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ABSTRACT

Aerial surveys of Hector's dolphin (*Cephalorhynchus hectori*) distribution in and around the Banks Peninsula Marine Mammal Sanctuary were carried out in summer and winter 2004. The primary set of transect lines was placed at 45° to the coast, spaced 4 nautical miles (n.m.) apart and extended to 15 n.m. offshore. A further five transect lines were placed between 15 and 20 n.m. offshore. Two independent teams of two observers recorded details of Hector's dolphin sightings. Forty-two separate groups of Hector's dolphins were seen during both the summer and winter surveys. In summer, Hector's dolphins were mostly observed close to shore in water less than 20 m deep. In winter, they had spread out further from the coast into deeper water, and were seen right out to the limits of the survey area. In summer, 93% of all groups sighted were inside the 4-n.m. offshore boundary of the sanctuary. This figure fell to 43% in winter, raising concerns that a large proportion of the population may be exposed to the risk of bycatch in commercial gillnets. It is proposed that the sanctuary is currently not spatially extensive enough to reduce bycatch to sustainable levels. Offshore and alongshore extensions of the sanctuary will be required to allow the recovery of the Hector's dolphin population at Banks Peninsula.

Keywords: Hector's dolphin, *Cephalorhynchus hectori*, Banks Peninsula Marine Mammal Sanctuary, aerial survey

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1. Introduction

Hector's dolphin (*Cephalorhynchus hectori*) is a small, coastal delphinid that is endemic to New Zealand. The abundance estimate for South Island Hector's dolphin, *C. h. hectori*, is 7270 animals (CV = 16.2%; Slooten et al. 2004). The North Island sub-species, *C. h. maui*, numbers only 111 individuals (CV = 44%; Slooten et al. in press). The species is listed as 'endangered' by the World Conservation Union (IUCN), while the North Island population is listed as 'critically endangered' (IUCN 2000).

Bycatch in gillnets is recognised as the major threat to Hector's dolphin. High levels of incidental mortality in gillnet fisheries have been documented for the Canterbury coast (Dawson 1991; Starr & Langley 2000), and bycatch in gillnets is known to occur throughout the species' range (Dawson 2001). Population recovery is limited by a low potential for population growth (c. 2–4% per annum; Slooten & Lad 1991) and very restricted alongshore dispersal (Bräger et al. 2002). Population modelling and the loss of genetic (mtDNA) diversity indicate both regional and national population decline (Martien et al. 1999; Pichler & Baker 2000). Studies of mtDNA variation have shown that the species is divided into at least four genetically isolated, regional populations (Pichler 2002). In combination, these studies show that a declining population is highly unlikely to be 'rescued' by immigration from a neighbouring, less-impacted population.

The Banks Peninsula Marine Mammal Sanctuary was established in 1988, in response to the unsustainable level of bycatch of Hector's dolphins in the local gillnet fishery (Dawson & Slooten 1993). It covers an area of 1170 km^2 from Sumner Head in the north to the Rakaia River in the south, out to 4 nautical miles (n.m.) offshore (Fig. 1). Commercial gillnetting is effectively prohibited within the sanctuary, and recreational gillnetting is subject to seasonal restrictions. Additional regulation by the Ministry of Fisheries has banned recreational gillnetting from

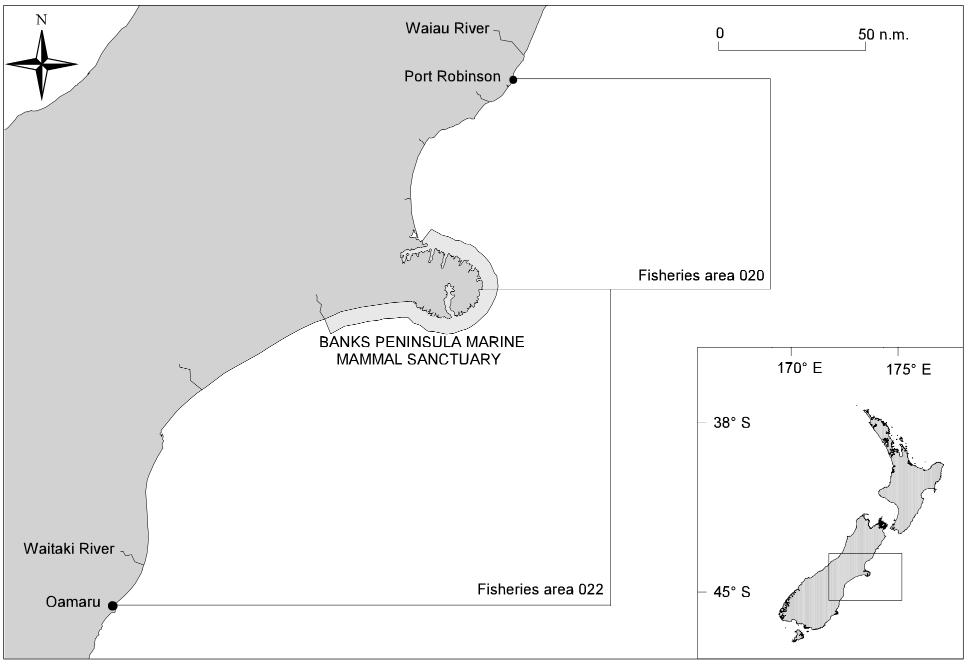


Figure 1. The east coast of the South Island, New Zealand, showing the Banks Peninsula Marine Mammal Sanctuary, fisheries areas and the boundaries of the recreational gillnetting regulations (Waiau River and Waitaki River).

the Waitaki River to the Waiau River during the calving and breeding season. Together, these regulations result in a year-round ban of commercial gillnetting between Sumner Head and the Rakaia River, and recreational gillnetting is banned from 1 October to 31 March between the Waiau River and the Waitaki River, with the exception of the South Timaru Reef Area and the Banks Peninsula Flounder Areas, where the prohibition runs from 1 November to the last day of February. All of these regulations only prohibit commercial and recreational gillnetting within 4 n.m. of the coast.

