Te Waewae Bay Hector's dolphins

Abundance, distribution and threats

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Foreword

The Hector's dolphin is a species endemic to New Zealand and found in relatively small numbers in the Southland region. It is listed as "nationally endangered. As such, information on abundance and distribution are important factors in the management of this species.

This report includes data from two field seasons of research into the distribution and abundance of Hector's dolphins in Te Waewae Bay. Further data collected as part of a longer term research project will provide greater confidence and certainty on the parameters of the Te Waewae Bay population when analysis is completed.

There has been some debate regarding different survey methods and how they relate to differences in population estimates. However, discrepancies between methods, when taken from a sound understanding of the limitations of each survey type, are expected. Regardless of survey method and population parameter measured, a commonality exists between all surveys conducted in Te Waewae Bay. That is, that the population is small and that research suggests no human related removal from the population is sustainable. It is the Department of Conservation's responsibility to administer the Marine Mammals Protection Act 1978 and it is the key agency responsible for marine mammal welfare in New Zealand, and as such, we place importance on such studies to inform and aid management. It is clear that we are indeed looking at a vulnerable species and accordingly we need to ensure that we do not adversely impact this population and threaten their survival.

I look forward to the future when the full dataset can be analysed and the entire picture of seasonal distribution, abundance and survivorship is available. In the interim, this report is a valuable guide for management to ensure the continued survival of Te Waewae Bay Hector's dolphins.

Barry Hanson
Conservator
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June 2008

Abstract

This report presents information from two field seasons, each with just under 100 hours of survey effort, on the population of Hector's dolphin *(Cephalorhynchus hectori)* that use Te Waewae Bay, Southland, New Zealand. The principal aims of the project were to provide an estimate of abundance and document dolphin distribution within the bay. In addition, data on sightings, group composition, range, local fishing activity and other cetacean sightings were collected and, where appropriate, analysed. Other data, collected from 2004 to 2006 by JL Rodda, University of Otago, should allow a more robust estimate of abundance as well as development of estimates of other parameters, such as survival.

Surveys of the bay were made in a 5.3 m stabicraft on 19 days during April, May and June 2004 (the 'autumn' period) and on a further 19 days during December 2004 and January and February 2005 (the 'summer' period). Survey routes during both periods followed a coastal transect and three offshore transects along which photographs were taken of the dorsal fins of dolphins encountered. The layout of the offshore transects was modified between the two study periods to improve coverage of the bay.

The marked dolphin catalogue for Te Waewae Bay at the end of the two study periods contained approximately 70 marked dolphins, 29 of which were animals with sufficient markings to be used for capture-recapture analysis. Seventeen of these dolphins were seen during the autumn season and 23 during summer. Application of a Robust Design model in program MARK to these photographic data indicates that an estimated population of 251 (CV = 0.162; 95% CI = 183-343) animals used Te Waewae Bay in autumn and 403 (CV = 0.121; 95% CI = 280-488) in summer. These estimates may be improved upon by estimates developed from a data set collected using the same techniques by Rodda over a longer term. As this is the first abundance estimate for the population calculated using capture-recapture methods, no conclusions can be drawn about trends in abundance. Previous surveys of the Te Waewae Bay were done using line-transect methods, which estimate the number of dolphins in the bay at one point in time. By contrast, Mark-recapture surveys estimate the total number of individual dolphins that have used the bay during the entire field season. It is important to emphasise that even using the higher abundance estimates of 250-400 individuals provided in this study, conclusions about the likely sustainable level of human impact on this population are unaffected; the sustainable number of dolphin deaths per year for Te Waewae Bay, based on the concept of Potential Biological Removals, would still be less than one individual per year.

Hector's dolphin sightings were concentrated along the coastal transect along the length of the bay, but were sighted less frequently at the western and eastern extremes of the bay. Some evidence is provided to suggest that this population may be concentrated closer to shore in the warmer summer months and are more dispersed in autumn/winter. However, this needs to be tested using the same offshore transects in different seasons. Due to time and weather constraints only one survey outside Te Waewae Bay was conducted; in Toetoe Bay. Comparison of photographs of marked animals seen in Toetoe Bay on this survey failed to find any matches with animals from the Te Waewae Bay catalogue. Neither were there any

matches of animals from the Te Waewae Bay catalogue with catalogues from other studies of Toetoe Bay and Porpoise Bay. Insufficient data were collected during this initial study to determine the range of Te Waewae Bay dolphins.

In addition to observations of commercial and recreational boats, ten fishing nets were observed set in the bay during the study. Confirmed as well as credible anecdotal reports of fishing-induced mortalities and the overlap of set net use with areas of high dolphin use documented here indicate that the threat posed to this population by fisheries bycatch may be high. There is also some risk of boat strike, as demonstrated by the presence of a dolphin with scarring likely to have been caused by a collision with a vessel.

This report includes important data on Te Waewae Bay Hector's dolphin abundance, distribution and threats that will be essential as input into ongoing discussions about management options for Hector's dolphin. Recommendations for future research are provided in the discussion.

Acknowledgements

We would like to acknowledge the support of Ros Cole, Sally Chesterfield, Chris Rance, Murray Willans and Greig Funnell of the Department of Conservation Southland Conservancy in assisting with this project, and a number of volunteers for their help with field work. We would like to thank Danilo Hegg and particularly, Andrew Gormley, for their assistance with the use of the program MARK, and Andrew for his generous help discussing and interpreting results. Thanks to Steve Dawson for his thoughts on causes of injury to a marked dolphin. Finally, many thanks to the four reviewers for their comments and suggested amendments on drafts of this report.

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1 Introduction

1.1 HECTOR'S DOLPHIN AND THE NEED FOR LOCALISED STUDIES

Hector's dolphin (*Cephalorhynchus hectori*) is endemic to New Zealand with the majority of the species found in the coastal waters of the South Island (Baker 1978; Dawson & Slooten 1988; Dawson et al. 2004; Slooten et al. 2004). It is one of the rarest marine dolphins in the world, as well as being one of the smallest. Aerial and boat-based line-transect surveys have been used estimate the total abundance of South Island Hector's dolphins at 7,270 animals (95% CI = 5,303-9,966; Dawson et al. 2004; Slooten et al. 2004). The World Conservation Union (IUCN 2006) and the Department of Conservation (DOC; Hitchmough et al. 2007) have classified the species as "endangered".

There are four distinguishable genetic groups of Hector's dolphin. Three groups are found off the west, east and south coasts of the South Island, and the other is the subspecies Maui's dolphin, found off the west coast of the North Island (Baker et al. 2002; Pichler 2002a; Pichler & Baker 2000a; Pichler et al. 1998a, b; Pichler & Baker 2000b). Research on the oceanographic conditions where Hector's dolphins are found indicates a preference for shallow (< 100 m), turbid (< 4 m Secchi disk visibility) and relatively warm waters (> 14 ºC; Brãger et al. 2003; Slooten et al. 2006; Rayment et al. 2006). In the areas in which they are found, Hectors' dolphin are most often observed within one to two nautical miles (nm) from the shore, and rarely beyond 15 nm (Brown et al. 1992; Clement et al. 2001; Dawson et al. 2004; Dawson 2001; Dawson & Slooten 1988; Rayment et al. 2006; Slooten et al. 2004, 2005, 2006). Aerial surveys indicate a depth preference of less than 100 m at Banks Peninsula and off the upper West Coast (Rayment et al. 2003, 2006; Slooten et al. 2006).

Research indicates that Hector's dolphins are residential animals that have limited alongshore ranges (Brãger et al. 2002; Fletcher et al. 2002). Around Banks Peninsula Brãger and colleagues (2002) found that the average alongshore range of a sample of 32 Hector's dolphins was 31 km (SE = 2.43). The farthest two sightings were 106 km apart, while the remainder (94%) were sighted less than 60 km apart. While immediately adjacent populations may mix, there appears to be limited interaction along relatively small sections of coast, such as between Timaru and Banks Peninsula (Fletcher et al. 2002; Martien et al. 1999; Pichler 2002a, 2002b; Pichler & Baker 2000a; Pichler et al. 1998a). Researchers have reported seasonal differences in the distribution of Hector's dolphins, apparent to varying degrees in different populations (Rayment et al. 2003, 2006; Slooten et al. 2004; Slooten et al. 2006a, 2006b).

Anthropogenic threats to Hector's dolphin are area-specific and include pollution (e.g. Buckland et al. 1990; DeGuise et al. 1994; Martineau et al. 1999; Slooten & Dawson 1994), tourism (e.g. Bejder et al. 1999; Green 2004; Martinez 2003; Nichols et al. 2001; Stone & Yoshinaga 2000) and marine farming (e.g. Cole 2002; Lloyd 2003; Slooten et al. 2001). However, the most serious anthropogenic threat to Hector's dolphin is entanglement, primarily in inshore monofilament set nets and much less frequently in benthic and midwater trawl nets (Baird & Bradford 1999; Dawson 1991; Duignan et al. 2003, 2004; Starr & Langley 2000). Researchers believe that the species may have experienced significant decline in abundance since the 1970s, when set netting became widespread in New Zealand (Burkhart & Slooten 2003; Martien et al. 1999).

Given genetic variation and coastal fragmentation of the species, as well as area-specific characteristics and threats, separate management approaches are required for each of the populations. Such an approach requires accurate information on local populations. For example, a 1,140 km^2 Marine Mammal Sanctuary extending to 4 nm offshore was established around Banks Peninsula in 1988, which restricted recreational gill netting and effectively prohibited commercial set netting (Dawson & Slooten 1993). While bycatch mortality in the area has undoubtedly been reduced since establishment of the sanctuary, exposure to entanglement outside the sanctuary remains high, and survival rates of Hector's dolphins within the sanctuary probably remain too low for the population to recover (Baird & Bradford 1999; Burkhart & Slooten 2003; Cameron et al. 1999; DuFresne 2004; Martien et al. 1999; Slooten et al. 2000; Slooten et al. 2006b). This example demonstrates the need to understand a local population's range in order to implement effective management measures.

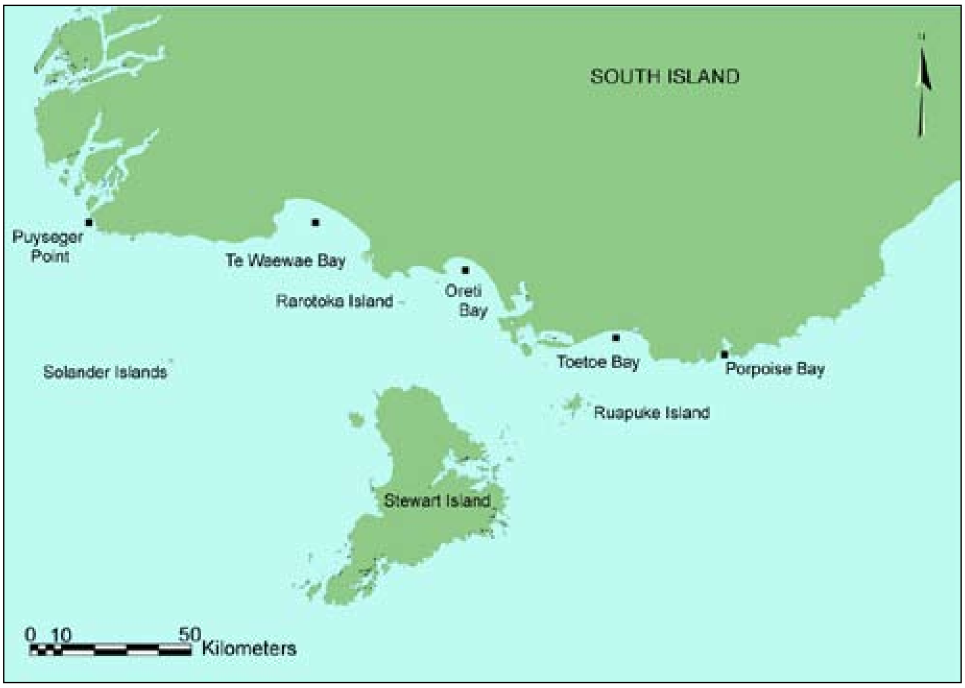
While Hector's dolphin is very well-studied compared with many other species of cetacean, the most intensive study of the species has been carried out at Banks Peninsula, with a continuous, long-term research programme since 1984. This is largely due to the accessibility and comparatively high density of Hector's dolphin there (e.g. Cameron et al. 1999; Nichols et al. 2001; Slooten et al. 1993; Stone & Yoshinaga 2000). The insights gained from Banks Peninsula research need to be complimented with localised studies as a basis for managing individual populations.

1.2 SOUTH COAST HECTOR'S DOLPHINS – BACKGROUND INFORMATION

In contrast to dolphins in the Banks Peninsula area, Hector's dolphins found on the south coast of the South Island (Figure 1) have been the subject of comparatively few studies. Two intensive studies have been conducted on the population of Hector's dolphins in Porpoise Bay; during the summer months of 1995-97 (Bejder & Dawson 2001; Bejder et al. 1999), and 2001-03 (Green 2003). Boat surveys by Green (2003) showed that some of the 43 dolphins (95% CI = 40 – 48) that use Porpoise Bay ranged at least from as far as Dummy's Beach in the north-east to Toetoe Bay in the south-west (Figure 1). Preliminary evidence suggests that members of this population may be exhibiting a seasonal alongshore movement, from Porpoise Bay during summer to Toetoe Bay during the remainder of the year (Green 2003). The accessibility of this population, combined with its popularity with tourists, focused research attention on the area. However, the majority of dolphins found on the south coast of the South Island are present in Te Waewae Bay (Figure 1).

The first survey of Te Waewae Bay was in 1984/85, as part of a nation-wide coastal strip-transect survey to estimate total abundance of Hector's dolphin (Dawson & Slooten 1988). Sightings were adjusted to account for seasonal distribution and

Figure 1. The southern coastline of the South Island of New Zealand.



sighting probability to generate a broad estimate of approximately 341 dolphins for Te Waewae Bay (Dawson & Slooten 1988). More recently, Dawson and colleagues (2004) conducted a stratified line-transect survey from a catamaran in the summer of 1998/99 and estimated that 89 dolphins were in the bay at that point in time (CV = 0.324; 95% CI = 36-218). This local estimate contributed to an estimate of the total abundance of the species of 7,270 by combining estimates from line-transect surveys elsewhere (Dawson et al. 2004).

