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Population Biology and the Effects of Tourism on Hector's Dolphins (*Cephalorhynchus hectori*), in Porpoise Bay, NZ

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Abstract

A small population of Hector’s dolphins (Cephalorhynchus hectori) in Porpoise Bay, New Zealand, attracts a single commercial dolphin-watch vessel as well as an increasing number of swimmers who enter the water from the shore. The aims of this study were to collect data on the effects of this tourism, estimate abundance of the population, quantify distribution and alongshore range, and provide recommendations for management.

Photo-identification surveys were conducted on 39 and 62 days during the summers of 2001/02 and 2002/03 respectively. Nineteen dolphins were identifiable from naturally occurring markings. Ten of these had been identified during 1995-97, showing dolphins are seasonally resident over the long term. Large variability in the number of times individuals were sighted suggests that some dolphins are resident and others are occasional visitors. Chapman’s version of the Lincoln-Petersen mark recapture estimate was scaled up using a mark rate of 46.8 % to provide an abundance estimate of 43 dolphins (95 % CI = 40 - 48). This estimate was lower than the estimate of 48 dolphins calculated five years ago (95 % CI = 45 - 55), though confidence intervals overlapped.

Theodolite tracking from a land-based station over 189 hours on 48 days during 2001/02 and 190 hours over 56 days during 2002/03 showed dolphins preferred a small area in the southern part of the bay. Overall distribution was similar to that observed during 1995-97. Dolphins became more congregated in the southern part of the bay during successive times of the day from morning to afternoon. Small differences in monthly distribution and distribution in the presence of boats and swimmers observed in 2002/03 were not apparent in 2001/02. Dolphins showed no sign of displacement from the bay since 1997.

Over the research summers dolphins in Porpoise Bay spent, on average, 33 % of observation time in the presence of boats and swimmers. This has increased from 24 % in five years. Time spent with swimmers within 200 metres has increased almost three-fold. Analysis of theodolite data showed dolphins approached boats no more frequently than would be expected by chance during 2001/02, but were attracted to boats during 2002/03. Although the duration of an encounter had no effect on the probability of a dolphin heading towards a boat, dolphins became less interested in swimmers with time. Whereas in 1995-97 dolphin pods were found to become tighter in the presence of boats and swimmers, during the current research dolphin pods became more dispersed. In addition, behavioural budgets differed in the presence of tourism, with dolphins ‘diving’ less and ‘milling’ and ‘socialising’ more when near boats and swimmers. Effects were strongest in response to boats and inevitably have some metabolic cost.

Boat surveys along the coast comprised the first attempt to document this population’s range beyond the bay. High dolphin density was found at Toetoe Bay, 35 km west. Low survey effort meant few conclusions about density to the east could be drawn. Comparison of identifiable dolphins seen in Toetoe Bay showed they comprise the same population as dolphins in Porpoise Bay. Some evidence suggests that dolphins exhibit a seasonal alongshore shift, though higher survey effort is needed to test this hypothesis.

Implications of these data are discussed with regard to the establishment of a Marine Mammal Sanctuary in the area. Recommendations to aid the management of this population are proposed and potential avenues for future research are discussed.
Acknowledgements

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Chapter 1. Introduction

1.1 Hector’s dolphin

Hector’s dolphin (*Cephalorhynchus hectori*)\(^1\) is one of four species that comprise the genus *Cephalorhynchus*. Like the other species in the genus, namely the Chilean dolphin (*C. eutropia*), Commerson’s dolphin (*C. commersoni*) and Heaviside’s dolphin (*C. heavisidii*), they are small marine dolphins with a highly coastal distribution in the Southern Hemisphere (Slooten and Dawson, 1994).