When the sanctuary was established in 1988, the 4-n.m. offshore boundary was decided upon using the best data available at the time. It was fully understood that the sanctuary area was a compromise between protection of Hector's dolphins and the continuation of gillnetting, and that the sanctuary was not extensive enough, either spatially or temporally, to provide ideal levels of protection (Dawson & Slooten 1993).

An observer programme with the objective of estimating the rate of entanglement of Hector's dolphins in setnet fisheries in Pegasus Bay and the Canterbury Bight was run during the 1997–98 fishing year. In fisheries areas 020 and 022 (Port Robinson to Oamaru), a total of 112 days of commercial setnet fishing involving 187 setnet fishing events were observed between October 1997 and July 1998 (Starr & Langley 2000; Baird & Bradford 2000). A total of seven Hector's dolphins were observed incidentally caught in gillnets to the north and south of the Banks Peninsula Marine Mammal Sanctuary and beyond the sanctuary's offshore boundary (Starr & Langley 2000). Extrapolating from these data, the total estimated number of Hector's dolphins caught in commercial gillnets in fisheries areas 020 and 022 during the observed period was 17 (Starr 2000; Baird & Bradford 2000). To put this number in context, under the United States' bycatch management system, the Maximum Allowable Fisheries Related Mortality (MALFIRM) (Wade 1998) for Hector's dolphin in this area would be two individuals per annum. The MALFIRM formula incorporates estimates of population size and growth rate to yield a bycatch limit which would allow for maintenance at, or recovery to, sustainable population levels after a specified period. In addition to the bycatch in commercial gillnets, Hector's dolphins on the Canterbury coast outside the Banks Peninsula Marine Mammal Sanctuary continue to die as a result of recreational nets (DOC & MinFish 2001) and trawl nets (e.g. Starr & Langley 2000). It is not surprising, therefore, that adult survival rate has not significantly increased since the creation of the sanctuary (Cameron et al. 1999). The latest estimates of survival rate from photo-ID data suggest that the population size is probably still decreasing (Dufresne 2004).

The data presented in this report enable us to quantify the proportion of the Hector's dolphin population found beyond the spatial boundaries of the sanctuary and therefore potentially exposed to the gillnet fishery. Several boat-based surveys have investigated the alongshore and nearshore distribution of Hector's dolphins, and this is now relatively well understood (e.g. Dawson & Slooten 1988; Bräger & Schneider 1998; Dawson et al. 2004). In contrast, the distribution of Hector's dolphins beyond 4 n.m. from the coast has received relatively little attention. Dawson & Slooten (1988) conducted offshore transects in a small boat at Banks Peninsula and concluded that although Hector's dolphins are most frequently seen within the first kilometre from the shore in summer, there is a net movement offshore in winter. Aerial monitoring of the Banks Peninsula Marine

Mammal Sanctuary by the Department of Conservation provided some data on relative sighting rates of Hector's dolphins between the coast and 10 n.m. offshore (Brown et al. 1992). The purpose of these surveys was to monitor abundance; consequently, all surveys were conducted in summer (January–March), and the majority of transects (80%) only extended to 4 n.m. from the coast. On transects that extended to 10 n.m. offshore, 40% of dolphins sighted were outside the sanctuary (Brown et al. 1992). The first systematic surveys specifically designed to investigate seasonal variation in the offshore distribution of Hector's dolphin were undertaken by the Otago University Marine Mammal Research Group at Banks Peninsula in February and June 2002. This series of aerial surveys provided coverage between the coast and 15 n.m. offshore, and revealed that although the majority of Hector's dolphin groups (79%) were found within the sanctuary in summer, this proportion fell to 35% in winter (unpubl. data). Consequently, there is real concern that many of the Hector's dolphins protected by the Banks Peninsula Marine Mammal Sanctuary in summer may disperse offshore in winter and may possibly be exposed to the risk of bycatch.

This study was conducted because it was clear that more data were required to clarify the seasonal changes in the offshore distribution of Hector's dolphins, allowing the design of current and future management areas to be optimised for the conservation of this species. We decided that the most appropriate way to gather these data was by further aerial surveys. Aerial surveys are now an established technique for investigating the abundance and distribution of small cetaceans (e.g. Barlow et al. 1988; Leatherwood et al. 1988), and their effectiveness for surveying Hector's dolphin populations has been proven (Slooten et al. 2004). In this context, we considered aerial surveys to be preferable to boat surveys as we were able to cover a large area in a relatively short time and there was no responsive movement of the animals.

In this report we present the results of a second set of aerial surveys for Hector's dolphin around Banks Peninsula in summer and winter 2004. These surveys are part of an ongoing 3-year project; hence the results are a portion of a larger dataset that will be published in its entirety when the project is completed. For this reason, analysis of the data and discussion of the findings have been kept to a minimum. Further analysis and discussion of the 3-year dataset will follow.

