales (*Physeter macrocephalus*), for example, adult males and females are only seen together when breeding. For the rest of the year, they utilise different habitats—females are confined to tropical and subtropical waters between 40° North and South, while males favour higher latitudes (Rice, 1989). Social segregation occurs when individuals group together by sex but within the same region or habitat (Michaud, 2005; Shelton, 2006). Males and females may also segregate spatially, either using entirely different habitats or different areas within the same habitat.

In the absence of obvious distinctive features, such as extreme size dimorphism, other methods need to be employed to determine sex. Non-invasive methods have involved the use of post-anal humps to identify sexually mature males (Neumann et al., 2002). Underwater systems have also been employed to determine the sex of marine mammal groups (Spitz et al., 2000).

Hector's dolphin is an endangered delphinid endemic to the coastal waters of New Zealand.

Very little work to date has been undertaken specifically on group composition or the occurrence of sex segregation (Bräger et al., 1999). Hector's dolphin groups are typically small, numbering just a few individuals (Dawson & Slooten, 1988). Hector's dolphins are sexually dimorphic in size and genital colouration (Slooten, 1991). Size differences (adult females are about 5 to 7% longer than males; Slooten & Dawson, 1994) are too slight to allow reliable sexing in the field. Obvious distinctions in the genital regions make it easy to tell the sexes apart, however, provided you get a reasonable view of the dolphin's underside. The sex of free-ranging Hector's dolphins has typically been determined during opportunistic sightings during photo-ID surveys (Slooten, 1991), and small numbers of individuals have also been sexed using underwater video (Stone, 1992; Bräger et al., 1999). For this study, we used a simple pole-camera system that could be deployed opportunistically to determine the sex of individual Hector's dolphins and to ultimately examine group composition.

Materials and Methods

To determine the sex of individuals and groups, video footage of Hector's dolphins was taken

during photo-ID surveys undertaken from a 6 m-centre-console research vessel. Between December 2005 and February 2007, data were collected using an underwater pole-camera system at Banks Peninsula on the east coast of the South Island of New Zealand (Figure 1). A strict survey protocol was adhered to for boat surveys which were only conducted in Beaufort sea state < 3 (or wind speeds < 10 kts), low swell conditions (< 2 m), and in good visibility (> 20 km).

A professional quality, compact integrated camera (Sony® XC555P) fitted with the widest angle lens available (3.5 mm Sony® VCL03S12XM) was housed inside a custom-built anodised aluminium underwater casing. The housing (17.5 cm long, 4.5 cm maximum diameter) was bolted to an extendable pole to allow the camera to penetrate up to a metre below the sea surface. A cable from the camera ran up the pole to the A/V input of a Sony® DCR-DVD 703E Handycam® camcorder that recorded onto a mini-DVD. The pole-camera was powered by a 12 V battery. A splash-proof box housed the Handycam® and enabled the dolphins to be monitored via the screen.

Hector's dolphins were observed using the camera system while they were in close association with the research vessel, typically bow-riding. The