Hector’s dolphins are endemic to New Zealand and have a range and abundance that is much smaller and, in the case of the North Island population, more fragmented than it was historically (Martien et al., 1999; Dawson et al., 2001; Baker et al., 2002). In fact, the North Island population is now so genetically distinct that it has recently been declared a subspecies, named Maui’s dolphin (*C. hectori maui*; Baker et al., 2002). South Island Hector’s dolphins (*C. hectori hectori*) consist of three separate genetic groups, found on the west, east and south coasts (Pichler et al., 1998; Pichler and Baker, 2000). Concentrations of dolphins are found in areas on the west coast, around Banks Peninsula and at Te Waewae Bay (Slooten et al., 2002). Local populations of Hector’s dolphin appear to be discrete with small home ranges and little long-shore movement (Bräger et al., 2002). Although home ranges can extend up to 60 km along the shore, dolphins typically utilise small areas within these ranges (Bräger et al., 2002).

Estimates of Hector’s dolphin abundance have involved both boat and aerial surveys, the most recent of which estimates a total South Island population of 7,270 (95 % CI = 5303 - 9966; Slooten et al., 2002). The North Island sub-species may consist of fewer than 100 individuals (Martien et al., 1999; Russell, 1999; Dawson et al., 2001). These figures have led the IUCN to classify Maui’s dolphin as ‘critically endangered’, and the South Island population as ‘endangered’ (Reeves et al., 2003). The Department of Conservation’s (DOC) threat classification lists *C. hectori hectori* as

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\(^1\) While there exist a number of Maori names for dolphins, Dawson and Slooten (1996) suggest that *tutumairekurai* is the most widely used in reference to Hector’s dolphin.
nationally vulnerable and *C. hectori maui* as nationally critical (DOC, 2002). The department is currently in the process of drafting a population management plan with the aim of bringing the species to an unthreatened status within twenty years (DOC, 2002).

1.2 The effects of human activities

Human activities on water and land can affect marine mammals in a number of ways. The effects of such activities can be indirect or direct, immediate, short-term or long-term, and may alter the behaviour and physiology of animals, sometimes even resulting in the injury or death of an animal. For example, a recreational boater may travel at speed near a pod of dolphins, unaware of their presence, and accidentally strike an animal. Here, the boat strike is the ‘direct impact’ and the animal’s injury or death is the ‘effect’. Human activities can have a less serious effect, for example a boat may travel at some distance from a pod, increasing the ambient noise level in the dolphins’ environment (the indirect impact), with the result that feeding is temporarily disrupted (the effect). Such threats may not influence an individual’s survival or reproductive success in the long-term, however, if the impact is repeated and/or prolonged, the animal’s survival may be compromised. If enough animals are affected the survival of the population may become threatened.

The similarities among the species within the genus *Cephalorhynchus* extend beyond factors of their ecology to include the anthropogenic activities that affect them. All four species suffer serious fisheries related mortalities, largely because their coastal distribution overlaps with areas used for gill-netting (Dawson, 2002). The extent of net related mortalities on Hector’s dolphin was better understood with research by Dawson (1991) who found that at least 230 dolphins were killed in gillnets between 1984 and 1988 in the Banks Peninsula region alone. This level of bycatch was well in excess of what was considered sustainable (Slooten and Lad, 1991). In addition to low total abundance (Slooten et al., 2002), Hector’s dolphin, like many other cetaceans, is thought to have a low maximum potential growth rate, of approximately 2 % (Barlow and Boveng, 1991; Slooten et al., 1992). This low potential for growth means that recovery from fisheries mortalities will be a slow process, even under ideal, zero bycatch conditions (Slooten and Lad, 1991).
While fisheries-related mortalities undoubtedly remain the most serious threat to the conservation of this and other coastal dolphin species, other threats are present and increasing. These threats include newly recognised factors such as reduced prey availability and possible changes to the environment as a result of global warming (Fair and Becker, 2000; Reeves et al., 2003). In addition, sea and river developments such as those involved in aquaculture result in reduced habitat availability, a problem that was once faced only by land animals (e.g. Richardson and Fraker, 1985; Clement, et al., 2001). Pollution too is of significant concern as pollutants such as Polychlorinated Dibenzo-p-dioxins (PCDDs) and Dibenzofurans (PCDFs) have been implicated in reproductive and immune disorders in cetaceans (Addison, 1989; Buckland et al., 1990). Hector’s dolphins’ coastal distribution and their position near the top of the food chain, mean that they have a high chance of exposure to pollutants.