2. Methods

2.1 DESIGN

Design principles followed those used on previous Hector's dolphin aerial line-transect surveys (e.g. see Slooten et al. 2004). The coast between Sumner Head and the Rakaia River was first divided into four sections of relatively straight coastline and a straight baseline was drawn along the coast. Within these sections, transects were placed at 45° to the baseline. The coastal start-point of one transect within each section was chosen randomly, with the rest of the transect lines spaced evenly at 4-n.m. intervals. This resulted in 21 transect lines extending out to 15 n.m. from the coast. Five additional transect lines were placed at 15–20 n.m. from the coast; these were spaced at approximately equal intervals throughout the survey area.

2.2 SURVEY PLATFORM AND EFFORT

The summer surveys were carried out between 6 January and 13 January 2004. The winter surveys were carried out between 13 June and 26 June and on 8 August 2004.

The survey platform was a Partenavia P-68; a twin-engine, six-seater, high-wing aircraft. Prior to the survey, the aircraft was modified by replacing the flat rear windows with bubble-windows, allowing the rear observers to survey the track line.

While flying transects, the aircraft was flown at an altitude of 500 ft (152 m) at a speed of approximately 100 knots (185 km/h). Transect lines were navigated using a Garmin GPS11^{+} Global Positioning System (GPS), with transect waypoints previously loaded into the memory. The direction in which transect lines were flown was decided in the field according to the sea conditions and glare at that time. All survey effort was completed in sea states of Beaufort 3 or less. Survey effort was discontinued if bubble-window observers were not confident that they could see all dolphin groups close to the track line. Sampling effort commenced no sooner than 30 min after sunrise and was completed no later than 30 min before sunset.

The survey was conducted in passing mode (Buckland et al. 1993), meaning that the course of the aircraft was not diverted when a sighting was made. This was possible because Hector's dolphins are easy to identify from the air and their typically small group-size makes them easy to count.

2.3 OBSERVER TEAM AND PROTOCOL

The survey team consisted of four observers (two on each side of the aircraft) and the pilot. To reduce the risk of bias and fatigue, observers swapped positions diagonally between flights (i.e. the observer in the front right position on the first flight would be in the rear left position on the next flight). To ensure consistency between summer and winter surveys, we tried to keep the same observer team where possible. Three of the four observers participated in both the summer and winter surveys.

While flying transect lines, the rear observers focused their attention on and near the track line and the front observers focused on the steepest angle that the flat windows would allow (60° from horizontal). This resulted in an overlapping field of vision between 40° and 60°. Observers wore headphones to receive instructions from the survey leader, but did not communicate when 'on effort'. The noisy environment of the aircraft and the layout within the aircraft itself ensured that observers gained no visual or acoustic cues from each other. Information about sightings was shared only when 'off effort' between transect lines.

When a group of Hector's dolphins was sighted, the observer measured the downward angle to the group perpendicular to the aircraft's track using a hand-held inclinometer (Suunto PC5/36D PCB). Sighting details were dictated into personal dictaphones, with the time of the sighting noted to the second from digital clocks attached to the window ledge (so that observers could see the time without taking their eyes off the sighting). Clocks were synchronised with local time according to the GPS at the start of each flight. The time of each sighting was later used to locate positions of sightings on transects by interpolation. A GPS-linked Hewlett-Packard 200LX palmtop computer with custom-written software was used to record starts and ends of transect lines, details of effort (by recording a GPS fix every 10 s) and sighting conditions (recorded by the survey leader at the start of each transect, and whenever they changed). Sighting conditions recorded were Beaufort sea state, glare (scored on an arbitrary scale of 0–4, where 0 is no glare and 4 is a level of glare uncomfortable for the observer), water colour (categorised as blue, green or brown) and swell height (categorised as < 1 m, 1–2 m or > 2 m). Data were downloaded from the dictaphones and the palmtop computer at the end of each day and were backed up.

To familiarise the pilot and observers with survey protocols, two training flights were conducted in summer and three in winter, during which the observers made 119 and 54 sightings of Hector's dolphin groups respectively. These data were used for training only. Actual survey flights were only attempted once all observers and the pilot were confident with the protocol.

2.4 DATA ANALYSIS

The positions of Hector's dolphin groups were plotted and distances from shore measured in program Arcview GIS v. 3.3. The water depths in which sightings occurred were determined by plotting sightings onto a digitised nautical chart using program MacGPS Pro v. 4.0.5. Survey effort per transect line was calculated by adding distances between successive on effort GPS fixes. The proportion of survey effort relative to distance offshore and depth was calculated by plotting actual survey tracks using program ArcView GIS v. 3.3. Survey effort in each distance or depth bin was determined using ArcView's measuring tool. Statistical analyses were performed using program Statistica (1998 edition).

3. Results

Each complete set of surveys comprised 26 transect lines between Sumner Head and the Rakaia River. A summary of survey effort is displayed in Table 1. The partition of sampling effort is displayed in relation to distance offshore (Table 2) and depth (Table 3). Sighting conditions were very similar during the summer and winter surveys (Table 4).

In total, 49 sightings of Hector's dolphin groups were made during the summer survey and 54 sightings were made during the winter survey. After removing duplicate and data-deficient sightings (e.g. angle or time missed or estimated), 42 sightings remained for both surveys (Fig. 2).

Encounter rate of dolphin groups per transect line was calculated as number of dolphin groups per n.m. of survey effort on that line. Comparing encounter rates of dolphins between seasons was complicated by the fact that there were no sightings on many lines; consequently, the distributions of encounter rates were highly skewed. A non-parametric test suggested that there was no difference in encounter rate between summer and winter (Mann Whitney U-test adjusted for tied ranks: $z = -0.05$, $P = 0.96$). Similarly, a randomised ANOVA using natural log-transformed encounter-rate data showed no significant difference between seasons (a significance level is obtained from the percentage of randomised test statistics as large as, or larger than, the test statistic for the observed values; after 10 000 iterations, $P = 0.29$). There was no evidence, therefore, for a difference in encounter rates between summer and winter.