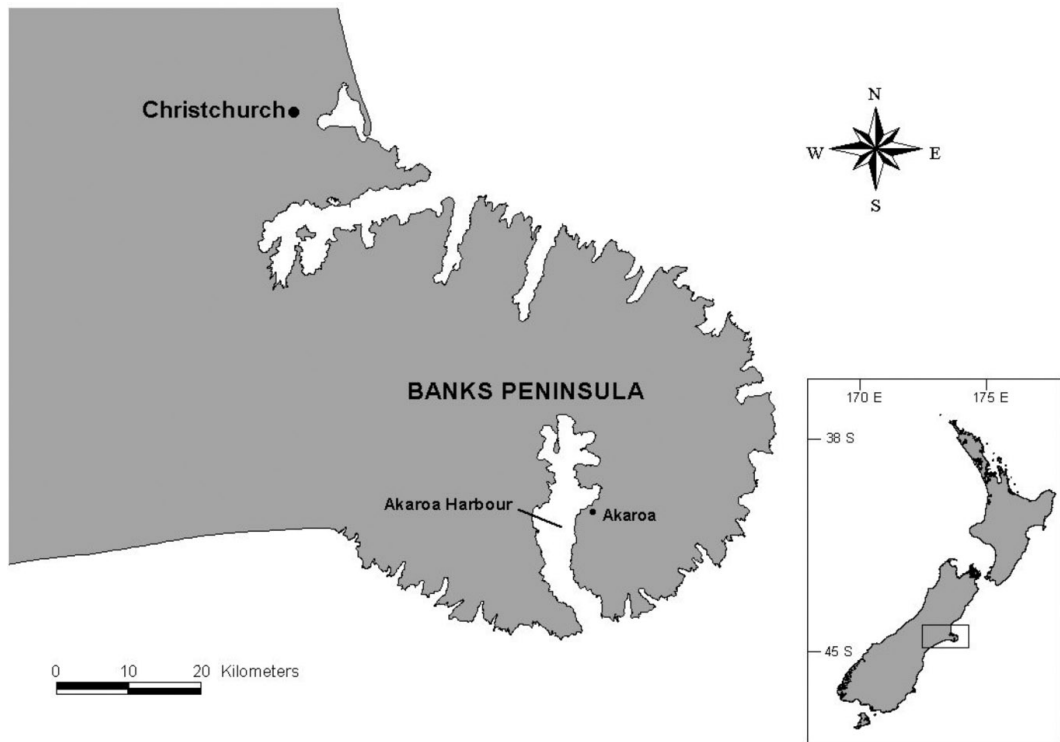


Figure 1. Survey area, Banks Peninsula, New Zealand

open bow area of the vessel allowed easy access to bow-riding or interactive dolphins. Only discrete groups were selected for sexing (i.e., there was no mixing with other dolphin groups during the time it took to determine sex) to ensure that we knew which individuals had been sexed. A group was defined as individuals within approximately five body lengths of each other, closely associating and engaged in similar activities (Constantine et al., 2004). Dolphins within the same geographical area were not automatically described as a group. An aggregation was defined as dolphins in the same geographical area but not closely associating or necessarily engaged in similar activities. Nursery groups containing mother-calf and mother-juvenile pairs were also observed using the pole-camera system.

Use of the pole-camera required reasonable water clarity (> 2 m), low swell, and no rain. While the sex of any observed dolphin was straightforward to determine, the sex ratio within the group could be determined only if individuals were recognisable from obvious markings, or if all dolphins were visible on the screen at any one time.

Sexing was accomplished by aiming the video camera towards the underside of each dolphin while the boat was slowly idling forward. Location and time was taken using a Garmin® 126 GPS at the start and end of each video encounter with a dolphin group. The GPS was interfaced with a Hewlett Packard® (HP) 200LX palmtop computer in splash-proof housing, which ran custom software (written by D. Coup, University of Otago) for recording vessel track and sightings data. Information on the specific recording segment of the mini-DVD and details of each encounter were recorded on the palmtop computer. Video footage was replayed on land in order to ascertain the sex of individuals.

The degree of sex segregation was examined by comparing the observed group compositions with the expected group compositions, assuming that the sexes associate randomly. The expected frequencies of single sex groups ($E_{s(n)}$) were calculated as follows:

$$E_{s(n)} = P_s N_n$$

where P_s is the probability of a single sex group occurring, n is group size, and N_n is the number of groups of size n .

The probability of a single sex group occurring (P_s) is calculated by

$$P_s = 2(0.5^n)$$

Fisher's exact test was used to test deviations from expected frequencies. The locations of single sex groups were then plotted using the *ArcView* 3.3 program.

The degree of segregation in Hector's dolphin groups in which all individuals had been sexed was measured using the segregation coefficient (Conradt, 1998). The degree of social sexual segregation (SC_{social}) is measured using the following formula:

$$SC_{social} = \sqrt{1 - \frac{N-1}{XY} \sum_{i=1}^k \frac{x_i y_i}{n_i - 1}}$$

where x_i is the number of males in the i th group, y_i is the number of females in the i th group, k is the number of groups with at least two animals, X is the total number of males sampled (excluding solitary males), Y is the total number of females sampled (excluding solitary females), and N is the total number of males and females sampled.