In 2003 the Department of Conservation conducted three aerial surveys of Te Waewae Bay, and other parts of the south coast, to take a snap-shot of winter and summer distribution using a purely descriptive survey approach. In March 2003 six dolphins were observed in Te Waewae Bay using a fixed wing aircraft (DOC Internal Correspondence 2003a). Using helicopters, 43 dolphins were sighted in Te Waewae Bay during the July survey and 108 dolphins were sighted on the same survey route in December, with eight dolphins estimated to be double-counted in the latter survey (DOC Internal Correspondence 2003a, 2003b).

The alongshore and offshore range of dolphins that use Te Waewae Bay is currently unknown. Sighting records and previous survey work in Southland indicates Hector’s dolphins are seen occasionally along the south coast from Long Point to Oreti Beach (north-west of Bluff) and from Toetoe Bay (north-east of Bluff) to Dummy’s Beach in the Catlins, with regular sightings in areas such as Te Waewae Bay, Oreti Beach and Porpoise Bay (DOC Incidence Database.; DOC internal correspondence 2003b, 2003c). No sightings have been recorded by DOC in Bluff Harbour. While dolphins have been sighted on a regular basis just north-east of Bluff in Toetoe Bay (Green 2003), it is not currently known whether these animals interact with, or are part of the population that uses Te Waewae Bay. To the west of Te Waewae Bay there have been very few sightings of Hector’s dolphins in Fiordland. Confirmed and photographically recorded sightings include one dolphin in Dusky Sound and another lone animal in Milford Sound. In addition, unconfirmed sightings have occurred in Preservation Inlet (MFish and DOC 2007).

Genetic analysis of mitochondrial DNA collected from Hector's dolphins indicates the Te Waewae Bay dolphins share limited female geneflow (2.7 to 3.7 female migrants per generation) with the west coast population and almost no geneflow with the east coast population, whose southern-most sample was taken from around Timaru (Pichler 2002a). Based on these genetic data and sightings discussed above, it seems that Hector's dolphins may very occasionally move between the west coast and south coast populations.

Commercial and recreational set netting is practiced on the south coast of the South Island. Most recreational set netting in Te Waewae Bay occurs during the summer months and generally occurs within 500 m of shore to target various reef species and small sharks (MFish and DOC 2007). Data from the Ministry of Fisheries indicates that four or five commercial set netters regularly fish in Te Waewae Bay (MFish and DOC 2007). As information on fishing distribution is pooled into statistical areas by the Ministry of Fisheries, information on the actual number of sets in the bay is not available.

From the start of 1988 until 15 March 2007, there have been 13 reported Hector's dolphin mortalities in the DOC Southland Conservancy (MFish and DOC 2007). The cause of death was determined for four of these dolphins, one of which was an adult with net marks around its head that died as a result of asphyxiation, consistent with entanglement (Duignan 2004).

1.3 SOUTH COAST HECTOR'S DOLPHINS – CURRENT MANAGEMENT AND RESEARCH

Nationally, the Department of Conservation and Ministry of Fisheries are jointly developing a 'Threat Management Plan' for all Hector's dolphins (including Maui's dolphins). This plan will aim to establish a national strategy for protecting these dolphins by imposing a range of measures to address the potential threats to their survival. It is intended that the current study will assist with developing localised measures for the effective management of the Hector's dolphins that use Te Waewae Bay.

The Ministry of Fisheries implemented interim measures in late 2006 requiring recreational fishers to stay with their set nets at all times when setting nets between the Waiau and Clarence Rivers on the east coast of the South Island, and in Te Waewae Bay, in an attempt to reduce the likelihood of entanglement prior to development of the Threat Management Plan. The Ministry of Fisheries is also working with commercial set-netters on a national voluntary code of practice to attempt to minimise the likelihood of Hector's dolphins being caught in nets.

Differences in genetics, diet, seasonal distribution and threats facing the west and east coast populations of Hector's dolphin emphasise the importance of studying each population of dolphins separately to enable implementation of the most appropriate management measures (Brāger et al. 2002; Pichler et al. 1998a). In the absence of detailed information for the south coast population, the Department of Conservation has taken a precautionary approach with regard to managing tourism effects by prohibiting commercial boat-based dolphin watching operations in this area (DOC 1998). The Department of Conservation has sought further information to assist with management of the Te Waewae Bay population of Hector's dolphin.

Biopsy samples were collected from dolphins in Te Waewae Bay and in Toetoe Bay, off Fortrose, in 2005 (Russell pers. comm.). The results from comparative analysis of these samples will help to establish the level of genetic difference of the Te Waewae population to dolphins sighted in Toetoe Bay, and thereby assist with determining the eastern limit of the alongshore range of the Te Waewae Bay dolphins.

The Department of Conservation has also commissioned development of an aerial survey research plan to detect changes in abundance of the population using an index rather than using a series of more resource-intensive full abundance estimates (DuFresne, 2007). The method proposed entails double-observer helicopter surveys and capture-recapture analysis to correct the raw data for differences in dolphin availability and capture probability.

1.4 STUDY AIMS

The principal aims of this research project were to provide an estimate of abundance of Hector's dolphins in Te Waewae Bay and document dolphin distribution within the bay. Information on group composition, fishing activity and other cetacean sightings was also sought. We also aimed, if possible, to examine the alongshore range of this population of Hector's dolphin by undertaking surveys outside Te Waewae Bay.

2 Methods

2.1 STUDY SITE

Te Waewae Bay is located on the western half of the south coast of the South Island. It is a large, sweeping bay approximately 24 km across at the widest point. The depth gradient out from Te Waewae Bay is relatively gradual compared to bathymetry to the west. The maximum depth within the bay is approximately 30 m. Key locations around Te Waewae Bay are outlined in Figure 2. The Waiau River feeds into the bay at approximately its centre (Figure 2).

2.2 SURVEYS OF TE WAEWAE BAY

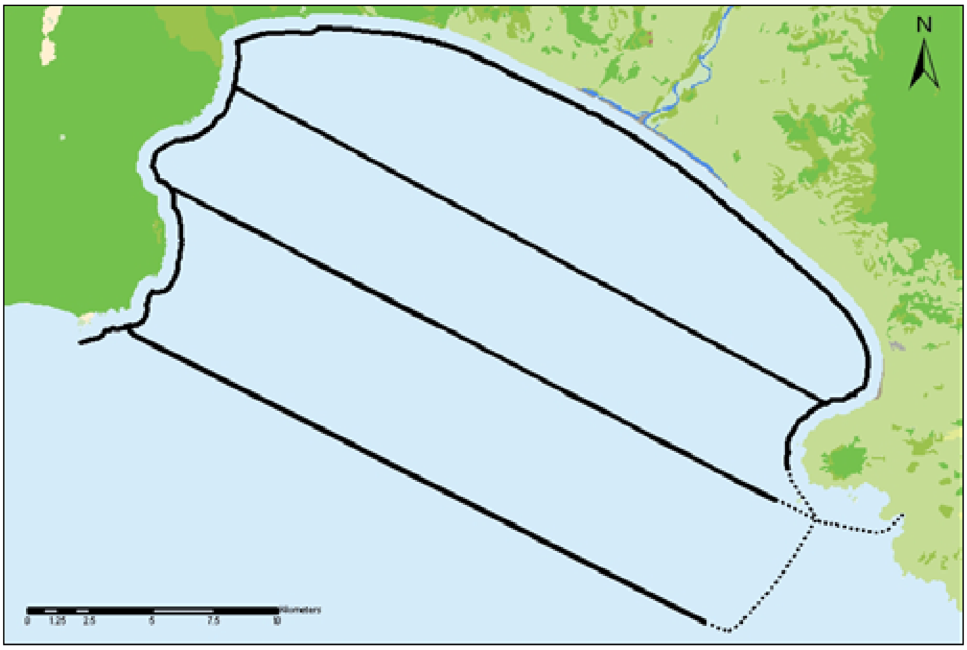
Boat-based surveys of Te Waewae Bay were conducted in a 5.3 m stabicraft fitted with a 90 hp outboard engine during two separate three-month study periods. The first period was during April, May and June 2004, hereafter, the "autumn period", and the second took place during December 2004, and January and February 2005, hereafter the "summer period".

2.2.1 Autumn survey routes

Three north-west/south-east "offshore" transects were developed, running roughly parallel to the coast at the mid part of the bay, at distances of approximately 5, 10 and 15 km from the shore (Figure 3). A "coastal" transect was also developed, which followed the coastline at a distance of approximately 200 m from the shore, from Pahia Point to Sand Hill Point (Figure 3). Every effort was made to travel along one of the offshore transects and the coastal transect each day. The direction of the survey

Figure 2. The locations of key places in and around Te Waewae Bay.

Figure 3. Approximate location of autumn transects within Te Waewae Bay. The solid line shows where we were 'on effort' (i.e. actively searching for dolphins) and the dotted line indicates 'off effort' travel to reach the survey transects.



route was reversed each field day (depending on weather conditions), so that the coastal and offshore transects were run at different times of the day. Running one offshore transect and the coastal transect took approximately one full day of operation on the water.

2.2.2 Summer survey routes

The survey route was altered for the summer study period in order to better assess the offshore distribution of dolphins within the bay. The autumn offshore transects were replaced with three new c-shaped transect lines at distances of approximately 1.9, 5.6, and 9.3 km (1, 3 and 5 nm) from shore with additional Garmin Global Positioning System (GPS) points for each transect to allow for more precise survey replication (Figure 4). These c-shaped lines were considered better lines for measuring offshore distribution as each line was a uniform distance from the coast and covered a larger area of the bay. Otherwise, the techniques for carrying out daily surveys were identical to those employed in the autumn period.

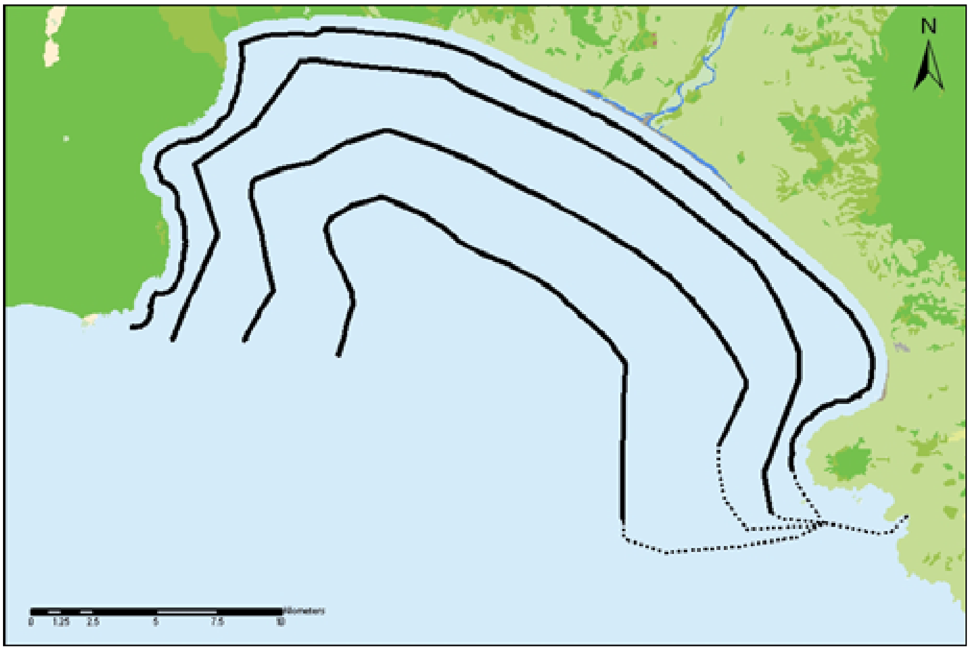


Figure 4. Location of summer transects within Te Waewae Bay. The solid line shows where we were 'on effort' (i.e. actively searching for dolphins) and the dotted line indicates 'off effort' travel to reach the survey transects.

2.2.3 General survey method

The survey route was recorded using a Hewlett Packard (HP) palmtop computer in a water resistant housing that was linked to a handheld GPS. As with research on Hector's dolphins elsewhere, surveys were conducted at speeds of approximately 10-12 knots so that:

- we could be reasonably sure that dolphins at the surface when the boat passed could be spotted (Clement et al. 2001); and
- the bay could be surveyed relatively quickly and efficiently.

Surveys of the bay were only undertaken on days when the Beaufort Sea State was two or lower. When weather conditions deteriorated during surveys, surveying was either abandoned or ceased until conditions became suitable again (surveying effort was recorded as 'off' on the palmtop computer). Generally, two observers were present on the boat, one of whom was the skipper. One observer was responsible for scanning the area to the left of the boat in a 90º arc from 270º to 360º, while the other scanned right of the boat in an arc from 0º to 90º (with the bow of the boat considered 360º/0º). The sighting range extended approximately 200 m from the boat.

Upon sighting a dolphin the boat was slowed and stopped near the group so that the dorsal fins of individual dolphins could be photographed. The dolphins usually approached the boat. If they did not swim towards the boat an attempt was made to approach them using protocols consistent with the Marine Mammal Protection Regulations (1992). The GPS position of the group was recorded on the palmtop computer and a number of parameters were noted, including:

- total size of the encounter (i.e. the total number of dolphins around the boat, which could be made up of one or more groups);[1]
- number of calves and juveniles present;[2]
- depth and sea conditions;
- beginning and ending times of the encounter;
- identification numbers of the films and photographs taken of dolphins; and,
- general observations/comments.

Lateral photographs of dolphins' dorsal fins were taken using a Nikon F90X film camera fitted with a Nikkor f2.8 28-200 mm zoom lens during the autumn period, and either the same camera or a Nikon D70 digital SLR body with the same Nikkor lens during the summer period. Shutter speed was set at 1/1000 sec to ensure that photographs were sharp. Pictures were taken of dolphins preferably within approximately 10 m of the boat to ensure that the subject adequately filled the photograph frame. Researchers attempted to photograph each dolphin in every encounter. On most days, particular effort was also made to ensure that all dolphins with distinctive natural markings were photographed. This targeted approach was preferable to random photography as it was more efficient and effective at 'capturing' marked animals, especially given the relatively short study period and large study area.