TABLE 1. SUMMARY OF SAMPLING EFFORT DURING THE SUMMER AND WINTER SURVEYS, 2004.

	SUMMER SURVEY	WINTER SURVEY
Number of transects	26	26
Number of survey flights	4	6
Total sampling effort	333.6 n.m. (618.2 km)	333.2 n.m. (617.5 km)

TABLE 2. SURVEY EFFORT AND SIGHTING RATE OF HECTOR'S DOLPHINS (*Cephalorhynchus hectori*) IN RELATION TO DISTANCE OFFSHORE IN SUMMER AND WINTER 2004.

DISTANCE OFFSHORE/ n.m.	EFFORT/ n.m.	NO. DOLPHIN GROUPS	NO. GROUPS/ n.m. EFFORT	NO. DOLPHINS	NO. DOLPHINS/ n.m. EFFORT
Summer 2004:					
0–1	14.54	11	0.76	27	1.86
1–2	16.11	10	0.62	25	1.55
2–3	17.55	18	1.03	39	2.22
3–4	21.96	0	0.00	0	0.00
4–5	16.32	0	0.00	0	0.00
5–6	16.43	0	0.00	0	0.00
6–7	19.60	1	0.05	8	0.41
7–8	24.6	1	0.04	2	0.08
8–9	20.55	0	0.00	0	0.00
9–10	17.60	1	0.06	2	0.11
10–11	20.42	0	0.00	0	0.00
11–12	29.16	0	0.00	0	0.00
12–13	24.34	0	0.00	0	0.00
13–14	19.26	0	0.00	0	0.00
14–15	21.89	0	0.00	0	0.00
15–16	6.52	0	0.00	0	0.00
16–17	6.58	0	0.00	0	0.00
17–18	6.62	0	0.00	0	0.00
18–19	7.19	0	0.00	0	0.00
19–20	6.36	0	0.00	0	0.00
Winter 2004:					
0–1	13.87	2	0.14	2	0.14
1–2	15.75	2	0.13	3	0.19
2–3	17.70	9	0.51	16	0.90
3–4	22.65	4	0.18	8	0.35
4–5	16.92	1	0.06	1	0.06
5–6	16.01	3	0.19	5	0.31
6–7	19.89	2	0.10	3	0.15
7–8	24.10	1	0.04	2	0.08
8–9	20.55	4	0.19	8	0.39
9–10	17.95	4	0.22	7	0.39
10–11	20.70	0	0.00	0	0.00
11–12	28.63	3	0.10	3	0.10
12–13	22.76	0	0.00	0	0.00
13–14	19.37	3	0.15	4	0.21
14–15	22.42	2	0.09	3	0.13
15–16	6.69	0	0.00	0	0.00
16–17	6.56	0	0.00	0	0.00
17–18	6.73	1	0.15	1	0.15
18–19	7.04	1	0.14	1	0.14
19–20	6.93	0	0.00	0	0.00

TABLE 3. SURVEY EFFORT AND SIGHTING RATE OF HECTOR'S DOLPHINS.

	DEPTH/m	EFFORT/n.m.	NO. DOLPHIN GROUPS	NO. GROUPS/ n.m. EFFORT
Summer 2004:	0–20	42.59	36	0.85
	20–50	100.12	4	0.04
	50–100	188.77	2	0.01
	100–150	2.12	0	0.00
Winter 2004:	0–20	40.94	5	0.12
	20–50	101.31	19	0.19
	50–100	188.65	18	0.10
	100–150	2.32	0	0.00

TABLE 4. PERCENTAGE OF TIME ON SURVEY EFFORT IN EACH OF THE SIGHTING CONDITION CATEGORIES DURING THE SUMMER AND WINTER SURVEYS.

Total time on survey effort was 3 h 13 min 59 s in summer and 3 h 16 min 39 s in winter.

	BEAUFORT			GLARE					SWELL			WATER COLOUR		
	1	2	3	0	1	2	3	4	< 1 m	1–2 m	> 2 m	BLUE	GREEN	BROWN
Summer	0	48	52	92	8	0	0	0	61	39	0	64	34	2
Winter	0	60	40	93	6	2	0	0	49	51	0	54	45	1

3.1 GROUP SIZE

Group size was typically small (fewer than four dolphins), although groups of up to eight individuals were seen in summer. Group-size characteristics are summarised in Table 5. Group size was significantly larger in summer than winter ($t = 3.19$, df = 82, $P = 0.002$).

TABLE 5. SUMMARY OF HECTOR'S DOLPHIN (*Cephalorhynchus hectori*) SIGHTINGS DURING THE SUMMER AND WINTER SURVEYS, 2004.

	SUMMER SURVEY	WINTER SURVEY
Number of Hector's dolphin sightings	42	42
Total number of dolphins seen	103	67
Mean group size (CV)	2.5 (64%)	1.6 (48%)
Min.; max.; modal group size	1; 8; 2	1; 4; 1

