Abundance, residency, and habitat utilisation of Hector's dolphins (*Cephalorhynchus hectori*) in Porpoise Bay, New Zealand

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Abstract   Theodolite tracking and boat-based photo-identification surveys were carried out in the austral summers of 1995/96 and 1996/97 to assess abundance, residency, and habitat utilisation of Hector's dolphins (*Cephalorhynchus hectori* van Beneden 1881) in Porpoise Bay, on the south-east corner of the South Island of New Zealand. Data are consistent with the model of a small resident population that is visited occasionally by members of neighbouring populations. Mark-recapture analysis of photographically identified individuals, along with data on the proportion of animals bearing identifying marks, indicates a local population of 48 dolphins (95% CI = 44–55) in 1996/97. Dolphins spent a large proportion of their time in a small area inside the bay. Dolphin sightings were more congregated in successive time periods from early morning to late afternoon. No pattern of diurnal movement into and out of the bay was observed.

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INTRODUCTION

Hector's dolphins (*Cephalorhynchus hectori* van Beneden 1881) have been studied on a large scale (c. 1000 km) throughout their geographic distribution (Dawson & Slooten 1988; Bräger 1998). On an intermediate scale (c. 90 km), one regional population (around Banks Peninsula) has been studied intensively for more than a decade (Slooten & Dawson 1994). Little is known about small populations, however, or about habitat utilisation at fine scales (<5km).

Hector's dolphins are restricted to New Zealand, and have a strictly coastal distribution. Despite wide-ranging survey effort, there is no evidence of alongshore movement of more than a few tens of kilometres (Slooten et al. 1993; Bräger 1998). Current distribution is highly localised and fragmented into genetically distinct populations (Pichler et al. 1998). The species is listed by the International Union for the Conservation of Nature as "Endangered" (2000 IUCN red list of threatened species. www.redlist.org. International Union for Conservation of Nature and Natural Resources, Species Survival Commission). From both ecological and conservation perspectives, these observations highlight the need for an understanding of small, isolated populations.

This study is based on two research methods that have each proven powerful in studies of the biology and behaviour of cetaceans. Photographic identification of naturally distinctive individuals facilitates studies of movement patterns, social structure, and population parameters such as abundance, age at first reproduction, birthing interval, survival rates (e.g., Hammond 1986; Wells et al. 1990; Rugh et al. 1992; Slooten et al. 1992; Best et al. 1995). Theodolite tracking has proven extremely useful for documenting small-scale movements (e.g., Würsig & Würsig 1979, 1980) and habitat utilisation (Smith 1993). Because it offers reliable position fixing without disturbance to the study animals, it has also been widely used to document responses to various stimuli, including acoustic alarm devices (Todd et al. 1992; Goodson & Mayo 1995) and boats (Baker

& Herman 1989; Polacheck & Thorpe 1990; Acevedo 1991; Kruse 1991; Corkeron 1995; Barr 1997; Bejder et al. 1999).

Dawson & Slooten (1988) describe a general in-shore movement of Hector's dolphins in summer time and an offshore movement in winter time. Stone et al. (1995) described a diurnal pattern in which dolphins tended to be seen entering Banks Peninsula's Akaroa Harbour in the morning, and leaving in the late evening. Limited data on habitat utilisation are available from resightings of distinctive individuals in the long-term study at Banks Peninsula (Slooten & Dawson unpubl. data), but there is no detailed information on movement patterns over time scales of hours to months. In this contribution we provide data on the number of Hector's dolphins using Porpoise Bay, information on individual residency of dolphins using the bay, and a fine-scale analysis of their distribution within the bay.

MATERIALS AND METHODS

Study site

Porpoise Bay (46°39′S, 169°6′E) is situated on the south-east corner of the South Island of New Zealand and covers an area of c. 4 km^2 (Fig. 1). The bay is confined by volcanic rock headlands on both its north-eastern and south-western boundaries and has a gently sloping sandy beach. An estuary flows into the north-eastern end of the bay. A semi-submerged reef is situated off the south-western headland. Average water depth in the bay is c. 12 m and the maximum depth is c. 18 m. Fieldwork was conducted in the Austral summers of 1995/96 (December–April) and 1996/97 (November–April).