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1 In the summer period, the size of the group/s that made up each overall encounter was also recorded.

2 Consistent with research elsewhere, a calf was identified as a small animal in close association with an adult, and with foetal folds (Slooten and Dawson 1994). A juvenile was defined as an animal noticeably smaller than an adult, also swimming in close association with an adult, but lacking foetal folds.

When all details had been recorded and we considered that all dolphins in the group had been photographed, or if dolphins farther down the survey line were observed to head towards the boat, the research vessel made a short graduated burst of speed to ensure that the current group of dolphins were left behind. This was done in an attempt to intercept the new group as close as possible to its position to record its location for distribution analysis and so that the new dolphins could be photographed before the previously encountered dolphins could follow the boat to its new position. This differs from the approach used in other study areas. The estimated number of any dolphins that had been observed to follow the boat from previous encounters was recorded to reduce double-counting in the raw sighting data and distribution analysis. The survey route and speed were then resumed and the same procedure was followed for subsequent encounters.

During two days in summer, photographs of dolphins in each encounter were taken randomly in order to collect data on the proportion of dolphins with distinctive marks (i.e. the mark rate). Random photography was used so that all dolphins encountered would have an equal chance of being photographed. We attempted to take at least three times more random photographs than the number of dolphins in each encounter to ensure that each dolphin was photographed (Würsig 1978; Würsig & Jefferson 1990). For instance, for an encounter with four dolphins we attempted to take a minimum of twelve photographs before the subjects moved away or previously encountered dolphins approached the vessel.

The sample size from the two days of random photography was considered too small to provide a robust estimate of mark rate for use in abundance estimation. The low number of days dedicated to estimating mark rate was the trade-off with using a targeted approach on most days to maximise the number of marked dolphins photographed throughout the bay. In order to derive a more robust estimate of the mark rate we combined random photography data from this study with data gathered by JL Rodda (unpublished data) over 19 days during summer and autumn 2005 using the same field techniques (including the same survey route and camera). While Rodda's data was collected up to twelve months after the targeted photography of marked dolphins, this was not considered to be problematic given that it is assumed that the mark rate of a population does not change substantially over the course of one year (e.g. Gormley et al. 2005).

2.3 SURVEYS BEYOND TE WAEWAE BAY

Our intention was to undertake surveys along the coastline east of Te Waewae Bay as weather and time constraints allowed following the same procedure used for the coastal transect within Te Waewae Bay (i.e. surveying parallel to the coastline at a distance of approximately 200 m from shore). Surveys to the west of the bay were not possible due to absence of a suitable boat ramp, road access, and safe harbour in the event of an emergency.

2.4 RECORDING OF FISHING ACTIVITY

The approximate location of all fishing activity observed in Te Waewae Bay was recorded and an attempt was made to ascertain the nature of the vessel (i.e. recreational or commercial) and the type of fishing involved (e.g. trawling, set netting). Every effort was also made to record the location of every set net observed in the bay. The accuracy of observations depended upon the distance of the fishing activity from the survey transects, given that we preferred not to stray very far from the predetermined survey routes.

2.5 SIGHTINGS OF OTHER CETACEANS

When incidental sightings of other cetacean species were made during surveys, the group was approached by the research vessel. Researchers were considered to be "off effort" whenever working on cetaceans other than Hector's dolphin. Photographs for identification and collection of sighting information proceeded using the methods that were employed for Hector's dolphin encounters.

3 Analysis

3.1 SURVEY, SIGHTING AND PHOTOGRAPHIC DATA

All photographs and data from the palmtop computer were collated into a digital database using Filemaker Pro 7 (©2004 Filemaker, Inc.). The database consists of the following four tables:

- digital photographic catalogue of identifiable dolphins;
- digital photographs from each day of survey work;
- GPS points of the survey track; and
- information recorded at each encounter with Hector's dolphins.

Film photographs collected during the autumn period were scanned onto CD and were sorted into the correct encounter for the day based on information from the encounter table notes pertaining to films used and time of day. Digital photographs were sorted in a similar manner utilising the time/date stamp from the photograph itself. The photographs were then linked in Filemaker to the encounter, tracking, and catalogue tables. All digitally stored photographs in the database were then manually classified according to whether they were of appropriate quality and whether they were of a marked dolphin.

The use of photographic identification as a tool to study cetaceans requires strict quality criterion for photograph inclusion to ensure the accuracy of data from which conclusions about population abundance are drawn (Hammond 1990; Slooten et al. 1992). As in studies on Hector's dolphin elsewhere (e.g. Bejder & Dawson 2001; Gormley et al. 2005; Cameron et al. 1999) the only photographs used were those which were lateral or almost lateral to the dorsal fin, sharply focused, and in which the fin covered a sufficiently large portion of the frame (Slooten et al. 1992). This criteria was applied to all photographs used in the abundance analysis (outlined in Section 3.2).

Identifiable animals were sorted into categories based on the degree and distinctiveness of their marking. The most obvious marks and/or discolouration were included in category 1, decreasing in distinctiveness to category 4, which included dolphins with very subtle marks. Photographs without a marked dorsal fin were assigned a zero to show that the animal had no identifiable markings. All photographs of dolphins with the same identifying marks were given a specific individual 'dolphin number'.

Only dolphins with category 1, 2 or 3 marks were included in the catalogue of marked animals. Category 4 marks were considered too subtle to be included. However, as discussed further in Sections 3.2.3 and 4.3, only category 1 and 2 marks were considered distinctive enough to be used for abundance analysis.

3.2 ABUNDANCE

3.2.1 Program MARK

Program MARK (©2006 v 4.3) has models that can be used to estimate the abundance of a population based on the probability of the survival and recapture of individuals over successive sampling periods. The probabilities can be constant, time dependent or a variety of combinations. Capture data (i.e. photographs of marked dolphins) are often gathered over multiple sampling periods and then summarised into capture histories. An individual is 'captured' if seen at least once during a sampling period. Duration of sampling periods can vary between studies, such as annual or monthly, depending upon research objectives and data availability.

The first step in applying a MARK model is to produce the capture history for each identifiable animal by denoting either a "1" indicating an animal was 'captured' or a "0" indicating an animal was not 'captured', for each of the sampling periods (Amstrup et al. 2005). The capture histories of each unique animal are then combined into a matrix of all captures across each of the sampling periods. Capture histories for Hector's dolphins were summarized into a matrix consisting of a row for each individually marked dolphin, and six columns for the six survey months in the two seasonal survey periods. Multiple sightings of the same individual during the same monthly sampling period were ignored, as per the recommendation of Calambokidis and colleagues (1990).

The next step was to select the type of model to use, based on the degree to which the various model assumptions fit the data gathered. There are a large number of models in program MARK that can be used to produce estimates of population parameters from the capture histories (White et al. 2006). Gormley and colleagues (2005) used a version of the live-recapture population model, Cormack-Jolly-Seber (CJS), where capture probabilities were scaled by numbers of captures to estimate Hector's dolphin abundance around Banks Peninsula. In our study a Robust Design model was used as the primary means of deriving an abundance estimate, mainly because it produces more precise abundance estimates and can be used in the future to account for temporary emigration.

3.2.2 Robust Design

Pollock (1982) combined features from both open and closed population studies into a set of models termed "Robust Design". The purpose was to use closed population models to model subsets of samples over shorter secondary sampling periods and then open population modelling to measure population parameters over longer time periods (i.e. between primary periods). The secondary sampling periods are essentially different attempts at measuring the same population during one primary period (e.g. 3 separate monthly surveys over the same season). Deriving the population estimate from the pooled secondary samples means that higher precision can be expected (i.e. a lower coefficient of variation, CV) than under the classical Jolly-Seber approaches (Kendall et al. 1995). For this study of Te Waewae Bay Hector's dolphins the primary sampling periods were autumn 2004 and summer 2004/05, and the secondary intervals were the survey months within each season.

The main assumptions of the Robust Design model used was that all animals have an equal chance of capture and survival, marked animals do not lose their marks (nor are they so small or non-distinct they are easily mistaken for another animal), and the secondary sampling intervals are short (i.e. the population is closed during each primary period). These assumptions are common to other capture-recapture studies and we considered that they held for this study also. For example, misidentification of dolphin marks or loss of marks was considered to be mitigated by use of marks that were sufficiently distinct to ensure they could be recognised over the duration of the study (see section 3.2.3).

While the population is assumed to be closed during the primary sampling periods or seasons using this Robust Design model there also needs to be a large enough gap between them to allow for deaths and relocation (whether permanent or temporary). If no photograph was obtained of a marked dolphin in a primary period it could have either; died or left the sampling area (either permanently or temporarily); may have been present but not photographed; or photographed but unable to be identified from the photograph. Robust Design accounts for these possibilities via survival and capture probability calculations. In this study, the assumption of closed seasonal populations was supported by the rate of first sightings of marked animals in Te Waewae Bay (see results in Section 4). This assumption was also made by Gormley and colleagues (2005) when deriving abundance estimates for Hector's dolphin at Banks Peninsula, and studies of the Porpoise Bay population (e.g. Green 2003).

3.2.3 Categorisation of marked animals

Category 1 and 2 marked dolphins (i.e. the more distinctively marked dolphins) have been used to estimate population parameters in other studies of Hector's dolphin, such as Dufresne (2004) and Gormley and colleagues (2005). However, both studies used data from the larger population of dolphins at Banks Peninsula and their data was pooled across many years, and therefore needed to account for much higher chances of marks changing. At the other end of the scale, Green (2003) used category 1, 2 and 3 marked animals to derive a summer abundance estimate of the much smaller (43 dolphins; 95% CI = 40-48) Porpoise Bay population of Hector's dolphin over two consecutive summers (also see Bejder and Dawson, 2001).

The two capture-recapture primary sampling periods of this Te Waewae Bay study occurred over an 11-month period – with three sampling months in autumn/winter and three in summer. In addition to the short study timeframe, this population of Hector's dolphins is considered to be much smaller than that around Banks Peninsula. On these grounds, we considered that the inclusion of category 2 animals of slightly more subtle marking than used for Banks Peninsula, but not as subtle as the marks used for Porpoise Bay abundance estimates, was justified. We were satisfied that all marked animals were able to be accurately re-identified in any photographs included in analyses. Dolphins with other marks considered too subtle to use were categorised as unmarked for the purposes of abundance analysis.

3.2.4 Deriving abundance estimates from the marked population abundance estimate and the mark rate

The average mark rate (Q) was the proportion of randomly taken photographs of appropriate quality that showed marked individuals. In other words, it was calculated by dividing the number of sufficient-quality random photographs of dolphins with category 1 and 2 marks (I) by the total number of random photographs (T) (i.e.

$Q = I/T$). The mark threshold and photograph quality criteria used to define whether an animal was 'marked' was the same as that used to develop the capture histories for program MARK. Although we did not test for stability of mark rate in this study, we followed the assumption used in research by Gormley and colleagues (2005) at Banks Peninsula that the mark rate was unlikely to change over time, an assumption that is even more likely to hold in this study given its short nature. The average mark rate was used to scale up the abundance estimates of the marked population (N_{mark}) in order to produce estimates of total abundance of the population $(N_{pop})(i.e. N_{pop} = N_{mark}/Q)$.

3.2.5 Statistical precision

The precision of the estimates of the marked population and total population abundance were measured as the CV and log-normal 95% confidence intervals (CI), which were derived from a combination of the variances (var) of the marked population estimates and the mark rate. Amstrup and colleagues (2005) describe the CV as the relative precision of an estimate. It is defined as the standard error (SE) of an estimate divided by the estimate itself (N) $(i.e. CV = SE\,(N)/\,N)$. The standard error of the marked abundance estimates are provided by program MARK.

The method for determining the variance of the average mark rate (Q) is similar to the general approach used by Gormley and colleagues (2005) for the Banks Peninsula Hector's dolphin population, where variance is assumed to be

$$var(Q) = (Q \times \frac{(1-Q)}{T})$$

However, we went one step further than other studies to account for any replication of random photography samples. By attempting to take multiple (i.e. three) photographs of the same dolphin in the same encounter, we were artificially increasing the sample size (T) (Gormley, pers comm.). For example, if a marked dolphin was photographed three times in an encounter, the true sample size should be one; not three. Following this argument, we sought to remove replicated sightings of both unmarked and marked animals on the same day to provide more appropriate values for T and Q for measuring variance.

To account for replication the total number of captures of individually marked dolphins (with multiple sightings of the same marked dolphins seen on the same day removed) was divided by the total number of marked photographs. The result was the average proportion of uniquely marked photographs (hereafter the "true sampling ratio"). The total number of suitable random photographs (both marked and unmarked) was multiplied by the true sampling ratio, to provide the true sample size of photographs for estimating variance of the mark rate. This is based on the assumption that there is no difference in the behaviour of marked and unmarked dolphins (i.e. that the proportion of marked dolphins that are photographed more than once is the same as the proportion of unmarked dolphins photographed more than once). This is a fundamental assumption of capture-recapture analysis in general. Removing replicated sightings changed only the statistical precision of the mark rate, not the value of the mark rate, because the number of marked and unmarked photographs were reduced by the same proportion.

These adjusted values for the total number of suitable random photographs (*T*) and the number of photographs of marked animals (*I*) were used to derive variance of the mark rate, using the formulae provided earlier, i.e.:

$$CV(Q) = \frac{\left(SQRT\left(Q \times \frac{(1-Q)}{T}\right)\right)}{Q} \quad \text{where } Q = \frac{I}{T}Q = \frac{I}{T}$$

As for Banks Peninsula, the CV of the total abundance estimates can be separated into two components: the CV of the mark rate and the CV of the marked abundance estimate (Gormley et al. 2005):

$$CV(N_{pop}) = SQRT\ (CV(Q)^2 + CV(N_{mark})^2)$$

Limits for both the lower and upper confidence intervals were calculated as log-normal because it would be biologically unrealistic to have confidence limits with a lower limit below zero (Burnham et al. 1987). The formulae for deriving the log-normal confidence intervals were:

Lower 95% interval = $\frac{N_{pop}}{exp\ (1.96\ \times SQRT\ (\log (1 + CV\ (N_{pop})^2)))}$

Upper 95% interval = $N_{pop} \times\ exp\ (1.96\ \times SQRT\ (\log\ (1 + CV(N_{pop})^2)))$

3.3 DISTRIBUTION

The geographic locations of Hector's dolphin encounters for both study periods were plotted on maps of the bay, with the size of the symbol indicating the total number of dolphins in the encounter. While displaying data in this way is useful to provide a basic summary of the raw data or sightings, it can also be misleading for two reasons: 1) it fails to consider survey effort, and 2) it obscures multiple sightings in the same position (due to overlapping dots).