An SC value of zero would indicate no sex segregation, while a value of one would suggest total segregation of males and females.

Results

A total of 27 identifiable individuals from the Banks Peninsula photo-ID catalogue were sexed using the pole-camera, of which 13 were female and 14 were male (see Figure 2). Minimum age (ascertained from photo-ID data) for these 27 individuals varied between one and 22 y.

Naturally marked dolphins were sexed with the pole-camera on 29 occasions; two of these dolphins were duplicates. Mothers with calves were not targeted with the pole-camera as a mother's sex was already apparent. During the same period (December 2005 to February 2007), five males and one female were sexed using only visual opportunistic methods (Smolker et al., 1992), excluding mothers associating with calves, to allow for comparability with the pole-camera method. Use of the underwater video set-up therefore increased the opportunities for sexing individuals 4.5-fold. There was no significant difference in the number of males ($n = 85$) and females ($n = 83$) bow-riding ($G = 0.02$, $df = 1$, $0.75 < p < 0.90$).

There were a total of 43 groups in which all of the individuals were sexed via the pole-camera (Figure 3). These 43 exclude nursery groups, which are treated separately. During this study it was only possible to sex every individual in groups with between one and five members. Sexes were obtained from larger groups, but not of every individual. These groups are also considered separately. Examination of all groups encountered during photo-ID studies ($N = 1,335$) confirm that Hector's dolphin groups are typically small. Mean group size was 3.8 individuals ($SE = 0.097$), modal group size was two, and the majority of groups



Figure 2. The genital regions of a male (left) and female (right) Hector's dolphin (*Cephalorhynchus hectori*) (Photos taken by W. Rayment)

(82.8%) contained fewer than six individuals. Therefore, the sexing of small groups (≤ 5 members) is most appropriate for Hector's dolphin.

Both females and males were encountered on their own, but females were more often solitary (64% of groups). The vast majority of groups (91%) containing between two and five individuals were single sex (i.e., either all male or all female) (Table 1). Only three of the small groups observed were of mixed sex, and in one of these groups, sexual activity (including lots of body contact, pouncing, and an everted penis) was observed. Groups containing five or fewer members showed a strong tendency to be segregated by sex (Table 2). Conradt's (1998) measure of social sexual segregation (SC_{social}) was calculated as 0.918, indicating strong sex segregation.

Sexual segregation was observed to occur in spring (September to November), summer (December to February), and winter (June to August). No groups were sexed during autumn

(March to May). More data were gathered during the austral summer as weather and sea conditions were more suitable for underwater video, and the dolphins were found in larger numbers close to shore (Dawson & Slooten, 1988; Rayment et al., 2006).

The locations of single sex groups showed no clear evidence of particular areas being preferred by either sex. Male and female single sex groups were found to the north and south of Banks Peninsula and within Akaroa Harbour.

Individuals were sexed in 11 larger groups (with > 5 members) in which it was not possible to determine the sex of every group member. These groups ranged in size from six to 16 individuals. Of the 11 groups observed, the majority (73%) were of mixed sex. In three of the groups, only males or females were observed.

In addition to those groups described above, there were a further 11 encounters with aggregations of between 20 and 40 individuals, whose