Field methods

Boat-based fieldwork

Photographic-identification surveys of Hector's dolphins were conducted from 3.5–6 m boats at slow planing speeds (10–15 knots), with the vessel slowing to <3 knots for photography once dolphins were sighted. Photographs were taken with 400 ASA black and white film, using autofocus 35 mm cameras with zoom lenses (28–200 mm), at ranges of <10 m. Upon encountering dolphins, group size, number of calves, number of juveniles, location, and time were recorded. Dolphins were individually identified from photographs of naturally occurring marks such as nicks in the trailing edge of the dorsal
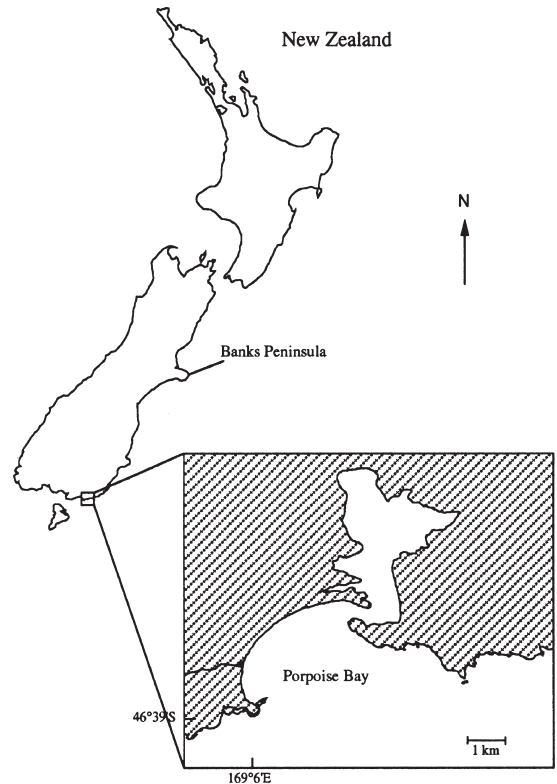

Fig. 1   Map of study area.

fin and from body blotches and scars (for more detail on our Photo-ID methods see Slooten et al. 1992). Only surveys with complete coverage of the study area were included in the following analyses.

A "group" was defined as dolphins close (<20 m) to each other. Hector's dolphins are most often observed in groups of two to eight, which often fuse together and split up (Slooten & Dawson 1988). Dolphins were considered part of the same group if they merged in the time span when photographs were being taken during an encounter. An encounter was defined as the period spent with the same group.

Different photographic strategies were adopted in the two field seasons. In 1995/96, photographic effort was biased towards the more distinctive dolphins. In 1996/97, photographs were randomly taken of all dolphins that surfaced in the close vicinity of the boat. At least four exposures were taken per dolphin, i.e., if group size was 10 dolphins a minimum of 40 exposures were taken at random. On average, this assures that all individuals in a group had a better than 95% chance of being photographed (Würsig 1978; Ballance 1990).

The positions of Hector's dolphins in the study area were determined using a theodolite on a 27.4 m vantage point on the southern headland overlooking Porpoise Bay (Fig. 1). The height of our observation point was measured by leveling (3 times) from a surveyed trig station. Resulting observation height measurements were within 20 cm of each other. The precision of theodolite fixes is proportional to the instrument's elevation above sea level and inversely proportional to the distance of the acquired fix. At our site a 20 cm error in theodolite height would cause a position error of c. 7 m at a range of 1000 m (Würsig et al. 1991).

Custom-written software (running on a Hewlett-Packard 95LX palmtop computer) allowed automated storage of theodolite fixes and their timing, and allowed keyboard entry of associated observations. Each position was later converted into (x,y) co-ordinates using the computer program "T-Trak" (Cipriano 1990).

Land-based observations were made over the same two summers as the boat observations, between 0600 and 1630 h. The study area was scanned at the beginning of each tracking day with 10-power binoculars. In most cases only one group was present; if not, the largest of the groups was tracked via theodolite. This group was then tracked throughout the entire observation period using focal group sampling (Martin & Bateson 1993). If the focal group split, the larger of the resulting groups was tracked. Theodolite fixes were taken from the centre of the dolphin group. Fixes more than 60 s apart (<2% of the total) were discarded from analyses. This was done to ensure that each track was a continuous observation of the same group for the entire tracking period, and to help identify when tracking was compromised by sighting conditions. Tracking sessions varied in duration from 20 min to 8 h. Theodolite observations were restricted to Beaufort Sea State 2 or less, ensuring that dolphin groups could be tracked continuously.