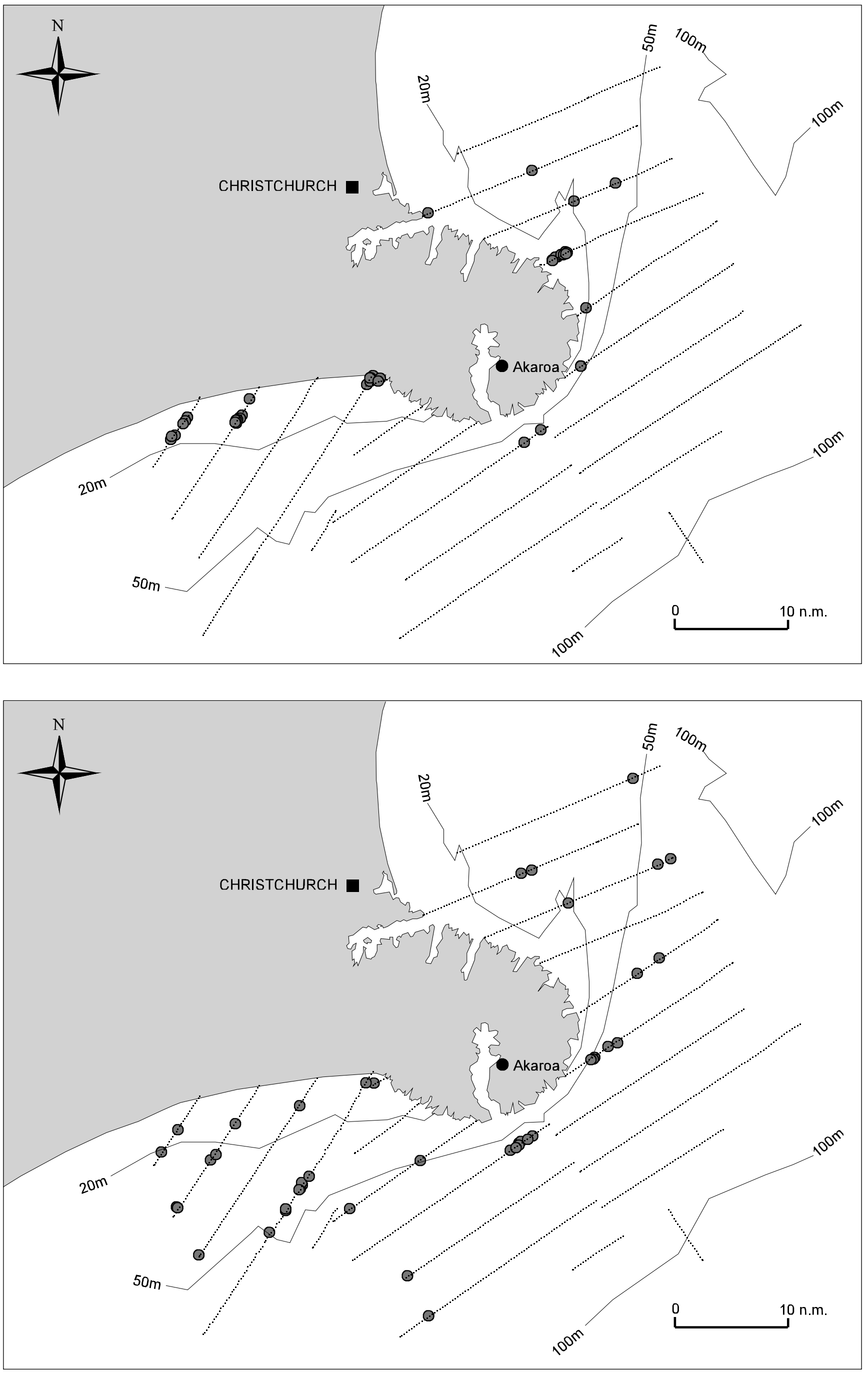
3.2 ALONGSHORE DISTRIBUTION

In summer, Hector's dolphin sightings were concentrated inshore to the north-east and south-west of Banks Peninsula (Fig. 2A). In winter, sightings were more evenly spread throughout the survey area, although few sightings were made in the deeper water to the south-east of the peninsula (Fig. 2B). Distances between sightings were measured in ArcView v. 3.3. Sightings were further apart in winter than summer, although the difference was not significant at the 5% level (distance to nearest neighbouring sighting, Mann Whitney U-test adjusted for tied ranks: $z = -1.82$, $P = 0.07$). However, the result was sensitive to removal of the outliers (distance to nearest neighbouring sighting with truncation of largest 5% of values; Mann Whitney U-test adjusted for tied ranks: $z = -2.00$, $P = 0.046$).

Figure 2. Transect lines and sightings of Hector's dolphins (*Cephalorhynchus hectori*) around Banks Peninsula. Each grey circle represents a group of Hector's dolphins. Dotted lines are actual survey tracks (GPS fixes at 10-second intervals). Solid lines are depth contours. A. Summer 2004; and B. Winter 2004.

A

B



3.3 DISTRIBUTION IN RELATION TO DISTANCE OFFSHORE

In summer, the occurrence of Hector's dolphins decreased with increasing distance from shore (Table 2 and Fig. 3A). The maximum offshore distance recorded was 9.64 n.m. In winter, although dolphins were slightly more common close to shore, the trend was far less apparent and dolphins were sighted up to the offshore limits of the survey area (Table 2 and Fig. 3B). Between seasons, there was a significant difference in distribution with respect to distance offshore. Of the dolphins sighted between the coast and 15 n.m. offshore, 88% of all individuals and 93% of all groups were inside the 4-n.m. sanctuary boundary in summer. These figures were 45% and 43% respectively in winter. (Fisher's exact test on seasonal difference in proportion of groups inside the sanctuary: $P < 0.001$.)

There was no relationship between group size and distance offshore in either summer ($r^2 = 0.014$, df = 1, 40, $F = 0.581$, $P > 0.05$) or winter ($r^2 = 0.033$, df = 1, 40, $F = 1.347$, $P > 0.05$).