Vessel traffic in New Zealand coastal waters and in harbours mean that boat strikes are a risk to cetaceans here (Beck et al., 1982; Stone and Yoshinaga, 2002). While such strikes can result in mortalities, the effect of increased noise levels that these boats create is also of concern (e.g. Au and Green, 2000). Cetacean species all rely on sound for essential daily functions such as communicating, finding prey and navigating. While there are an increasing number of studies investigating how elevated background noise effects cetacean behaviour, it is still poorly understood (e.g. Richardson et al., 1995; Richardson and Würsig, 1997; Erbe, 2002). The biological implications of these changes are even less well understood and are notoriously difficult to measure especially in the long term, however they may be serious, particularly if cumulative effects occur.

While cetacean tourism is undoubtedly preferred over hunting as a means to generate an income from whales and dolphins, it is essential that management authorities govern commercial activities in a way that is least invasive to the cetacean species being targeted (Corkeron, 1995). Of special concern is the establishment of new tourism ventures where studies of the whales or dolphins have not been made and where the cetaceans have previously been exposed to low levels of boat traffic.
1.3 The development and growth of the whale-watching industry

Since the first commercial watching of gray whales (*Eschrichtus robustus*) began in the 1950s the growth of the whale-watching industry has thrived and spread around the world (Tilt, 1989; Hoyt, 2001). Tourism is now the largest industry on earth, and whale-watching, which is offered in 87 countries, generates an estimated US $1billion annually (Hoyt, 2000). In addition to the economic benefits that communities with successful whale-watching industries experience, it is argued that the potential educational opportunities it provides are highly valuable (Forestell, 1993; Amante-Helweg, 1996). Guided encounters with cetaceans provide tourist operators an audience of interested public who are generally open to ideas about conservation of that species, as well as other marine issues (Gordon et al., 1992; Higham et al., 2001). Research into whether tourist operators fully utilise these opportunities, and to what extent people learn from their involvement in cetacean viewing and swimming is limited. However, whale-watching can certainly generate funding for conservation and scientific research (Ris, 1993).

1.4 The downside of the industry

Though the economic benefits of whale-watching are clear, research on the effects on the often unregulated vessel interactions has, not surprisingly, fallen behind the growth of the industry. Ideally, research should begin prior to the development of any such venture (Berrow and Holmes, 1999). This way an appropriate tourist carrying capacity can be determined and implemented, and any changes in cetacean behaviour can better be attributed to tourism presence. Changes in cetacean behaviours in response to tourism may lead to reduction of time spent in crucial behaviours such as mating, resting and feeding (Kruse, 1991; Nichols et al., 2001). In turn, the biological fitness of individuals, and the population as a whole may be decreased (Kruse, 1991; Gordon et al., 1992; Erbe, 2002).

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2 In the cetacean tourism literature the term ‘whale-watching’ encompasses all forms of cetacean watching, both whale and dolphin based. I shall also use this definition throughout this thesis.
Whale-watch ventures exist to various degrees of development worldwide, from single boat operations carrying a few passengers to see whales once a day during a particular season to large businesses with a number of boats carrying up to 100 passengers and making multiple trips per day, year-round. Such ventures in some areas can mean that animals have few daylight hours when they are not exposed to boats, for example, bottlenose dolphins (*Tursiops truncatus*) in the Bay of Islands (Constantine 1995) and dusky dolphins (*Lagenorhynchus obscurus*) in Kaikoura. Also in Kaikoura, Richter and colleagues (2002) found that resident sperm whales (*Physeter macrocephalus*) were accompanied by at least one boat approximately half of the total time they spent surfacing. In another study, killer whales (*Orcinus orca*) in Johnston Straight, British Colombia, were found to be accompanied by a boat approximately 50 per cent of the time they were observed and were commonly followed by up to four boats at a time (Kruse, 1991).