In order to standardise distribution data, sightings also were plotted as a density figure based on survey effort (i.e. average number of dolphins sighted each time an area of the bay was surveyed). As dolphins were likely to be sighted within 200 m of either side of the research boat, the effective survey strip width along each transect was 400 m. These strips were divided into sections of approximately 2 km in length. This distance was deemed to be an acceptable balance between being large enough to include a suitable number of sightings of dolphins per section while also being small enough to create a detailed division of the bay. These sections, which for autumn are indicative of the general area surveyed and are more precise for summer, were mapped and shaded according to the mean number of dolphins sighted in each section per survey (i.e. total number of dolphins sighted in the section divided by the total number of times the section was surveyed). The width of the sections was exaggerated on maps in order to be more visually informative. These distribution densities were plotted separately for the autumn and summer periods to enable comparison between the two seasons. This analysis was supplemented with the calculation of average dolphin densities along the coastal transect and those parts of offshore transects greater than approximately 3 nm or 5.6 km from shore.

The locations of calf sightings for each study period were mapped in order to determine whether dolphins with calves were utilising particular areas of the bay. Locations of a subset of the five most identifiable marked Hector's dolphins that were sighted during at least five of the six survey months were also plotted on a map to investigate whether there were distribution patterns for individual dolphins. We used the average nearest neighbour distance calculation from the program ArcGIS 9.0 (ESRI 2004) to test if any differences in individual distribution were statistically valid, or merely a random pattern. This program calculates the distance of each individual dolphin to all other dolphin sightings (i.e. the observed mean distance) and the shortest distance to the next dolphin (i.e. the nearest neighbour). ArcGIS also calculates an expected mean distance for each dolphin. Values can be viewed as a ratio of the observed to expected distances (Mitchell 2005). If the ratio is less than one the pattern is considered be clustered; or dispersed if greater than one.

3.4 SURVEYS BEYOND TE WAEWAE BAY

The area of coastline surveyed and the location of dolphin sightings beyond Te Waewae Bay were mapped. In addition, photographs taken of marked individuals sighted outside Te Waewae Bay were compared with the catalogues of identifiable dolphins seen in Porpoise Bay (Green 2003), Toetoe Bay (Green 2003) and Te Waewae Bay (this study) to determine whether there were any matches with the photograph catalogues established for these other areas.

3.5 FISHING ACTIVITY

Information on fishing activity observed in the bay was tabulated and discussed.

3.6 OTHER CETACEANS

Photographic data of cetaceans other than Hector's dolphin were not analysed, but were instead passed on to other researchers of those species for comparison with any appropriate photographic catalogue.

4 Results

4.1 SURVEY EFFORT

Survey effort in Te Waewae Bay was largely dictated by weather conditions, with researchers available to conduct surveys on almost every suitable day during the two study periods, with the exception of the Christmas period (23 Dec to 26 Dec). Autumn surveys were undertaken on 19 days between 14 April and 30 June 2004 (Table 1). Summer surveys took place on 19 days between 4 December 2004 and 27 February 2005.

TABLE 1. SURVEY EFFORT IN TE WAEWAE BAY OVER THE TWO STUDY PERIODS, AUTUMN 2004, AND SUMMER 2004/05.

PARAMETER	AUTUMN 2004	SUMMER 2004/05
Total no. survey days	19	19
Total no. hours on effort	94 hr	98 hr
Approx. total no. km surveyed ('On Effort')	942 km	1,068 km
Coastal transect	675 km	607 km
Offshore transects	267 km	461 km

Total hours 'on effort' and distance surveyed were similar for each of the study periods (Table 1). The main difference in effort between seasons was an additional 73% effort along offshore transects in summer 2004/05 compared to autumn 2004. Distribution of effort between the coastal and offshore transects is discussed further in the distribution section (Section 4.7). Compared to the seasonal comparison provided above, the monthly effort profiles were less evenly balanced. Figure 6 shows that many more kilometres were surveyed in January 2005 than in any of the other months.

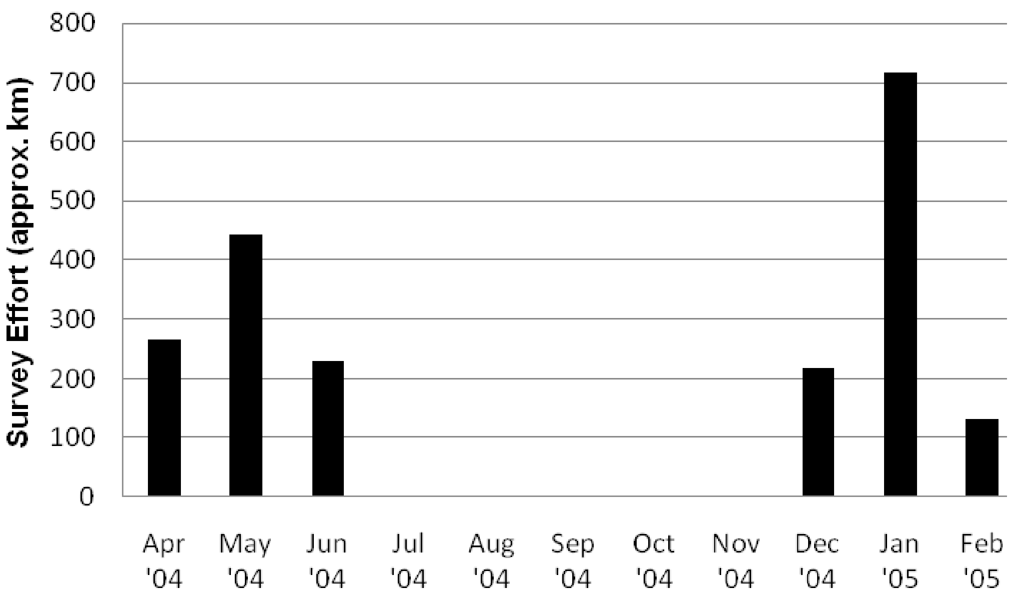


Figure 6. Survey effort (approximate kilometres surveyed) in Te Waewae Bay by month.

4.2 DOLPHIN SIGHTINGS AND GROUP COMPOSITION

During autumn surveys, there were 274 encounters which encompassed a total of 1,283 dolphin sightings (Table 2). Many of these animals would have been counted numerous times across different days. Dolphins were sighted at depths ranging from 2.0 to 28.0 m. The average depth of sightings was 6.7 m (SD = 4.2). During summer surveys, we had 415 encounters with dolphins in a total of 652 groups (Table 2). These groups contained a total of 1,841 dolphins (including multiple sightings of the same dolphin), sighted at depths ranging from 1.4 to 22.0 m and an average depth of 6.5 m (SD = 3.2). On the two days that additional observers were present on the boat, sighting rate was unaffected. The only indication available of the level of double counting within a single day was that approximately 7.1% of marked dolphins used for abundance analysis were sighted in different encounters on the same day. However, most (62.5%) of these replicated encounters were discounted from the sighting data based on our observations that these animals had followed the research vessel from the previous encounter. This indicates that approximately 2.7% of animals were likely double counted. However, as this estimated proportion is so low, no correction has been applied to figures presented in Table 2.

TABLE 2. SIGHTINGS AND GROUP COMPOSITION IN AUTUMN AND SUMMER STUDY PERIODS.

PARAMETER	AUTUMN 2004	SUMMER 2004/05
Total no. dolphins seen (includes multiple sightings of the same dolphins)	1,283	1,841
Mean no. dolphins seen/day (with a full coastal transect)	80.4 (SD = 26.4)	144.5 (SD = 30.7)
Range in no. dolphins seen/day (with a full coastal transect)	46 – 118	95 – 202
Total no. encounters	274	415
Mean no. of dolphins seen/encounter	4.7 (SD = 4.0)	4.4 (SD = 3.0)
Range in no. dolphins seen/encounter	1 – 35	1 – 17
Total no. of groups seen (may have been multiple groups/encounter)	NA*	652
Mean no. dolphins/group	NA*	2.8 (SD = 1.1)
Range in no. dolphins/group	NA*	1 – 9
Total no. calves seen	17	68
% total dolphins sighted that were calves	1.3%	3.7%

* Data for this parameter was not collected during the autumn study period.

The average number of dolphins in an encounter was similar for each of the study periods, with between 4 and 5 animals per encounter. In summer we also collected information on group sizes within each encounter, and found an average of 2.8 (SD = 1.1) dolphins per group.

Both a higher number and proportion of calves were observed in the summer period compared with the autumn period (Table 2). An attempt was also made during surveys to record the presence of juveniles. However, the difficultly in positively determining a juvenile on every occasion raised our concerns about the reliability of the data, and these data were therefore excluded from group composition analysis.

4.3 PHOTOGRAPHIC DATA AND CATALOGUE

During the six survey months, 70 marked dolphins (categories 1-3) were identified and included in the Te Waewae Bay catalogue including 10 animals in category 1; 19 animals in category 2; and 41 animals in category 3. An example photograph of a dolphin from each of the four mark categories, including category 4 animals which were not included in the catalogue, is provided in Figure 7.

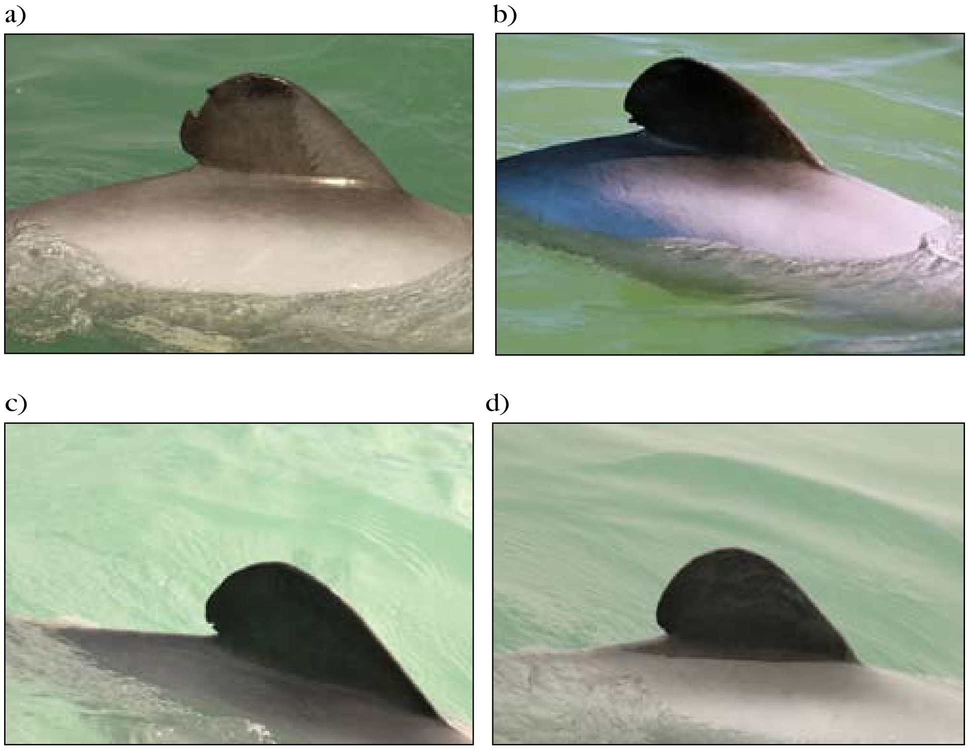


Figure 7. Examples of the four categories of marks: a) category 1; b) category 2; c) category 3; and, d) category 4.

4.4 POPULATION OF MARKED DOLPHINS

A total of 29 dolphins with marks sufficient for use in capture-recapture analysis (i.e. category 1 or 2) were recorded in Te Waewae Bay over the six survey months of this study. Seventeen category 1 and 2 marked dolphins were identified in autumn and 23 were identified in summer. Twelve of the 23 dolphins seen in summer were not sighted in autumn and six of the 17 dolphins sighted in autumn were not sighted in summer. Figure 8 outlines the total number of differently marked dolphins recorded in each of the survey months (secondary sampling periods). A monthly low of five differently marked dolphins were captured in December 2004, while the highest monthly capture was 17 in January 2005. The cumulative number of first sightings of each of the 29 marked dolphins over the study period (i.e. a discovery curve) is also provided in Figure 8. The discovery curve indicates that marked dolphins continued to be sighted for the first time (i.e. discovered) throughout the entire study period, but at a much reduced rate during the last month of each season (June 2004 and February 2005).