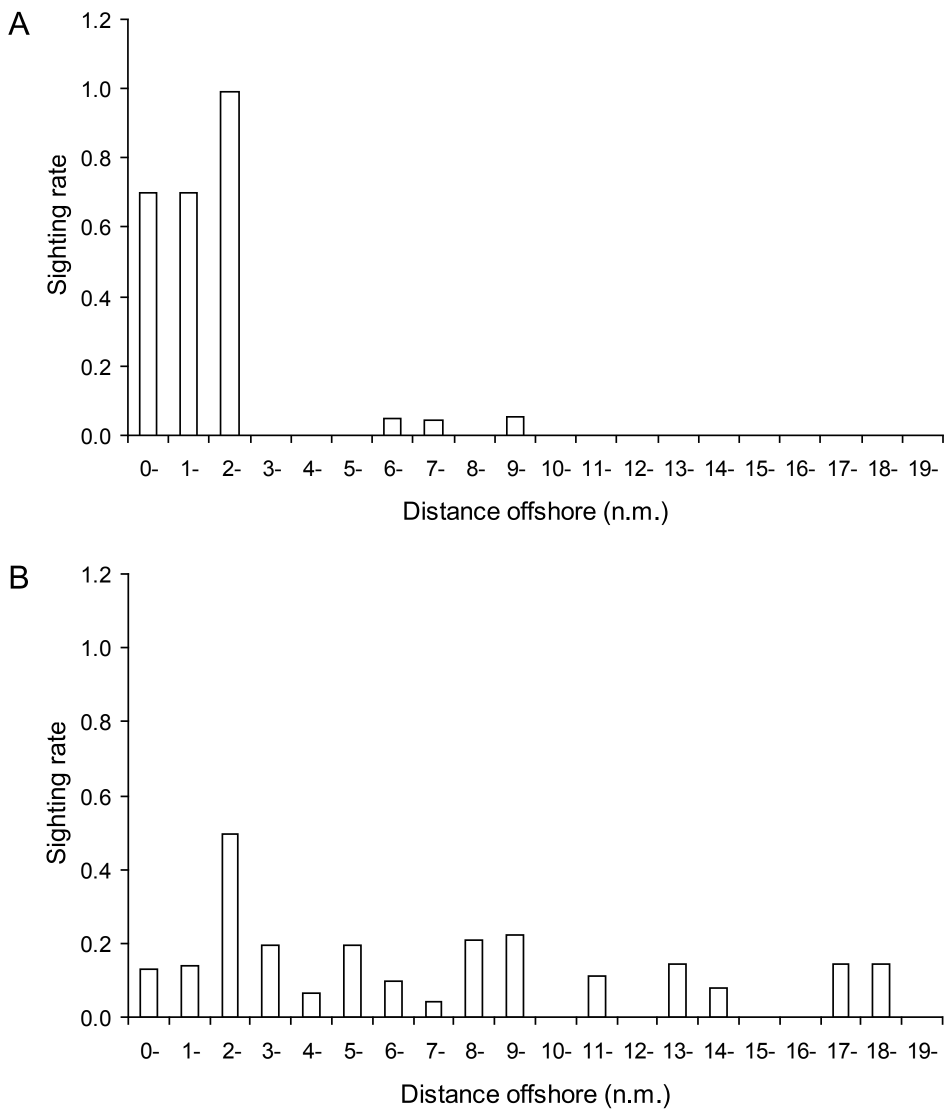


Figure 3. Hector's dolphin (*Cephalorhynchus hectori*) sightings in relation to distance offshore in A. Summer 2004; and B. Winter 2004. Sighting rate is the number of dolphin groups per nautical mile of sighting effort.

3.4 DISTRIBUTION IN RELATION TO DEPTH

Sightings were very concentrated in shallow water in summer, and their occurrence decreased with increasing depth (Table 3 and Fig. 4A). The sighting rate was very high in the 0–20-m depth bin. The deepest sighting was in approximately 70 m of water. In winter, dolphin sightings were more spread out across the depth bins; the highest sighting rate was in the 20–50-m bin and, unlike during the summer, there were many sightings in the 50–100-m bin (Table 3 and Fig. 4B). The deepest sighting was in approximately 80 m of water. The distribution of sightings with respect to depth differed significantly between seasons (2 × 3 *G*-test of independence (Sokal & Rohlf 1981: 745) with depth bins as per Table 3, summer v. winter: $G = 51.79$, $P < 0.001$).