Analysis methods

Photographic identification catalogue

Proof sheets were made of each roll of film, and prints made of all high-quality photographs of identifiable dolphins. To be used in the analysis, photographs had to: (1) show a lateral view of an identifiable dorsal fin; and (2) be well exposed and in focus. Toothrake marks were not used as an
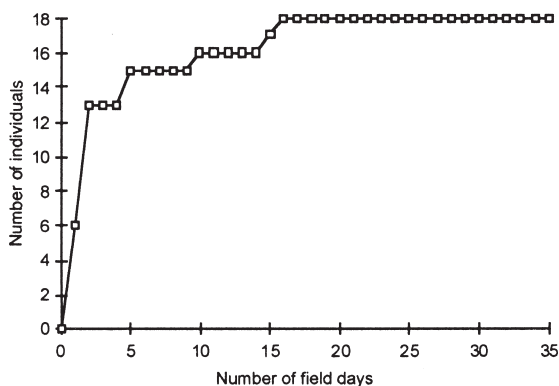

Fig. 2 Discovery curve of photographically identified Hector's dolphins (*Cephalorhyncus hectori*) in Porpoise Bay, New Zealand, in summer 1996/97.

identifying feature as these do not persist over time (Lockyer & Morris 1990).

Population estimation

The first summer's photo-ID surveys were used primarily to establish a catalog of individuals. For the second season, we estimated abundance via a Chapman mark-recapture estimate of the number of marked animals (Seber 1982), scaled up using data on the proportion of animals that bore identifying marks. We considered the first half of this field season as the "marking" period, and the second half as the "recapture" period.

This proportion of animals that bore identifying marks was estimated via randomly photographing whichever dolphins came into range, whether or not they were marked (see Williams et al. 1993). If marked and unmarked individuals are equally likely to be photographed, the ratio of photographic frames showing individuals with distinctive marks, divided by the total number of frames showing dolphins (photographed sufficiently well to have shown a mark had there been one) should provide an estimate of the proportion identifiable.

The extrapolated population estimate and its 95% confidence interval were calculated using profile likelihoods (McCullagh & Nalder 1989) and incorporate uncertainty in the proportion identifiable. The method used by Willams et al. (1993) does not correctly estimate variance when all or almost all the animals in the second sample are "recaptures" of those in the first. An additional advantage of using profile likelihoods is that the 95% confidence interval is asymmetrical (larger above the mean than below it) which better represents the uncertainty
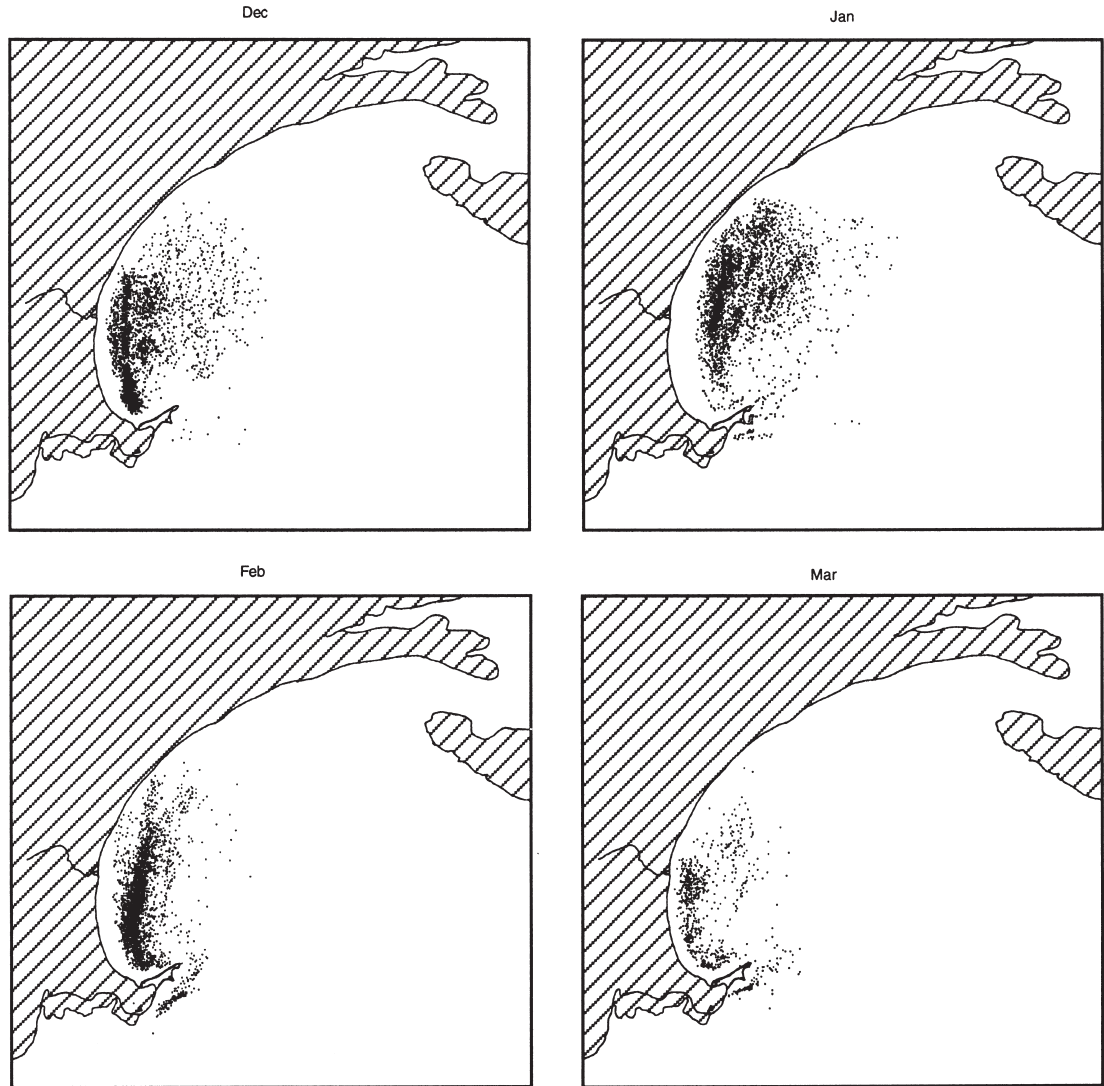
Fig. 3 Location of Hector's dolphin (*Cephalorhyncus hectori*) groups categorised by month. Data were collected through a 4-month period in 1996/97.