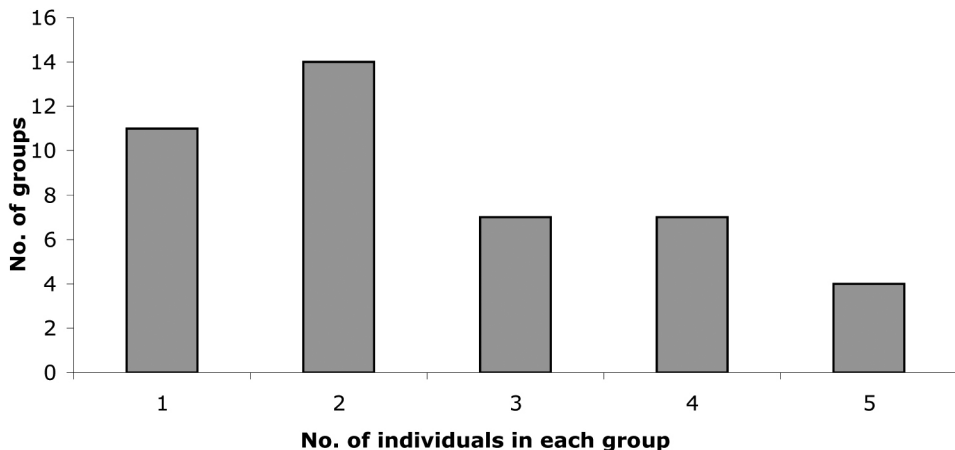


Figure 3. Frequency distribution of group sizes of Hector's dolphin in which sexes were determined for all members of the group

Table 1. Sex composition of Hector's dolphin (*Cephalorhynchus hectori*) groups where all individuals were sexed; where groups were mixed, the composition is indicated in brackets in terms of the number of males (M) and females (F).

Group size	Total	All male	All female	Mixed sex
1	11	4	7	N/A
2	14	9	5	0
3	7	3	3	1 (2M, 1F)
4	7	3	3	1 (2M, 2F)
5	4	1	2	1 (3M, 2F)
Total	43			

Table 2. Fisher's exact test values for small groups of Hector's dolphins

Group size	No. of single sex groups	No. of mixed sex groups	<i>p</i> (2-tailed)
2	14	0	0.006
3	6	1	0.029
4	6	1	0.005
5	3	1	0.143

members were in the same geographical area but not closely associated. A large proportion (46%) of these aggregations occurred behind a trawler, and sexual activity was involved in 64% of these cases. All of the observed aggregations were of mixed sex.

Seven nursery groups containing one mother-calf pair or mother-juvenile pair and other individual(s) were sexed using the pole-camera. Group size for these nursery groups was either three (i.e., one additional adult; $n = 3$) or four (i.e., two additional adults; $n = 4$). In each of these groups, all of the other adults associating with mothers and their young were observed to be female.

Discussion

The underwater pole-camera system was successful in determining the sex of identifiable Hector's dolphins as well as for documenting the sex composition of small groups. The likelihood of sex determination for individuals was greatly improved by the pole-camera when compared to opportunistic methods alone. The system involved minimal disturbance to individuals because no diver was required to enter the water. Genetic means of determining sex (e.g., Harlin et al., 1999; Gowans et al., 2000) require skin biopsies or skin swabs, which are relatively invasive procedures.

Skin biopsies in particular raise questions about short- and long-term impacts on the individuals sampled (Bearzi, 2000). Minimising disturbance is especially important in research on endangered species such as Hector's dolphin.

Of the recognisable Hector's dolphin individuals sexed using the pole-camera, 48% were female and 52% were male. There is no reason to suggest that one sex preferentially bow-rides or that different sexes behave differently towards boats. Mature Hector's dolphin females with young calves do sometimes exhibit avoidance behaviour (Slooten & Dawson, 1994). Therefore, the most parsimonious conclusion is that there is a 1:1 sex ratio within the population at Banks Peninsula. Population models that currently assume a 1:1 ratio of males to females (Slooten et al., 2000) are therefore considered to be realistic.

Hector's dolphins were shown to preferentially form small groups (≤ 5 members) with a high degree of sex segregation. On only 9% of occasions were small groups found to be of mixed sex. Segregation cannot occur continuously, however. For example, it would certainly not be possible during mating. Large groups (> 5 individuals) and aggregations of dolphins occurred less frequently than small groups (17% of the time) and tended to be of mixed sex. It is likely that feeding or sexual activity (Slooten, 1994; Slooten & Dawson, 1994) cause small single sex groups to join together and become larger mixed sex groups or aggregations. Although the sample size for nursery groups was small ($n = 7$), video footage showed that all of the individuals observed closely associating with mothers and their young were female. These nursery groups contained four or fewer individuals and again suggest that sex segregation occurs in small groups.