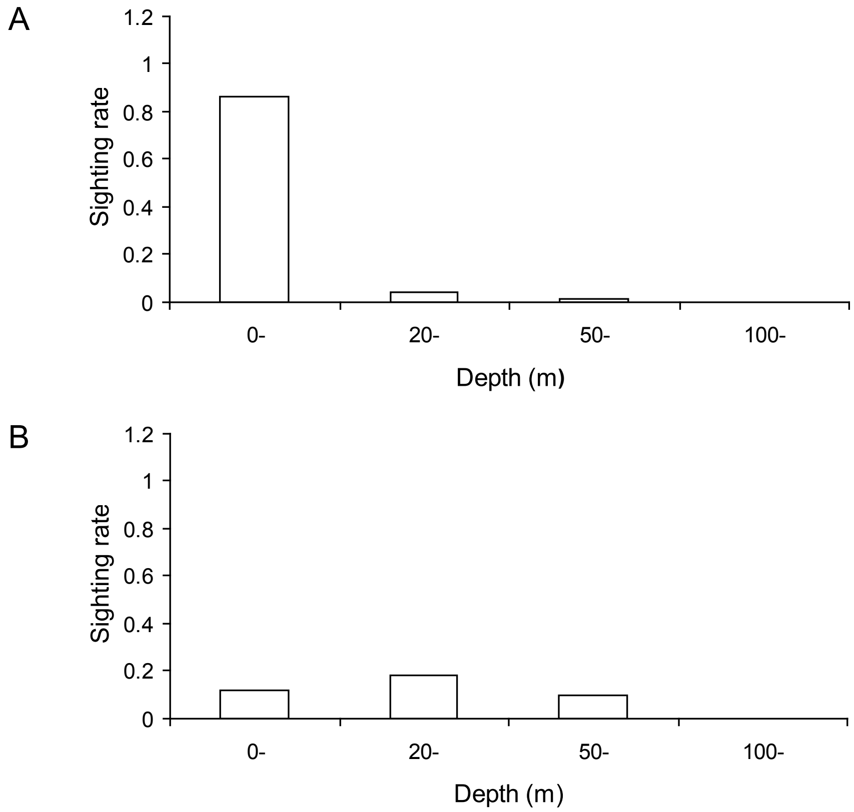


Figure 4. Hector's dolphin (*Cephalorhynchus hectori*) sightings in relation to depth in A. Summer 2004; and B. Winter 2004. Sighting rate is the number of dolphin groups per nautical mile of sighting effort.

3.5 OTHER CETACEAN SPECIES

During the summer surveys, two other cetacean species were sighted: a pod of 12 long finned pilot whales, *Globicephala melas*, and a pod of approximately 50 false killer whales, *Pseudorca crassidens*. Both sightings were made while off survey effort and travelling between transect lines. During the winter surveys, another two cetacean species were recorded: seven pods (1–12 individuals) of common dolphins, *Delphinus delphis*, were sighted on survey effort, and one pod of approximately 60 dusky dolphins, *Lagenorhynchus obscurus*, was seen while off effort.

4. Discussion

Previous studies have demonstrated that the distribution of cetaceans can be influenced by a number of biotic and abiotic factors. Biotic factors include prey availability (Heithaus & Dill 2002), predator avoidance (Heithaus & Dill 2002) and social organisation (Ersts & Rosenbaum 2003). Abiotic factors include oceanographic features (Davis et al. 2002), water temperature (Barco et al. 1999), water depth (Karczmarski et al. 2000; MacLeod et al. 2004), bathymetry (Canadas et al. 2002; Hastie et al. 2004), substrate type (Naud et al. 2003), water clarity (Bräger et al. 2003) and distance from shore (Ersts & Rosenbaum 2003). Abiotic factors may affect cetaceans directly, e.g. through energetic demands, or indirectly by influencing one or more of the biotic factors listed above.

The factors that influence cetacean distribution can vary both spatially and temporally over a variety of scales. For example, Ersts and Rosenbaum (2003) described diel variation in the distribution of humpback whales on a wintering ground in Madagascar with respect to depth and distance offshore, and also demonstrated variation within the population according to social organisation. Wilson et al. (1997) attributed seasonal patterns in bottlenose dolphin distribution in Scotland to increased availability of food and sheltered habitat for calving in inshore waters in summer, and Heithaus & Dill (2002) described the variation in bottlenose dolphin habitat use in Shark Bay, Western Australia, in relation to the seasonal presence of predatory tiger sharks.

Bräger et al. (2003) studied the role of three abiotic factors (water depth, water clarity and sea surface temperature) on habitat selection by Hector's dolphins. They concluded that all three factors had a significant effect on dolphin distribution, that habitat selection differed between study areas (particularly between the east and west coasts of the South Island) and that distribution changed seasonally, with a summer preference for shallower, more turbid waters. They attributed the previously observed seasonal shifts in distribution of Hector's dolphins to changes in food supply, as most potential prey species show some inshore migration in spring and summer and a more offshore distribution in winter. Such seasonal changes are often predictable, as resource availability changes in some extrinsically deterministic manner as a result of meteorological variation throughout the year (Boyce 1979).

In this study, there was a difference in the distribution of Hector's dolphins around Banks Peninsula between the summer and winter surveys. In summer, dolphin groups tended to be clumped in shallow water close to shore. In winter, they had spread out further from the coast into deeper water, and were seen right out to the limits of the survey area. From these survey data, it seems that the normal depth limit for Hector's dolphin around Banks Peninsula is approximately 80 m.

Conclusions concerning the proportions of dolphins seen at varying distances from the coast rely on the assumption of equal sightability with distance offshore. This is not necessarily the case and would need to be tested independently if absolute certainty in the relative proportions was required. If dolphins were more visible inshore (e.g. if they were easier to see in shallow water), it would lead to an overestimation of the proportion inside the sanctuary. If dolphins were more visible offshore (e.g. if they were easier to see in clearer water), it would lead to an overestimation of the proportion outside the sanctuary. Regardless of these details, for the purpose of this study it is possible to conclude that there is a seasonal shift in Hector's dolphin distribution and that dolphins are found outside the Banks Peninsula Marine Mammal Sanctuary in both summer and winter.

Although the same number of Hector's dolphin groups was seen in summer and winter, the total number of dolphins was higher and the mean group size was significantly larger in summer. Sightings of discrete dolphin groups were closer together in summer than winter, although the result was only significant when the dataset was truncated. It should be noted that these surveys were not designed to test the spatial distribution of dolphin groups relative to each other. For example, due to constraints of time and weather conditions, adjacent transect lines were not always surveyed consecutively. Therefore, the results of the nearest neighbour analyses should be treated with caution. The results of the encounter-rate analyses should also be considered with care. To compare the relative densities of dolphins in summer and winter, seasonal corrections for sighting availability would be required. This would account for the possibility that the diving behaviour of Hector's dolphins may vary during the year. It is feasible, for example, that increased sociality in summer means that dolphins spend less time feeding, more time near the surface and hence are more available to be counted. Such differences would affect relative densities in summer and winter, but would not affect the proportions sighted at varying offshore distances within a season.