associated with abundance estimates of small populations (Buckland et al. 1993).

Analysis of theodolite data

Spatial and temporal habitat utilisation of dolphins in Porpoise Bay were evaluated from the distribution of theodolite fixes. Positions within observation sessions were likely to be auto-correlated, i.e., subsequent data points are not independent. For this reason, we have avoided statistical testing and instead have plotted the points according to time period and month for visual inspection. Field effort was unevenly distributed among months and time periods, and thus categories contained unequal numbers of positions and thereby unequal amounts of data on distribution. To standardise, we randomly removed data from each category until all categories had the same number of positions. Contour plots of dolphin distributions were created from the standardised data sets using "Surfer" software. Evaluation of dolphin habitat utilisation was based on visual inspection of these plots.

0600 - 1000 h

1000 - 1400 h

1400 - 1800 h
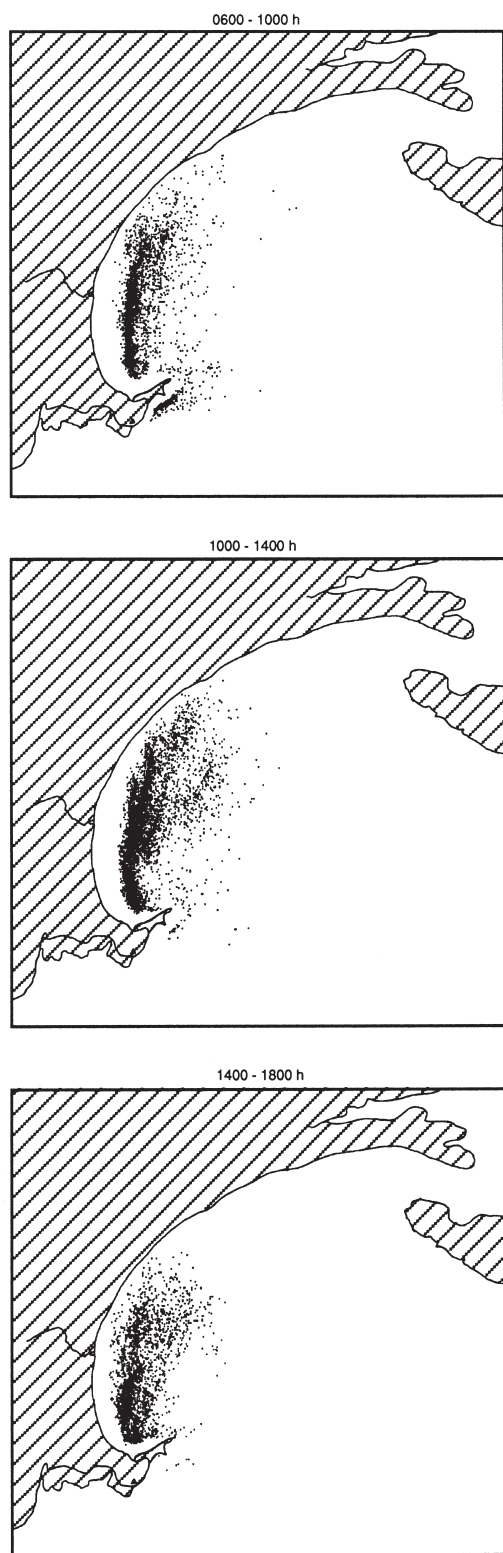
RESULTS

Residency and population size

Hector's dolphins were encountered during 91% of all surveys in the 1995/96 field season (n = 44 surveys) and on all surveys in the subsequent season (n = 35 surveys). Six surveys were interrupted because of poor sighting or sea conditions, and are not included in the following analyses. In most cases only one group was found on each survey; a total of 45 and 42 groups were encountered in the two field seasons respectively. Group size ranged from 1 to 26 individuals (1995/96: mean = 11.0 ± 0.85 (SE), median = 11; 1996/97: mean = 11.6 ± 0.89 (SE), median = 11).

Sixteen Hector's dolphins were photographically identified in the first season and 18 in the second. In 1996/97, 13 of 18 identified dolphins were identified within the first two field days and all identifiable dolphins had been observed before the 17th survey (Fig. 2). This suggests that all distinctive dolphins had been identified and that no dolphins immigrated into the study area after approximately half-way through the study period. Twelve dolphins were re-identified in 1996/97 from the first field season. Six dolphins were newly identified in the second field season. We cannot tell whether these were new individuals, or individuals which had been present in the previous season, but gained identifying marks in the intervening period.

Individual sighting frequencies of dolphins seen in both seasons varied from 4 to 40 sightings on a total of 79 surveys (mean = 13.0, median 17.0: 1–22 times in 1995/96 and from 2 to 24 in 1996/97). On average each identifiable dolphin was seen 7.6 times (median 4.5) in 1995/96 and 9.8 times (median 8.5) in 1996/97. The mean interval between consecutive sightings of the same individual was very similar in the two seasons (1995/96 = 5.14 days ± 2.53 (SE); 1996/97 = 4.77 days ± 1.61 (SE)).

In 1996/97, >3400 photographs were randomly taken of all dolphins that surfaced in close vicinity of the research boat. Of these, 667 frames were of sufficient quality to determine whether a dolphin was individually identifiable. Of these, 246 contained distinctive individuals (18 different individuals). Hence the proportion identifiable was estimated at 36.9%. This proportion includes all age classes and