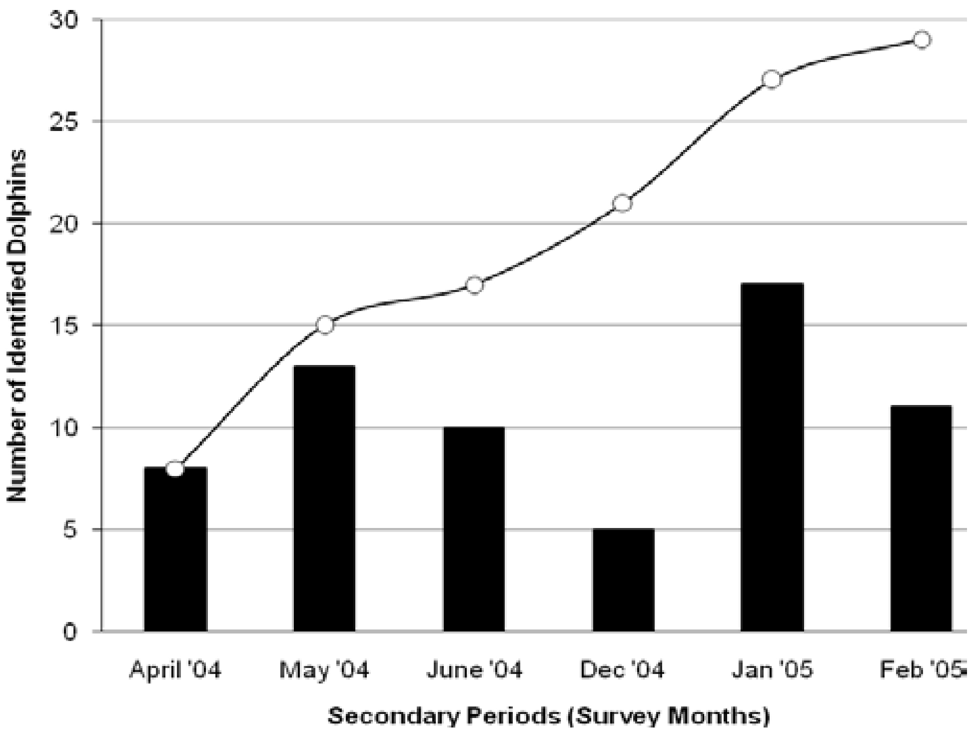


Figure 8. The number of different category 1 and 2 marked individuals identified during each of the monthly survey periods (bar graph) and the discovery curve of first sightings of each animal (line graph).

Standardisation of the first sighting data by photographic effort (i.e. by the number of suitable quality photographs of marked dolphins taken) is presented in Figure 9. The levelling of the seasonal discovery curves indicates seasonal population closure and the difference between the curves indicates that populations were open between primary sampling periods (Figure 9).

The data presented in Figures 8 and 9 indicate that the Te Waewae population of Hector's dolphins is closed within, but open between, primary sampling periods (seasons), and therefore provides support to the selection of the Robust Design model used to provide seasonal abundance estimates in this study.

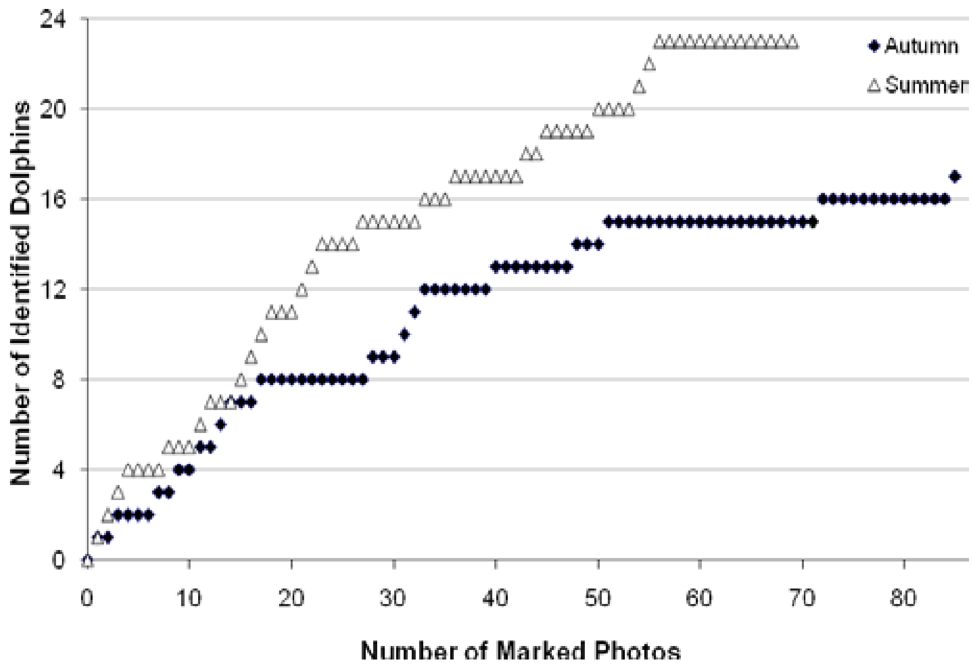


Figure 9. The discovery of category 1 and 2 marked individuals identified in relation to cumulative photographic effort (i.e. the cumulative number of suitable quality photographs of marked dolphins) for each of the seasonal survey periods.

4.5 MARK RATE ESTIMATE

The average mark rate for the population of category 1 and 2 marked dolphins for this study was 0.070 (CV = 0.142). This mark rate was derived from 446 random photographs of suitable quality taken over 15 days during autumn/winter months and 438 photographs taken over 6 days during summer months. All of the suitable autumn photographs and approximately half of the suitable summer photographs were provided by JL Rodda (unpublished data) from a larger dataset set gathered as part of a separate longer-term study.

Of the 884 suitable random photographs that were used in the analysis, 62 were of marked dolphins. In accounting for replication of samples we estimated a 'true' sample size of 656 photographs of which 46 were marked (as per Section 3.2.5). Without making this adjustment the CV for the mark rate would have been artificially low (i.e. CV = 0.122). This adjustment did not change the mark rate estimate; it simply improved the estimated precision of the mark rate.

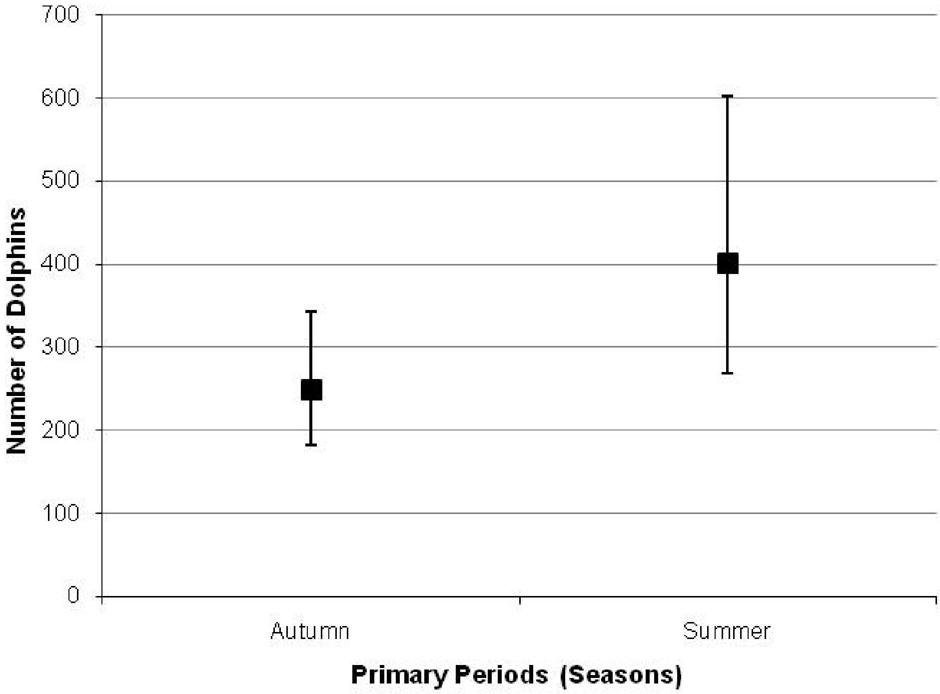
4.6 ABUNDANCE ESTIMATE

The autumn and summer abundance estimates using the Robust Design model are presented in Table 3. This model assumed constant survival by default (as there were only two primary periods), and time dependent capture probabilities (given uneven monthly survey effort). We estimate that 18 (CV = 0.077) marked dolphins used Te Waewae Bay in the autumn period and 28 (CV = 0.151) in the summer period. Using the average mark rate of 0.070 (CV = 0.142) to scale up the marked dolphin abundance estimates, the total number of dolphins estimated to use the bay in the autumn was 251 (CV = 0.162) and 403 (CV = 0.207) in summer. The seasonal abundance estimates from the Robust Design model and the log-normal 95% confidence intervals, are shown graphically in Figure 10.

TABLE 3. AUTUMN AND SUMMER ABUNDANCE ESTIMATES DERIVED FROM ROBUST DESIGN OF BOTH THE MARKED POPULATION AND THE TOTAL POPULATION OF HECTOR'S DOLPHIN USING TE WAEWAE BAY OVER THESE PERIODS.

SEASON	ABUNDANCE ESTIMATE	LOG-NORMAL 95% CONFIDENCE INTERVALS LOWER	UPPER	CV
Marked population				
Autumn	18	15	20	0.077
Summer	28	21	38	0.151
Total population				
Autumn	251	183	343	0.162
Summer	403	269	602	0.207

Figure 10. Estimates of the number of Hector's dolphins using Te Waewae Bay in the autumn and summer periods, with log-normal 95% confidence intervals.



4.7 DISTRIBUTION WITHIN TE WAEWAE BAY

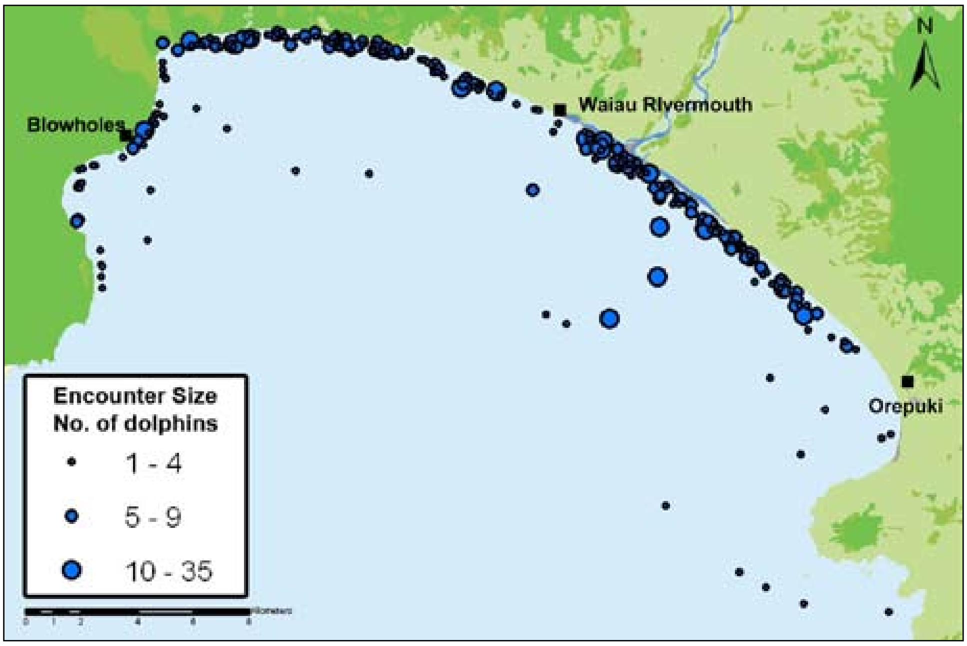
4.7.1 Absolute distribution

Figures 11 and 12 show that dolphin encounters were concentrated along the coastal transect in Te Waewae Bay with comparatively few sightings along the offshore transects during both autumn and summer periods. Dolphins were sighted along the majority of the coastal transect of the bay, with lower concentrations of sightings east of Orepuki and west of the Blowholes during the autumn period (Figure 11). During the summer period, the number of sightings off Orepuki and the Blowholes appear to be more aligned with other parts of the coastal transect, than in autumn. However, in summer, there remained a low number of sightings in the western and eastern extremities of the bay. Few groups were sighted directly off the mouth of the Waiau River during both study periods. During the autumn period more groups were sighted offshore than during summer, and these groups were larger on average (Figure 11 and Figure 12).

4.7.2 Standardised distribution

Sightings standardised according to survey effort are represented as density shadings in Figures 13 and 14. The colour of the sections represent sighting density, with a deeper shade of colour indicating a higher density, or number of dolphins sighted per survey. The number within each section shows how many times the area was surveyed over the study period and, therefore, how reliable or robust conclusions about dolphin density in that area may be. Figures 13 and 14 indicate that dolphin sightings in Te Waewae Bay during both autumn and summer periods were concentrated close to the coast, even after accounting for higher survey effort there.

Figure 11. The locations of Hector's dolphin sightings in Te Waewae Bay during the autumn 2004 period.



During the autumn period, sighting density was high along most of the coast compared to the offshore transects, with a concentration from Blowholes to Waihoaka (with the exception of directly off the mouth of the Waiau River) with on average 5.21 dolphins seen in each section per survey (Figure 13). Density along the coast was also lower in the west between Port Craig and Sand Hill Point (0.67 dolphins per survey), and in the east, near and around Pahia Peninsula (0.36 dolphins per survey). Density was patchy along the 5 km transect (with sightings on the ends and directly in the middle) and was very low along the 10 and 15 km transects, with sightings only at the ends of the 10 km transects, nearest the coast.