As suggested by Bräger et al. (2003), it is most likely that the observed differences in the distribution of dolphin groups with respect to distance offshore is related to seasonal changes in prey distribution, with most potential prey species displaying some inshore migration in spring and summer. At present, data on prey distribution are not available in sufficient detail to test this hypothesis. It is also possible that mature females seek shallower, more sheltered inshore waters when giving birth and nursing, to reduce the energetic requirements on themselves and their calves (Wilson et al. 1997). The observed differences in the spatial distribution of dolphins relative to each other, i.e. larger and more clumped groups in summer, may be explained by sociality. Nursing mothers may aggregate with other mother-calf pairs in order to increase vigilance against predators, and mature individuals may seek out conspecifics for mating.

During a similar survey on the northern west coast of the South Island, all Hector's dolphins were found within 6 n.m. of the coast in both summer and winter (Rayment et al. 2003). Again, sightings were concentrated closer to shore in summer, but the seasonal difference was much less pronounced than at Banks Peninsula. There are two plausible explanations for the difference in winter offshore distributions between the east and west coasts. Firstly, the bathymetry on the west coast is quite different to that around Banks Peninsula, with the seabed shelving much more steeply. This would provide much less relatively shallow habitat for dolphins to spread out into before their physiological diving limits are reached. Secondly, water temperatures are higher and it is possible that there is a less pronounced seasonal change in prey distribution on the west coast.

4.1. COMMENTS ON SURVEY DESIGN

Two potential sources of error were identified during the surveys. Firstly, the high travel speed of the aircraft (51 m/s) means that any delay in recording the sighting will have caused an error in the sighting position. Careful training and the use of experienced observers should have minimised this effect, so that this delay should never have been greater than 2 or 3 s; therefore, the errors in sighting locations are not likely to be more than 100–150 m. Secondly, due to the complex nature of the coastline, it was impractical to survey the two larger harbours on Banks Peninsula, Akaroa Harbour and Lyttelton Harbour. Hector's dolphins are known to aggregate in these harbours in summer. Therefore, it is likely that the proportion of dolphins recorded within the first nautical mile of the coast during the summer surveys is an underestimate of the real value. This would serve to increase the difference in Hector's dolphin distribution between seasons.

4.2 IMPLICATIONS FOR MANAGEMENT

The results of the surveys pose serious concerns for the current state of management of Hector's dolphins at Banks Peninsula. We have shown that although the majority of dolphins (93% of groups and 88% of individuals) were found within the Marine Mammal Sanctuary in summer, a large proportion (57% of groups and 55% of individuals) was sighted outside the sanctuary in winter. These results are broadly consistent with preliminary surveys conducted in 2002, in which the proportions for dolphin groups were 79% and 65% respectively (unpubl. data). If anything, the 2002 figures show that the situation could be even more concerning.

The gillnet fishery operates to the north and south of the sanctuary and offshore of its boundaries throughout the year (Baird & Bradford 2000). Therefore, Hector's dolphins are vulnerable to bycatch year-round, and there may be a far greater spatial overlap with the fishery than was previously expected, particularly in winter. These conclusions support the recent finding that despite the presence of the sanctuary since 1988, there has not been a sufficient reduction in bycatch to allow Hector's dolphin survival rate to increase to a level that will lead to growth of the population. At present, it seems that the Banks Peninsula Marine Mammal Sanctuary is simply not extensive enough. Bycatch of dolphins in commercial gillnets is clearly unsustainable and so spatial extensions of the sanctuary, both alongshore and offshore, will be required to reduce overlap between dolphin distribution and harmful fishing practices. Currently, little is known about bycatch in recreational nets around Banks Peninsula outside the summer time ban. Further study is required to determine whether a temporal extension of the recreational gillnetting regulations is required to help reduce bycatch to a sustainable level.

Following completion of the project, the data will be further analysed to try to reveal the relative effects of depth and distance offshore on Hector's dolphin distribution. If the analyses suggest that dolphins are more limited by water depth, it would be most sensible to decide the offshore boundaries of protected areas according to local bathymetry, rather than distance offshore as is currently the case. For example, a protected area designed to reduce bycatch of seabirds and marine mammals in California, United States, prohibits set gillnet fishing in water shallower than 60 fathoms (110 m) (NMFS 2001). At Banks Peninsula, however, it is unlikely that a depth contour would be a practical boundary. Instead, local bathymetry should be examined and a suitable offshore boundary chosen that encloses all Hector's dolphin habitat. This would not only provide the best solution for dolphin conservation, but could potentially also minimise the area closed to fisheries. For example, a line drawn to enclose the 80-m depth contour around Banks Peninsula could lie approximately 20 n.m. offshore, while the same result would be achieved by a 10-n.m. boundary for much of the South Island west coast. Similarly, in areas with pronounced seasonal differences in dolphin distribution, the offshore boundary could be different in summer and winter while always enclosing the majority of the dolphin population.

4.3 RECOMMENDED FURTHER RESEARCH

These surveys provided a detailed snapshot of Hector's dolphin distribution in 2004. However, because environmental conditions vary, this distribution is unlikely to be identical every year. We therefore recommend a further set of surveys in summer and winter 2005, to collect a 3-year dataset. This will provide data on inter-annual variability and will facilitate a robust estimate of Hector's dolphin distribution at Banks Peninsula.

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