Fig. 4 Location of Hector's dolphin (*Cephalorhyncus hectori*) groups categorised by time of day. Data were collected through a 4-month period in 1996/97.
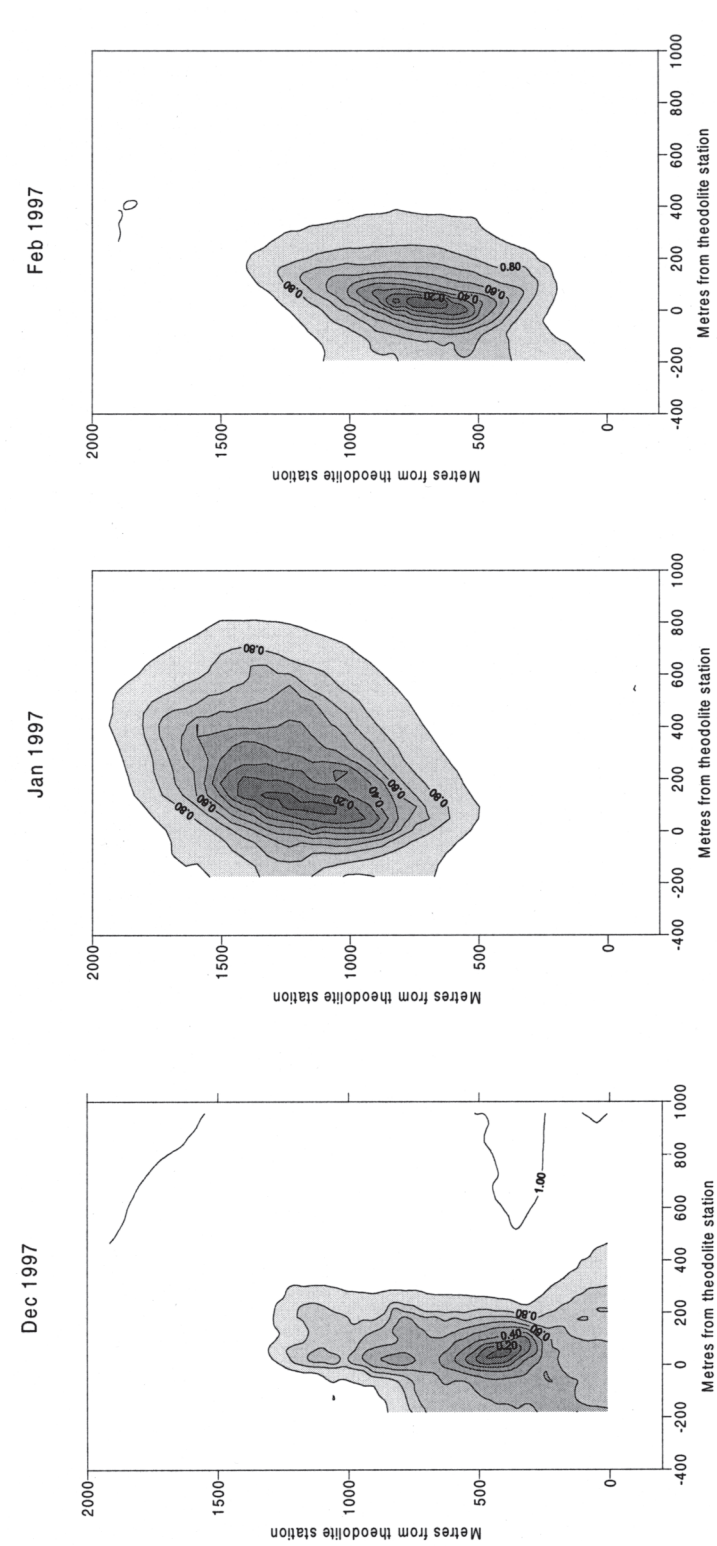
Fig. 5 Contour plots of theodolite fixes collected of Hector's dolphins (*Cephalorhyncus hectori*) in Porpoise Bay, New Zealand, December 1996 to February 1997. Each