During the summer period there were generally higher sighting densities along the coast than in the autumn period (Figure 14). As seen with the autumn sightings, density was particularly high in patches along the coastal transect in front of Track Burn, and Te Waewae along to Waihoaka (up to 13.2 dolphins per survey). Again, density was lower at the extremities of the bay and off the Waiau Rivermouth, but

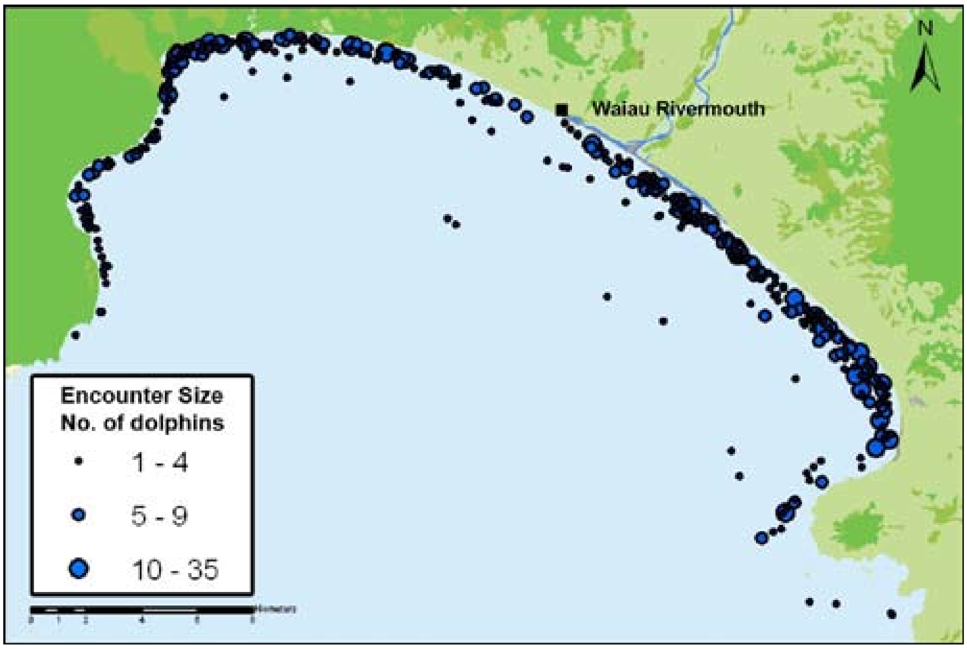


Figure 12. The locations of Hector's dolphin sightings in Te Waewae Bay during the summer 2004/05 period

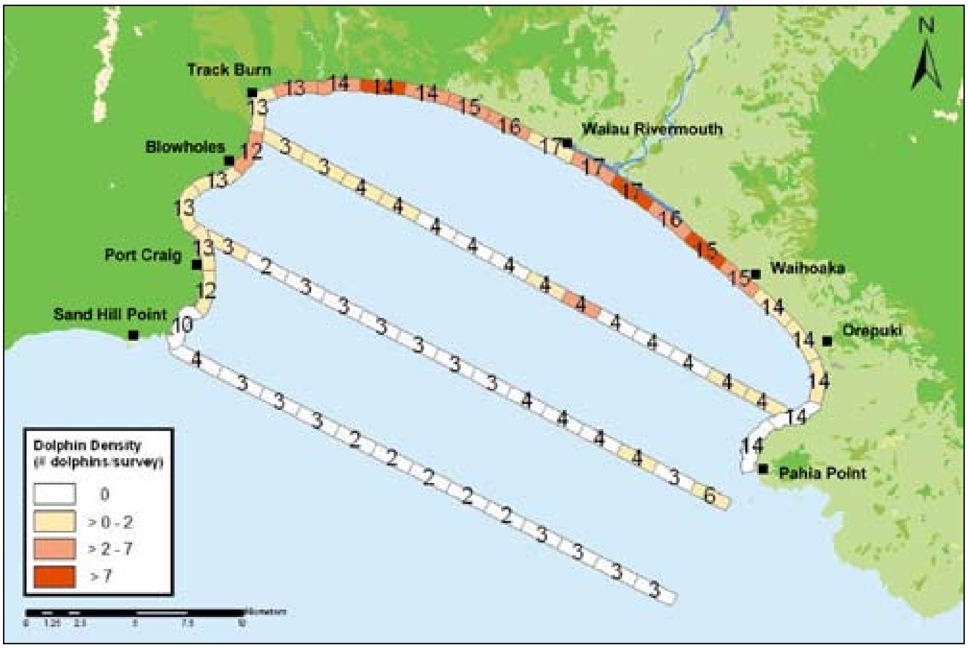


Figure 13. The distribution of Hector's dolphin sightings in Te Waewae Bay during the autumn period standardised by effort. Numbers show how many times each area was surveyed.

was higher in these areas than in autumn (1.8 in the west and 5.51 in the east). Sighting density was patchy along the 1.9 km (1 nm) transect, with concentrations in the eastern extremity and middle of the bay. The only other offshore areas where sighting density was greater than zero were two sections in the middle of the 5.6 km (3 nm) transect.

The average dolphin densities per kilometre on the coastal transect and offshore transects are shown in Table 4, with sightings between the coastal transect and approximately 5.6 km offshore excluded to provide a buffer between what we categorised as "onshore" and "offshore" distribution.

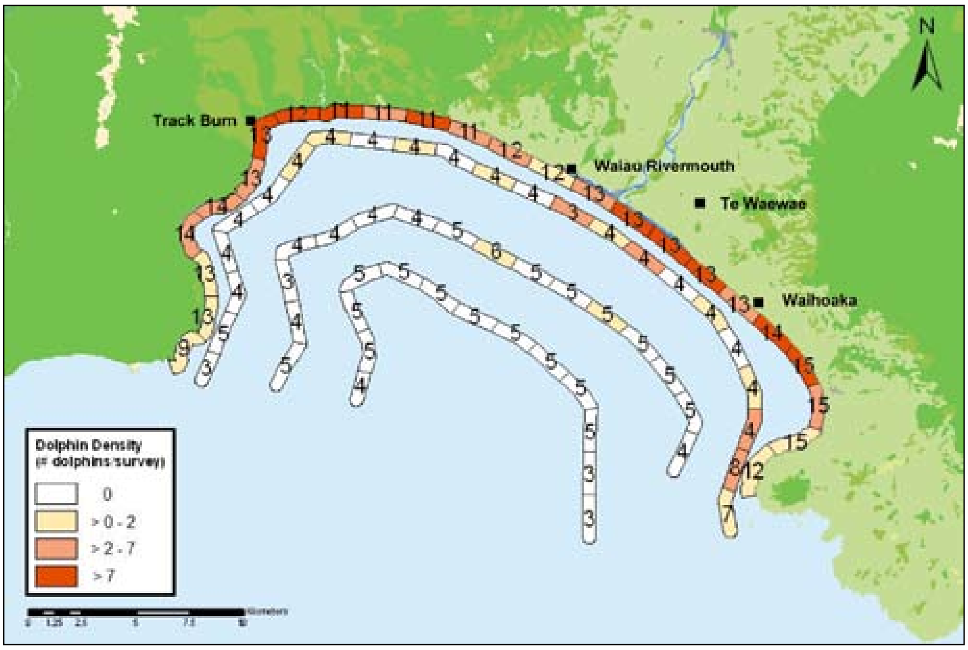


Figure 14. The distribution of Hector's dolphin sightings in Te Waewae Bay during the summer period standardised by effort. Numbers show how many times each area was surveyed.

TABLE 4. COMPARISON OF THE AVERAGE NUMBER OF DOLPHINS SEEN PER 'ON EFFORT' KILOMETRE ALONG THE COASTAL TRANSECT AND AT LEAST APPROXIMATELY 5.6 KM OFFSHORE IN AUTUMN AND SUMMER.[3]

	AUTUMN 2004			SUMMER 2004/05		
	COAST	≥5.6 KM	TOTAL	COAST	≥5.6 KM	TOTAL
Total number of dolphins seen	1158	26	1184	1723	6	1729
% of total dolphins seen	97.8%	2.2%	100%	99.7%	0.3%	100%
Approx. total km of survey effort	675	192	867	607	264	871
% of total effort	77.9%	22.1%	100%	69.7%	30.3%	100%
Dolphin density (mean number dolphins/km)	1.72	0.14	NA	2.84	0.02	NA
Expected proportion of sightings if effort even	92.7%	7.3%	100.0%	99.2%	0.8%	100.0%

The average density along the extent of the coast was higher in summer (2.84 dolphins/km) compared with autumn (1.72 dolphins/km). Average offshore densities also differed between study periods. Dolphin density per kilometre along offshore transects (≥ 5.6 km) was 0.14 dolphins/km in autumn and 0.02 dolphins/km in summer. Based on average relative densities, had survey effort been evenly distributed between the coastal transect and offshore transects at least 5.6 km offshore we would expect to have observed 92.7% of the sighted dolphins along the coast and 7.3% of sighted dolphins farther than 5.6 km from shore during the autumn period. For summer the expected proportions using the same technique would be 99.2% along the coast and 0.8% offshore (Table 4).

4.7.3 Calf distribution

Figures 15 and 16 show locations of groups that were observed with calves during the autumn and summer periods respectively. Four times as many sightings of calves were made during summer than in the autumn period(see Table 2).

Figure 15. The locations of groups containing calves observed in Te Waewae Bay during the autumn period.

3 This excludes any sightings that were made on sections of the offshore transects that were not at least 5.6 km from the coast.

Figure 16. The locations of groups containing calves observed in Te Waewae Bay during the summer period.

4.7.4 Individual dolphin movements

Sightings of the five most identifiable marked dolphins that were seen during at least five of the six survey months are plotted in Figure 17. These dolphins were mainly category 2 dolphins, as no category 1 dolphins were sighted in more than four months. Two of the five animals (depicted as white and red dots) were sighted only in areas west of the Waiau River and three (depicted as green, blue, and grey dots) were sighted only in the eastern side of the bay (Figure 17). Application of the average nearest neighbour distance calculation resulted in a ratio of 0.36 (the observed distance divided by the expected distance). As this ratio was less than 1 the pattern of individual distribution was shown to exhibit clustering ($p < 0.01$).

Figure 17. All sighting locations of five of the most identifiable dolphins that were seen in at least five of the six survey months. Sightings of each individual dolphin are represented by the same colour dot (green, blue, white, red and grey).

4.8 SURVEYS BEYOND TE WAEWAE BAY

Due to time and weather constraints, only one survey outside Te Waewae Bay was undertaken during the autumn period and none during the summer. Toetoe Bay was chosen as the location of this survey for three reasons: 1) it was protected from the westerly wind direction that day, 2) it was recognised as part of the range of the Porpoise Bay population, and 3) it was not known whether it was included in the range of the Te Waewae Bay population. The survey started at Bluff on 21 May 2004 and followed the coast east to Waipapa Point (Figure 18). Deteriorating weather conditions meant that it was not possible to run the survey back from Waipapa Point to Bluff. Figure 18 shows the locations of the four groups of Hector's dolphins sighted in Toetoe Bay during this survey. A total of 18 dolphins were encountered with encounter sizes of 2,2, 5 and 9 dolphins. Of the dolphins sighted, three were calves with faint foetal folds remaining, indicating that they were born over the preceding summer.

Comparison of photographs taken of dolphins in Toetoe Bay with the catalogues of individuals seen in Te Waewae Bay and Porpoise Bay showed that the three naturally marked dolphins sighted on the survey were seen regularly in Porpoise Bay over the summers of 2001/02 and 2002/03. Two of these dolphins had been sighted in Toetoe Bay on previous surveys of the bay, while the third had only been sighted in Porpoise Bay. No marked dolphins seen in Toetoe Bay were also seen in Te Waewae Bay during this study. Comparison of the catalogue of dolphins seen on nine previous surveys of Toetoe Bay and many more of Porpoise Bay by Green (2003) similarly failed to find any matches with the Te Waewae Bay catalogue.

4.9 FISHING ACTIVITY

Four boats were observed in Te Waewae Bay over the autumn period, compared with 16 boats over summer (most of which were recorded in January). Most of the boats were commercial fishing vessels that were either trawlers, set netters or paua divers. Generally, precise locations of the vessels observed were not recorded as we were reluctant to stray far from the survey route to obtain GPS positions and the positions of the boats changed during the day. This is especially true for trawlers, which were usually more than at least five kilometres offshore. The specific activity

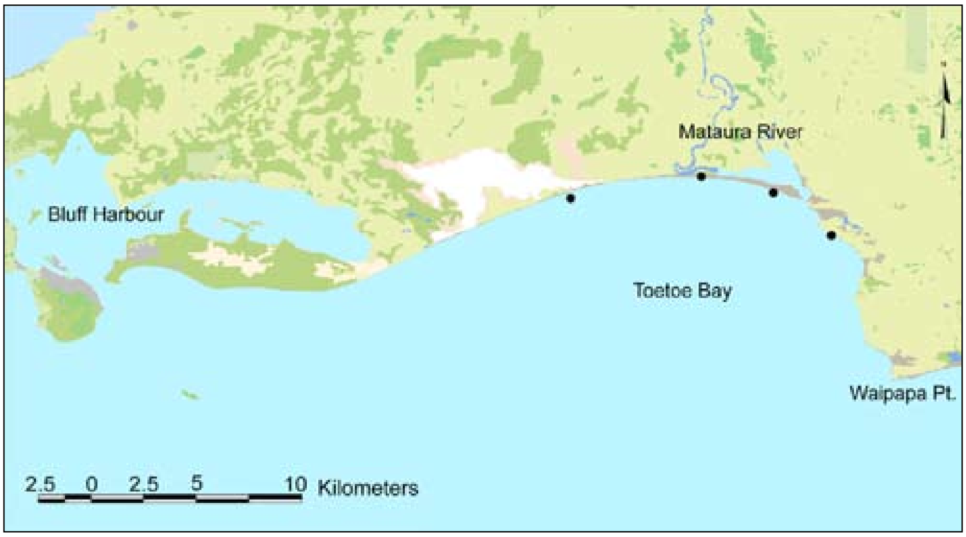


Figure 18. The location of the four groups of Hector's dolphins sighted during the autumn survey of Toetoe Bay.

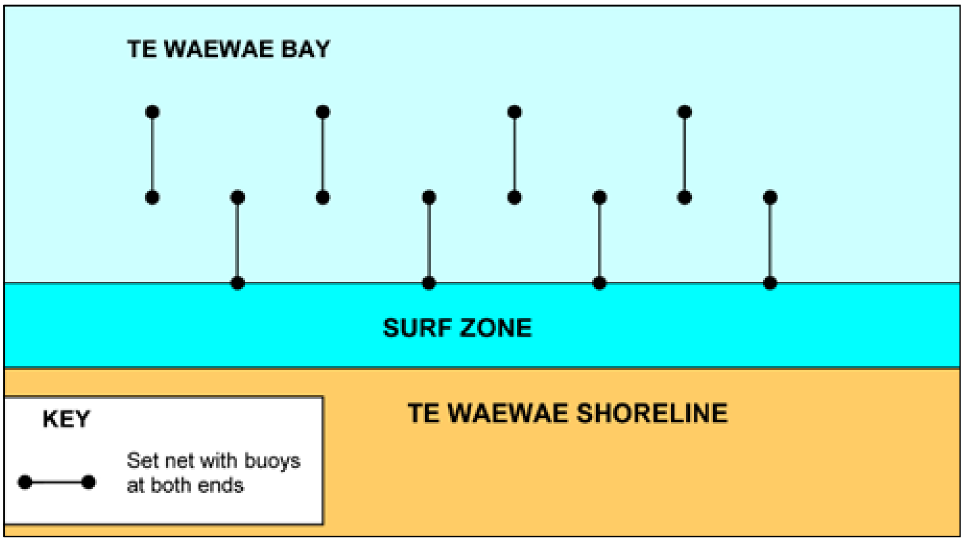
of some of these boats was indeterminable due to the distance from the research vessel; however it was possible to make a logical distinction between commercial and recreational vessels by size. A summary of fishing activity observed is provided in Table 5.