Sex segregation is widespread among social mammals (Ruckstuhl & Neuhaus, 2000). It is not surprising, therefore, that sex segregation occurs in Hector's dolphins. Several hypotheses have been proposed to explain sex segregation (Ruckstuhl & Neuhaus, 2000; Michaud, 2005), although the causes and advantages are still poorly understood and the ecological consequences are unknown (Conradt, 1998; Ruckstuhl & Kokko, 2002). The predation risk hypothesis is based on vulnerability to predators, which varies with body size and the presence or absence of a calf (Du Toit, 1995). The forage selection hypothesis suggests that segregation occurs as metabolic requirements vary with body size and reproductive status (LeBoeuf et al., 2000; Martin & Da Silva, 2004). Female albatross (*Thalassarche* sp.), for example, apparently take advantage of their smaller size to feed in tropical regions with lighter winds where males cannot go (Phillips et al., 2004). The activity budget hypothesis

also suggests that differences in body size and/or reproductive condition lead to variation in foraging behaviour, but in terms of time spent resting and feeding. Synchronisation of activity is thought to lead to cohesion of separate male and female groups (Conradt, 1998; Ruckstuhl & Neuhaus, 2000; Ruckstuhl & Kokko, 2002). When little food is available, intense feeding pressure by females could exclude males from preferred habitat in the scramble competition hypothesis (Main et al., 1996; Michaud, 2005). The final hypothesis is social preference in which single sex groups are favoured. Female grizzly bears (*Ursus arctos*), for example, separate from males to avoid harassment (Weilgus & Bunnell, 1994), and males may avoid inter-male aggression caused by the presence of females (Conradt, 1998). Social learning may also be optimised in single sex groups (Pérez-Barbería et al., 2005).

For Hector's dolphins, there is no evidence to support the forage selection or scramble competition hypotheses. Research at Banks Peninsula has not detected any sex-specific differences in home range (Bräger et al., 2002; Rayment et al., in press), and analysis of the distribution of single sex groups has not shown any clear differences in spatial use of the peninsula. Furthermore, there is no indication that male and female Hector's dolphins segregate by habitat due to differences in diet or diving capabilities. However, the predation risk, activity budget, and social preference hypotheses are all plausible. Sex segregation may occur because nursing mothers are at greater risk from predators; due to activity synchronisation of individuals at different reproductive stages; because of inter-male aggression in the presence of females; or because females are avoiding harassment from males seeking sexual activity. In reality, it is likely that the processes involved in sex segregation are not mutually exclusive and may be a combination of some or all of these reasons. A similar discussion of sex segregation theories has been conducted for sperm whales (Whitehead, 2003).

Sex segregation may have implications for reproduction in Hector's dolphins due to increased difficulty in finding mates. An Allee effect (Allee, 1931) occurs when a small population at low density has low survival or reproductive rates, which, in turn, leads to further population decline. An obvious mechanism causing an Allee effect is difficulty in finding mates, where potential mating encounters are few and far between because populations have reached very low densities. While it is difficult to observe in large, free-ranging species (e.g., North Atlantic right whales [*Eubalaena glacialis*], Fujiwara & Caswell, 2001; polar bears [*Ursus maritimus*], Molnár et al., 2008; Chatham Island taiko [*Pterodroma magentae*], Lawrence et al., 2008), most social animals would seem

vulnerable to Allee effects. Segregation by sex and population fragmentation are likely to exacerbate problems associated with reproduction. Unfortunately, Hector's dolphin populations are highly fragmented, with at least four genetically distinct populations (Pichler et al., 1998), one of which (Maui's dolphin [*Cephalorhynchus hectori maui*]) is considered a separate subspecies (Baker et al., 2002).

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