isopleth encompasses an additional 10% of dolphin positions.
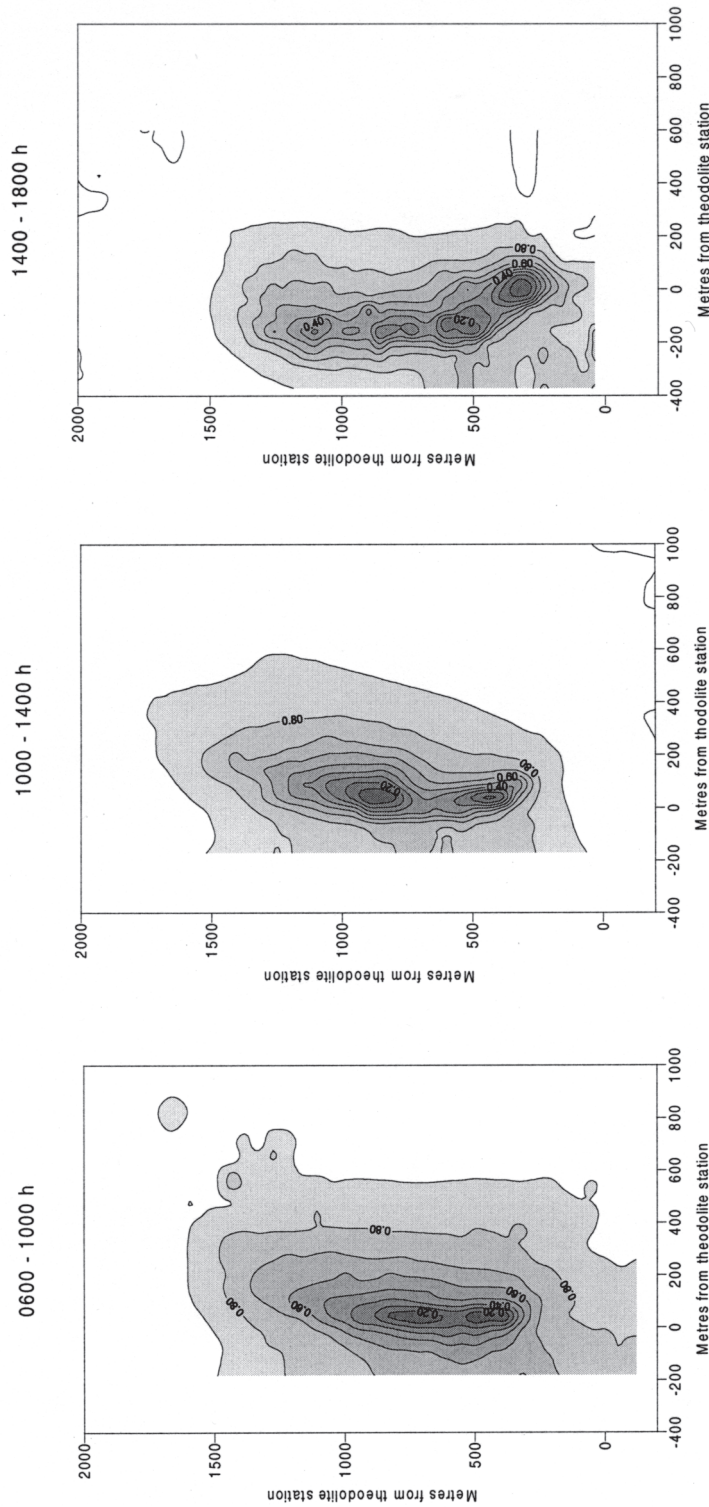
Fig. 6 Contour plots of theodolite fixes collected of Hector's dolphins (*Cephalorhyncus hectori*) in Porpoise Bay, New Zealand, December 1996 to February 1997, by time period. Each isopleth encompasses an additional 10% of obtained dolphin positions.