TABLE 5. OBSERVED FISHING ACTIVITY IN TE WAEWAE BAY OVER AUTUMN AND SUMMER STUDY PERIODS.

DATE	VESSEL TYPE	KNOWN OR ASSUMED VESSEL ACTIVITY (NO. OF NETS OBSERVED IF SET NETTING)	ACTIVELY FISHING AT TIME OF OBSERVATION?
22/04/2004	Recreational	Line fishing	Yes
26/04/2004	Commercial	Paua diver	Yes
10/06/2004	Commercial	Trawler (assumed)	Unknown
17/06/2004	Commercial	Trawler (assumed)	Unknown
15/12/2004	Commercial	Trawler (assumed)	Unknown
15/12/2004	Commercial	Trawler (assumed)	Unknown
6/01/2005	Commercial	Set-netter (1)	Yes
6/01/2005	Commercial	Paua diver	Yes
7/01/2005	Unknown	Recreational boat or paua diver	Unknown
10/01/2005	Unknown	Recreational boat or paua diver	Unknown
10/01/2005	Commercial	Trawler (assumed)	Unknown
11/01/2005	Commercial	Set-netter (1)	Yes
14/01/2005	Commercial	Trawler (assumed)	Unknown
23/01/2005	Commercial	Set-netter (8)	Yes
23/01/2005	Commercial	Unknown	No
26/01/2005	Commercial	Trawler	No
27/01/2005	Commercial	Trawler	Yes
27/01/2005	Commercial	Unknown	No
30/01/2005	Commercial	Trawler	Yes
31/01/2005	Commercial	Trawler	Yes

All of the 10 set nets that were recorded during the study were observed within one nautical mile of the coast with dolphins at distances of between 5 and 200 m of them. Most nets were set perpendicular to the shore with one end moored just seaward of the last breaking wave. All observations of nets were made in the summer study period. The majority of the nets (8) were observed on a single day in January between the Waikoau Rivermouth and the Rowallen Burn. A diagrammatic representation of the layout of nets on that day is presented in Figure 19.

Figure 19. A diagrammatic approximation of the layout of nets observed set in Te Waewae Bay between approximately the Waikoau rivermouth and the Rowallen Burn on 23/01/2005.



4.10 ADDITIONAL OBSERVED HUMAN IMPACTS

On examination of photographs for distinctive markings it was noticed that one dolphin with a marked fin also had two deep 'Vs' approximately 6 cm apart out of the base of its tailstock (Figure 20). On either side of these Vs are clear scars down its tailstock that slant forwards. The wounds were not deep enough to have injured either the spinal cord or the tendons to the flukes, however, the spinal processes of the vertebrae may have been damaged in this accident (Dawson pers. comm.). While attributing the cause of this injury with absolute certainty is not possible, the forward-sloping scars on this animal suggest that entanglement did not cause the marks (Dawson pers. com.). Instead, the markings are consistent with those caused by a propeller strike. The spacing of cuts resulting from propeller strikes provides information on the size of the engine likely to have been involved (Dawson pers. com.). The approximate 6 cm spacing of cuts on this animal indicates an engine with approximately an 8-8.5 inch pitch (Dawson pers. com.). This level of pitch is typical of a boat with a 15-25 hp engine, but it is possible the engine may have been as big as 50 hp (Dawson pers. com.). That the cuts slope forward suggests that the boat and animal were moving in opposite directions at the time of the collision and that the dolphin was not bow riding at the time (Dawson pers. com.).

Figure 20. A marked dolphin 'Fortune' which has healed cuts out of its tailstock.

4.11 OTHER CETACEANS

Five groups of bottlenose dolphins (*Tursiops sps.*) were sighted during the two study periods. In autumn, one group of approximately 15 animals near Sand Hill Point was encountered travelling rapidly west out of the bay, and a second group of between 40 and 50 at the entrance to Gardner's Bay (on the far east side of the bay). Bottlenose dolphins were encountered on three occasions during summer, in groups ranging in size from 15 to 30 animals. Comparison of photographs of a very distinctive animal within one of these groups with catalogues of bottlenose dolphins seen in Southland and Otago showed that the animal had been sighted in Otago Harbour on a previous occasion, but had not been sighted in Fiordland, where there are three populations of resident bottlenose dolphins.

5 Discussion

Previous research on this population of Hectors' dolphin consists of two boat-based transect surveys as well as collection and analysis of genetic material as part of wider national studies (Dawson et al. 2004; Dawson & Slooten 1988; Pichler 2002a; Pichler & Baker 2000b), in addition to several descriptive aerial surveys (DOC Internal Correspondence 2003a, 2003b, 2003c). This report presents the data from two field periods, each 19 days long, of research on the Te Waewae Bay population and provides a range of basic information, with a focus on abundance and within-the-bay distribution, upon which to build further research and management measures. Given the short period of this study and the corresponding size of the data set, the results presented here are more a snapshot in time of this population during the autumn 2004 and summer 2004/05 periods, rather than a definitive description of the population, and results should be used accordingly. Those qualifications aside, information presented here represents a significant increase in the state of knowledge of this remote population. Another study currently under way over a longer term (24 months) should result in a further increased understanding of this population.

5.1 SURVEY EFFORT

Survey effort was largely dictated by the weather conditions with only 19 days suitable for surveying during each three-month period (excluding a day each becoming familiar with Te Waewae Bay and surveying Toetoe Bay). Variable weather conditions, as often found along the south coast of the South Island, significantly influenced the amount of data collected and therefore the analysis that could be undertaken. For example, a month of excellent weather in January meant that considerably more survey effort took place in this month than in any other. Higher effort in January means that the results presented in this report for summer are likely to be more representative of that month than any other.

Weather conditions also influenced the actual methods that were employed in surveys. At the beginning of this study the intention was to complete a survey loop of the coastal transect and one offshore transect during each day. However, the coastal transect was often much calmer than the offshore transects. Given consistently poor weather conditions, a decision was made during the course of the study that as much time would be spent surveying as possible, even if meant that an entire loop could not be completed. Therefore effort was concentrated along the coast where dolphins more likely to be encountered, as one of the primary aims of this study was an abundance estimate for the dolphins that use the bay, which required as much photographic data as possible.

5.2 SIGHTING DATA

Dolphins were frequently encountered during both periods of the study, with on average, 80.4 (SD = 26.4) and 144.5 (SD = 30.7) dolphins seen each survey day that included a full coastal transect during autumn and summer respectively. The observed increased frequency of dolphin sightings in summer was not unexpected, given the seasonal inshore movement of Hector's dolphins that has been strongly demonstrated in Banks Peninsula (Rayment et al. 2006).

The methodology and daily survey routes within the bay were designed to avoid double counting of dolphins on the same day. While some groups attempted to follow the research vessel during the surveys, this was actively managed by distancing the vessel, at appropriate speeds, from groups upon completion of photography and photographing successive groups of dolphins as efficiently as possible. This involved a trade-off between maintaining the ability to keep dolphin groups separate and photographing all of the identifiable dolphins in each group. Despite these measures, photographic data indicates that approximately 2.7% of observed animals were double counted on the same day. However, this does not impact the abundance analysis as the unit of a day is irrelevant for the purposes of capture-recapture analysis where the secondary periods are months and the primary periods are seasons.

The presence of calves was recorded during both study periods. Calves were sighted more often and made up a greater proportion of the animals observed during summer than in autumn. This was an expected result given that calving generally occurs over spring and early summer (Slooten and Dawson 1994). Mothers with juveniles or calves can be more boat shy than other animals at other stages of life. This could have two effects: 1) these groups may not be sighted at all, or 2) the mothers and calves/juveniles within a group may stay further from the boat, increasing uncertainty about age. Considering these factors, it is likely that the proportion of the population made up by calves presented in this report is an under-representation.

Although we attempted to record the presence of juveniles in encounters there was occasionally uncertainty, because of the distance of the sighting from the boat, about whether or not an animal fitted the definition of a juvenile, and so these data were not included in analyses. To enable better assessment of the age of an animal in future studies, more time could be spent with each group. However as the primary aims of this study were documenting distribution and calculating an abundance estimate, it was only possible to spend a limited time in the vicinity of each group in order to survey as much of the bay as possible over a single day.

The sightings data (i.e. digital images of dolphin dorsal fins, and information on where and when the images were captured) collected over the two study periods were collated into a relational database. Until recently, sightings data of this kind were usually recorded into spreadsheets and photographs in a hard copy catalogue. Since about 2001 most researchers use digital images which are now usually stored in a digital database (usually together with copies of earlier slides and negatives). Use of a digital database to store and catalogue the digital images of marked dolphins has proved an efficient method to store and link information in this study also. Once the database is fully linked with the photographs it may also enable easier comparison of photographs from other populations and studies in the future. We also recognised significant benefit in using a digital camera for many of the summer surveys to photograph dorsal fins, rather than a film camera. Digital photography provides real-time feedback on the quality of the photographs and the opportunity to delete out of focus or less than lateral perspective photographs during the encounters. These benefits made it easier to collect a larger proportion of high quality photographs of dolphins meaning that the required quantity of data could be collected in less time for each encounter in the summer period.

5.3 MARKED DOLPHINS AND ABUNDANCE

The marked dolphin catalogue for Te Waewae Bay at the end of the two study periods contained approximately 70 marked dolphins, 29 of which were animals with sufficient markings (i.e. those we considered could be reliably re-identified throughout the course of this short study) to be used for capture-recapture analysis. The discovery curves of marked animals best supported the use of an open population model that assumed a closed population within autumn and summer. Closure of summer populations was also assumed by Gormley and colleagues (2005) for estimating the abundance of Hector's dolphins around Banks Peninsula.

While CJS models have been used to estimate Hector's dolphin abundance around Banks Peninsula, we opted in favour of using Robust Design in this study. As well as higher precision, another benefit of Robust Design is the ability to tease apart the estimated survival rate into components of temporary emigration (moving out of the sample area on a temporary basis) and permanently leaving the sample area (due to permanent relocation or death), when three or more primary sample periods are analysed (Kendall et al. 1995, Figure 5). Analysis of an additional two years of monthly photographic data (2004-2006) collected by JL Rodda should enable development of a more robust and precise estimate of abundance for the population of Hector's dolphins that use Te Waewae Bay, in addition to providing estimates of survival and temporary emigration.

The mark rate of 7.0% (CV=0.142) for this study of the population of Hector's dolphins at Te Waewae Bay was lower than the mark rate for category 1 and 2 Hector's dolphins at Banks Peninsula reported by Gormley et al. (2005) (Q = 10.46%, SE = 0.0057) despite using slightly more subtle marks in this study. However, mark rates are not anticipated to be the same between populations, given ecological differences and differences in human activity, such as fishing pressure, which probably influence mark rate. While we attempted to assess fishing activity in the bay during this research, we could not do this to a degree that would enable a worthwhile comparison with fishing around Banks Peninsula. Furthermore, Ministry of Fisheries' data on fishing effort is not at the appropriate scale to enable such a comparison. Given the results of this study it is important to emphasise that low mark rates make the final abundance estimates very sensitive to changes in the estimate of the marked population and changes in the mark rate itself (e.g. a change in the mark rate from 7% to 9% in this study would change the summer estimate to 314 dolphins (95% CI = 214-458).

Given the role of mark rate as the scaling factor in estimating abundance using mark recapture techniques, it is crucial that this value is both accurate and accompanied by appropriate estimates of precision. In this study the mark rate was derived from

884 photographs taken during both this field work and field work conducted by JL Rodda. Furthermore, in this study, the estimate of precision of the mark rate was improved by accounting for replication of samples (photographs) during collection, by calculating a "true sampling ratio". Adjustment of the sample size to remove pseudo-replication by applying this ratio meant that we were able to produce a mark rate with variances that were a better reflection of the actual precision of our estimate. Failure to apply the ratio would have resulted in estimates of variance that were artificially more precise. Future studies using a similar field approach of attempting to take multiple photographs per animal should also consider applying a scaling ratio to improve estimates of precision.

The seasonal abundance estimates for autumn of 251 (CV = 0.162; 95% CI = 183-343) and 403 (CV = 0.207; 95% CI = 269-602) for summer, suggest that more dolphins may use Te Waewae Bay in summer than in autumn. However, this could be due to seasonal re-distribution of individuals in the area, such as occur in other Hector's dolphin populations. Also, the difference is not significant as the confidence intervals overlap. Changing the layout of offshore transects between autumn and summer probably had little influence on any difference between the seasonal abundance estimates given that the overwhelming majority of dolphin sightings (95.4%) were made along the coastal transect, which remained unchanged and had similar survey effort between seasons. However, additional seasonal abundance estimates from data collected by JL Rodda should be useful in determining whether seasonal changes in abundance have occurred in other years, as well as improving the overall precision of the estimates. In particular this work will provide more data on mark rate and mark rate estimates. Similar seasonal changes in distribution have been observed elsewhere in Southland, such as the use of Porpoise Bay by a population of 43 (95% CI = 40-48, Green 2003) Hector's dolphins during the summer months only (also see Bejder and Dawson 2001).

The summer population abundance estimates calculated using Robust Design were higher than the corrected abundance estimate from line-transect surveys in 1998/1999 of 89 animals (CV = 0.324; 95% CI = 36-218, Dawson et al. 2004), although the lower confidence interval for the autumn estimate did overlap slightly. However, it is important to emphasise that these two types of estimates are not directly comparable as they measure different sampling areas and time periods and therefore different populations (Gormley et al. 2005). Line-transect surveys measure the population that is present in the study area at the exact time of the survey along the area defined by the specific transect lines. By contrast, capture-recapture methods use information gathered over a much longer period of time and provide an abundance estimate for the number of individuals that have used the area over that period (e.g. months, seasons or years). Because of this difference, capture-recapture sampling is more likely to capture animals that use the sampling area more infrequently (Childerhouse et al. 1995) thereby increasing the size of the effective sampling area (Gormley et al. 2005). As such, these results should not, under any circumstances, be interpreted as meaning that the Te Waewae population has increased in number since the line-transect surveys of 1998/99. There is no evidence at this time to establish if an increasing or decreasing trend in abundance has or is occurring over this timeframe.