was used to scale up the Chapman estimate of the number of marked dolphins. The resulting estimate of the number of animals that use the bay is 48 individuals (95% CI = 44–55). This is most likely to be a conservative estimate, as we cannot be completely sure we photographed every distinctive individual.

Spatial and temporal distribution

One hundred and ten hours spent theodolite tracking dolphin groups in 1995/96 were treated as a training period. Only observations from the 1996/97 season are presented here. Hector's dolphins were successfully tracked for 140 h via theodolite on 31 days during a 4-month period in 1996/97 (39, 44, 44, and 13 h in December, January, February, and March, respectively. Theodolite effort by time period was 48, 67, and 25 h between 0600–1000, 1000–1400, and 1400–1800 h, respectively). Dolphins were absent from the study area on five occasions when tracking was attempted. A total of 12 210 theodolite readings were made during the tracking period of 58 dolphin groups throughout the 4-month observation period in 1996/97.

The dolphins spent most of their time in a surprisingly small area (Fig. 3 and 4). This was not an artifact of sightability from the theodolite station. In our 79 boat surveys in which the whole bay was covered, we almost always found the dolphins in this location (Bejder 1997). No obvious change in distribution within the bay was seen over the four summer months (Fig. 3), though dolphins are not present in the bay for most of the non-summer months (Gee pers. comm.). No pattern of overall differences in diurnal distribution into and out of the bay was seen (Fig. 4).

Subtle differences in distribution were seen in the monthly spread of dolphin sightings (Fig. 5). Dolphins ranged throughout the same general area in December, January, and February but the intensity with which they used certain parts of the area varied. Dolphins tended to congregate in a smaller area in February compared to December/January and in December compared to January. These differences are clearer on the contour plots than on the plots of raw positions, which suffer from large numbers of overlapping points.

When all positions were lumped according to time period (0600–1000, 1000–1400, 1400–1800 h), visual inspection of plots shows that dolphin sightings were more congregated in successive time periods from early morning to late afternoon (Fig. 6).

DISCUSSION

Until this study, photographic identification surveys of Hector's dolphins have focused on larger populations and covered relatively large areas. Because of this, and to minimise biases caused by failing to identify an individual, or misidentifying it, only individuals with highly distinctive features have been used in studies of population parameters such as survival rate and calving interval (e.g., Slooten et al. 1992; Slooten & Dawson 1994). This study's focus on a small population, in a restricted area, allowed use of subtle marks for identification. Thus, our resulting estimate of proportion identifiable (37%), although low compared to other species (e.g., Bigg et al. 1990; Shane & McSweeney 1990; Würsig & Jefferson 1990) is high compared to other Hector's dolphin population studies (cf. 12.5% for obviously marked Hector's dolphins at Banks Peninsula; Slooten et al. 1992). We strongly advise against using subtle marks for identification unless the population is very small, and individuals seen frequently (see also Otis et al. 1978). Because subtly marked individuals are more difficult to resight, their inclusion in analyses has the effect of lowering apparent survival rate, and increasing apparent population size. These biases are doubly unfortunate because they could lead managers to unsafe conclusions about a population's conservation status.

Mark-recapture models have been widely applied to estimate animal abundances (for reviews see Seber 1982; Seber 1992). These models are usually classified into those suitable for open or closed populations. The basis for our abundance estimate is a closed model. We suggest that this is appropriate in this case because of: (1) the levelling off in the discovery curve in 1996/97, which suggests all individuals were identified; (2) the lack of movement found between this and other study sites (Bräger 1998); and (3) the existence of genetic differences over small geographic scales (Pichler et al. 1998).

One problem with interpreting mark-recapture abundance estimates is knowing what geographic range they apply to. Intensive long-term studies of photographically identified Hector's dolphins at Banks Peninsula suggest a typical (linear) home range of 31 km of coastline (Slooten & Dawson 1994; Bräger 1998). Thus our estimate of 48 dolphins using Porpoise Bay probably applies to a zone c. 15 km either side of the bay itself.

A primary goal of this study to document site fidelity of the dolphins using the bay. Some individuals were seen on half or more of the boat surveys.

These animals seem to be largely resident in the bay. Though Porpoise Bay cannot make up the entire home range of these individuals it appears to serve as an important or prime summer habitat within the overall home range. Other individuals were seen less consistently, but were frequent visitors to the bay. Almost half the individuals identified were seen fewer than 5 times. These data are consistent with the model of a small resident population that is visited occasionally by members of neighbouring populations. Alternatively, individuals sighted in the bay on a few occasions and with relatively long sighting intervals could be individuals with larger home ranges.

Seventy-five percent of dolphins identified in the first season were resighted in the second season, suggesting long-term residence. Newly identified dolphins in the second season could have been new arrivals to the study area or they could have acquired marks between the two field seasons. Long-term residence has been documented in studies at Banks Peninsula, where some individuals have been resighted regularly for up to 12 years (Bräger 1998). These animals show strong site fidelity to particular areas. Of 179 distinctive dolphins sighted on the southern side of Banks Peninsula only 13 were resighted on the north side of the Peninsula (Slooten & Dawson 1994). Additionally, home ranges are small; despite wide ranging surveys, the most extreme distance between two sightings of the same individual is 106 km (Bräger 1998). There is no evidence of long distance along-shore migration (Slooten & Dawson 1994).

Hector's dolphins were observed throughout most of Porpoise Bay but spent a high proportion of time in an area confined by a small reef system and the surf zone of the southern end of the bay. We cannot say why this preference occurred. Sighting plots show that sightings were more congregated in the successive time periods from early morning to late afternoon. The location of areas being used by dolphins within Porpoise Bay was thus more variable in the morning than afternoon. The reason for this is unclear.

This study provides no support for the suggestion by Stone et al. (1995) that Hector's dolphins show diurnal inshore-offshore movements. If that were so we would have expected distribution in the middle of the day to be further inshore than late in the day (as dolphins move offshore) or in the morning (as dolphins move back inshore). Dawson & Slooten (1988) describe a general inshore movement of Hector's dolphins in summer and an offshore movement in winter. This study was not able to document seasonal movements of Hector's dolphins in Porpoise Bay as field effort was conducted only during summers. However, of five visits to the study area in the winter between the two field seasons dolphins were observed only once. Furthermore, local residents living near Porpoise Bay report few sightings of dolphins in winter compared to summer (Nancy Gee pers. comm.). The winter distribution of the animals that frequent Porpoise Bay in summer is unknown.

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