We consider that capture-recapture methodology is particularly useful for local management purposes given that it provides estimates of the total number of dolphins that use the bay during the entire autumn and summer periods, rather than the number of dolphins that are in the bay at one instance in time (as provided by the line-transect method). It is fundamental that mangers understand the differences between estimates derived using these two approaches in order to ensure implementation of the appropriate level of protection.

The difference between line-transect and capture-recapture summer abundance estimates for Te Waewae Bay suggests that either dolphins were missed on the earlier survey or that only a portion of the population that uses the bay is within the bay at any one time. The latter theory is supported by the fact that the number of dolphins sighted each day for summer and autumn are much lower than the abundance estimates for these periods. This emphasises the importance of areas outside Te Waewae Bay to this population of Hector's dolphin. Assuming that this is an accurate description of these dolphins, an effective management plan for Hector's dolphins that use Te Waewae Bay would need to include implementation of management provisions to areas outside the bay. Therefore, information on alongshore and offshore ranges of these dolphins is crucial. In the absence of this information, effective interim management measures should be based on best available data from elsewhere. However, such information should only be used until better information on the local population is available given the marked differences between populations that have been observed elsewhere.

5.4 DISTRIBUTION

Mapping of dolphin sightings as a density figure was effective in normalising the sighting results for survey effort. In both autumn and summer dolphins were present fairly consistently within 400 m of the shore along the coast of most of the bay, with the exceptions of the most eastern and western parts of the bay and the area immediately in front of the Waiau rivermouth where sighting densities were lower. There are a number of environmental differences between the extremities of the bay and the main body of the bay that might help account for these differences. For example, the extremities are rocky reef areas, that are often more sheltered from the swell, especially along the western edge, whereas the body of the bay has a sandy bottom and faces an often large swell from the south or south-west. Irrespective of these differences in average density of dolphins within the bay, this study showed that the entire coast of Te Waewae Bay is used by this population, at least occasionally.

Information collected in this study on depth was limited by the design of the survey lines and by the relatively shallow depth of the bay (30m) compared to the depth at which Hector's dolphins are observed elsewhere (e.g. commonly up to 80 m off Banks Peninsula and 50 m off the upper west coast). Given that depth has been shown to be a good indicator of local distribution and that depth limits appear to be different for different populations, further work at greater, and variable, depths would be required to investigate any role of depth in influencing this population's distribution. The relatively shallow depth of not more than 50 m between the South Island and Rakiura / Stewart Island means that this whole area may at times be used by Hector's dolphins.

An inshore movement of animals in summer, compared to autumn, was indicated in this study and has also been noted in studies of Hectors' dolphins elsewhere, especially at Banks Peninsula (Rayment et al. 2006; Slooten et al. 2004). This finding for Te Waewae Bay needs to be caveated with recognition that the offshore transect survey routes were altered between the autumn and summer periods. Improved layout and precision of the offshore transects over the summer period allowed clearer investigation of distribution as a function of the distance of sightings from the shore. The negative consequence of this was that this undermined direct comparisons of data collected along the offshore transects between the two study periods. Further work would be required to properly asses seasonal movements.

Analysis of the sighting data of the five most commonly encountered distinguishable dolphins indicated evidence of clustering in specific areas of the bay. Three of the dolphins were always encountered at the mouth of the Waiau River and to the east, and two were only encountered to the west of the river. This finding is consistent with research elsewhere which has shown that individual animals have distinct ranges within their population's range (Brãger et al. 2002), and has implications for management given the vulnerability to fragmentation that this characteristic creates. The findings presented in this study however were based on a very small sample size over a relatively short duration of time, and so extension of these results to the whole population at this point would not be warranted. Further work on a larger proportion of the population over longer durations would be required to investigate aspects of individual animals' movements to provide information useful for management. Although we attempted to identify potential nursery areas, there was no evidence for such areas as the distribution of calves throughout the two sampling periods was not dissimilar to the distribution of all other sightings.

5.5 RANGE OUTSIDE TE WAEWAE BAY

The geographic definition of the population's full home range is a vital piece of information required to inform management provisions. The importance of such information is demonstrated by aerial surveys around Banks Peninsula in 2004 where 93% of groups were sighted inside the 4 nm sanctuary during summer, compared to only 43% in winter (Rayment et al. 2006). As such, there are concerns as to whether the sanctuary is adequately protecting this population of Hector's dolphin throughout the year (DuFresne 2004; King & Brooks 2004; Slooten et al. 2006b).

Time and weather were limiting factors in our ability to survey the Southland coast outside Te Waewae Bay during this study. Given that no dolphins from the catalogue of Te Waewae Bay dolphins have been seen in Toetoe Bay over a total of ten previous surveys, and that no dolphins from Toetoe Bay/Porpoise Bay were sighted in Te Waewae Bay on the one survey conducted during this research, it appears that individuals from these two populations may not, or may only rarely, mix. Additional survey effort will be needed to test this hypothesis. Hector's dolphins are reported with some regularity at Oreti beach, however the absence of reported sightings suggest they are not present in Bluff Harbour (DOC Incidence Database). The distance between the easternmost point of Te Waewae Bay and Bluff is approximately 65 km. This distance is farther than the maximum distance between sightings of 60 km for 30 of 32 animals in a study assessing home ranges of individual Hector's dolphins at Banks Peninsula (Brãger et al. 2002). However, given that sightings of the other two dolphins in the study were made at locations more than 100 km apart (Brāger et al. 2002), it is not an altogether unlikely scenario that some animals that use Te Waewae Bay also use areas as far east as Bluff or farther.

This would suggest that Bluff, or somewhere farther west, could be the eastern boundary for dolphins that use Te Waewae Bay. The relationship between this population, and those that use Toetoe and Porpoise Bays will be better understood with further analysis of genetic samples collected from the two populations, which is currently underway. The assumed western boundary of the normal range of Hector's dolphins that use Te Waewae Bay is Long Point, Fiordland. This is supported by genetic analysis of mitochondrial DNA which suggests that there is only a small amount of geneflow through the fiords between the south cost population and the west coast (estimated at a long-term effective migration rate of 2.7-3.7 females per generation). Perhaps more surprisingly, geneflow is even lower between the Te Waewae Bay and dolphins on the east coast of the South Island (Pichler 2002a, 2002b).

In addition to the genetic analysis already underway, further work is required to assess both the extent of the alongshore and offshore range (especially given the comparatively shallow depth gradient out to Rakiura / Stewart Island) of Hector's dolphins that use Te Waewae Bay, and the relative importance of these areas (whether they be within or outside the bay). This work should be linked to an assessment of the anthropogenic threats facing these dolphins throughout their range.

5.6 FISHING ACTIVITY

It is likely that more nets were present in the bay and on more occasions than were observed over this study period given the size of the bay and that fishing boats can operate in more diverse weather conditions than the research vessel. Although no recreational set netting was observed during the study, local fishers have indicated that it occurs in the bay, particularly over the months of summer, near the eastern end of the bay (Anon. pers. comm.). Given the observations of fishing effort made during this study and anecdotal evidence, it is apparent that set netting in Te Waewae Bay primarily occurs along the inshore strip of the bay, where the density of Hector's dolphins is highest.

Bycatch is a significant problem where set net fisheries overlap with the ranges of small inshore cetaceans around the world including Hector's dolphins in New Zealand (Burkhart & Slooten 2003; Martien et al. 1999; Slooten et al. 2000). Between 1988 and March 2007, 13 carcasses of Hector's dolphins were recovered in Southland. Of these, the cause of death was attributed in just 3 instances. One of these animals was an adult with net marks around its head which died as a result of asphyxiation, consistent with entanglement (Duignan 2004). Unfortunately it is not possible to provide an estimate of the level of bycatch of Hector's dolphin in and around Te Waewae Bay, despite this evidence of some fisheries-related mortalities occurring in Southland. This is because in addition to these recoveries, researchers were anonymously informed of other credible yet officially unreported deaths in Te Waewae Bay that were the result of net entanglement. This indicates that under-reporting of accidentally caught animals has occurred historically.

Furthermore, it is likely that the size and remoteness of Te Waewae Bay and the wild weather conditions that are often present there mean that the number of dead dolphins found in the bay and reported is only a fraction of the total number that actually wash up and are subsequently found. Although it is compulsory to report causing accidental mortality of a marine mammal species in New Zealand, the degree of actual reporting is thought to be low and even the requirement to do so may not be well-understood by fishers and the public (Anons. pers. comms.). All of these factors contribute to the likelihood that entanglement in nets is a significant threat to Hector's dolphins in Te Waewae Bay.

The Hector's Dolphin Threat Management Discussion Document (MFish & DOC 2007: 94) states that potential biological removal (PBR) analysis using the line-transect abundance estimate for Te Waewae Bay of 89 dolphins (CV = 0.324; 95% CI = 36-218) indicates that "no human-induced dolphin mortalities can occur each year". Using the same technique but with the much higher summer abundance estimate derived in this study, PBR analysis indicates that this population still cannot tolerate even one human-induced mortality each year in order to reach or maintain the optimum sustainable population[4].

Fishery bycatch is not the only human-induced threat to Hector's dolphin that was observed in Te Waewae Bay. One animal showing forward sloping wounds on its tailstock thought to be the result of boat strike, was observed and photographed during the study. In addition to this injured animal, necropsy of a dead Hector's dolphin body recovered from Te Waewae Bay during this study showed that the animal died as a result of choking on a flatfish that was too large to swallow safely. The examiner noted that the animal had a non-lethal spinal injury that was consistent with a boat strike and that this injury may have forced the dolphin to feed on less desirable prey, such as fish that may be too big to swallow (Duignan 2005).

Boat strike has been documented as having affected many cetacean and sirenean species around the world (e.g. Beck et al. 1982; Zhou & Zhang 1991; Wells & Scott 1997) and in New Zealand waters (Lusseau et al. 2002). Two incidents of boat strike resulting in the death of Hector's dolphin calves were reported from Akaroa Harbour over the summer of 1999 (Stone & Yoshinaga 2000). Compared to some other areas where Hector's dolphins are found, Te Waewae Bay has very low levels of boat traffic. However, the presence of one animal with non-lethal injuries probably from a propeller, and a dolphin carcass with injuries also consistent with boat-strike indicates that it may be a threat to Hector's dolphins even in this remote location. Although the threat is probably comparatively low, education about appropriate boat handling around dolphins is needed to reduce the risk of future strikes.

4 The analysis is based on a maximum productivity rate at a small stock size of 0.034 and a recovery factor of 0.15, as suggested by the Ministry of Fisheries and the Department of Conservation (2007). The optimum sustainable population is the number of animals that results in the maximum net productivity of a population, which is likely to be between 50% and 85% of the ecological carrying capacity.

5.7 OTHER CETACEANS

Very little information is available on bottlenose dolphins that use the south coast of the South Island. This study suggests that bottlenose dolphins appear to be reasonably frequent visitors to Te Waewae Bay. There are also anecdotal reports by local people of the regular sighting of bottlenose dolphins off Rarotoka (Centre Island), in the Aparima River mouth, and in Patterson's Inlet, however it is not known whether these include any of the same animals. One of the well-marked bottlenose dolphins observed in Te Waewae Bay had previously been observed in Dunedin Harbour in 2003. This animal has not been observed in Fiordland suggesting that it, and other dolphins it associates with, may be separate from the dolphins resident in Fiordland. Additional research and/or continued opportunistic photographing of bottlenose dolphins seen along the south coast in the future would enable a better understanding of the range of these southern-most bottlenose dolphins and the level of interaction with resident bottlenose dolphins in Fiordland and with animals found along the east coast.

5.8 RECOMMENDATIONS FOR FUTURE WORK

While specific future research priorities will be influenced by management provisions that arise out of the Threat Management Plan currently being developed and the need to monitor the effectiveness of those provisions, we consider that there are three primary research themes that require further attention (outlined below).

Population definition

Further work is required to assess the ranges and connectedness of populations along the south coast. Forthcoming genetic analysis should be of assistance in this regard. Research is also required to determine the offshore range of these dolphins. It may also be helpful to test for seasonal changes in distribution outside Te Waewae Bay to ensure appropriate management boundaries throughout all seasons. This would require alongshore and offshore surveys. The degree of research required would depend on the type of management provisions implemented via the Hector's Dolphin threat management process.

Threat identification

Available information both from this research and reported bycatch mortalities indicates that entanglement deaths currently pose a threat to the viability of this population. Further attention should therefore be given to examining the overlap of fishing activity throughout the range of south coast Hector's dolphins, and better quantifying the number of human-induced mortalities.

Abundance and survival

Future research can utilise and build upon conclusions from the data collected in this study to provide better abundance estimates, investigate abundance trends, and estimate survival. This will allow development of a localised population model that will be of greater use in determining how to best manage the population that uses Te Waewae Bay and the wider south coast population in the long-term.

In the first instance, this will involve analysis of the sightings data and photographs from 2004 to 2006 collected by JL Rodda, a PhD candidate at Otago University. Analysis of these data will be helpful in expanding our knowledge gained during the first two capture-recapture survey periods of the population of Hector's dolphins at Te Waewae Bay. However, further data collection will be required over the longer term to asses any changes in the population. Options for doing this include conducting the aerial survey programme suggested by DuFresne (2007), which aims to provide an index for changes in abundance, or to derive full capture-recapture abundance estimates at wider intervals (e.g. every five years). A combination of these two techniques might provide the best result, by being both cost-effective and allowing for comparison of results derived by the two techniques over time.

Given that there is a provision in the Southland/West Otago Conservation Management Strategy (CMS) prohibiting any boat-based commercial viewing of the Te Waewae Bay population, additional information on behaviour of this population is likely to be of lower management priority compared to the above three research themes. However, this would need to be reassessed if the relevant provision in the CMS was amended to allow for dolphin-watching.

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