Cetacean behaviour towards boats has been shown to be highly variable (e.g. Orams, 1997; Constantine, 1999). For example, fin whales (*Balaenoptera physalus*) off Cape Cod, Massachusetts, ceased to approach whale-watch boats over a period of 25 years, whereas humpbacks (*Megaptera novaengliae*) in the same area showed an increased proportion of approach responses to boats, suggesting that they may have habituated to the presence of the vessels (Watkins, 1986). In the most extreme documented reaction, gray whales in a Mexican lagoon stopped using an area in apparent response to intense boat traffic, returning when usage reduced (Jones and Swartz, 1984). Avoidance behaviours towards boats can be difficult to observe, either because the changes made are within the normal behavioural repertoire of the animal or because they occur at great distances. For example, belugas (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in the Beaufort Sea changed their course to avoid boats from as far away as 35 km (Myrberg, 1990).

In addition to avoidance versus approach behaviours, cetaceans change other behaviours in the presence of boats. For example, changes in ventilation times, vocalisation, orientation, aggression levels and swimming speed have all been documented (Corkeron, 1995; Janik and Thompson, 1996; Orams, 1997; Williams et al., 2002). In New Zealand, Barr and Slooten (1999) found that dusky dolphins displayed aerial behaviour more often in the presence of boats. Killer whales in
Johnston Straight increased swimming speed and changed direction to open water in response to boat disturbance (Kruse, 1991).

Variability in reactions can be attributed not just to species differences, but to differing tolerance levels of individuals within a species (Richter et al., 2002). An example of this can be seen among male sperm whales at Kaikoura, where a small number of resident whales are much more tolerant of tour boats than transient whales passing through the area. The tour operators, who can often identify individuals, are thus able to seek out animals that are habituated to their presence and whose behaviour seems to change very little regardless of the presence of boats (Richter et al., 2002). Recent research in Doubtful Sound, New Zealand, showed that bottlenose dolphins avoided boats vertically, increasing diving interval before boats were in visual contact (Lusseau, 2003a). These responses were observed in males as soon as boats were present, but not in females until boat driving became erratic. Lusseau (2003a) proposes that the different avoidance strategies observed based on sex reflect the different metabolic regime of the sexes with females avoiding boats, an energetically expensive exercise, only when risks of non-avoidance became too high.

Cetaceans are not only exposed to boats but also to swimmers entering the water. As with their reactions to boats, cetaceans’ reactions to swimmers are highly variable. For example, some rough toothed dolphins (*Steno bredanensis*) have been observed to be highly attracted to swimmers, while others ignored, or actively avoided them (Ritter, 2002). Bottlenose dolphins in Port Philip Bay, Australia, which are the target of three ‘swim-with’ and two ‘viewing’ tour operations, were found to significantly increase the number of whistles made in the presence of ‘swim-with’ tours (Scarpaci et al., 2000). This was irrespective of the behaviour they were engaged in before the swim-with attempts. Scarpaci and colleagues (2000) propose that the boats and swimmers affected in some way the pod’s cohesion, perhaps by increasing ambient noise, which left the dolphins unable to easily ascertain where other members in the group were. Alternatively, the increase in whistling may have been an indication of increased excitement of the dolphins when swimmers were present (Scarpaci et al., 2000). In the Bay of Islands, New Zealand, bottlenose dolphins exposed to swim-with attempts from a vessel actively avoided swimmers on 22 % of encounters while common dolphins (*Delphinus delphis*) did so on 38 % of attempted interactions.
(Constantine and Baker, 1997). Constantine (1995) found that swimmers placed from a boat abreast of dolphins invoked the least evasive actions when compared to swimmers placed in the path of the dolphins and swimmers that stayed around the boat.

As noted by Corkeron (1995), many changes that cetaceans make in the presence of tourism are within their normal pattern or overall rate of behaviours. Changes resulting from a specific interaction are therefore often hard to detect in the course of a normal tour. However, this does not mean that effects are not serious. In the only truly long-term study on the effects of tourism on cetacean behaviour in Monkey Mia, Australia, evidently harmless feeding of wild dolphins resulted in higher juvenile mortality in bottlenose dolphins (IFAW, 1995). This was attributed to the lower parental care, specifically protection of young from predators, by provisioned mothers.

Such findings have led many countries to implement guidelines regulating whale-watching. Ideally, the industry should be managed in a way to provide the greatest benefit to the species involved, through raised awareness of conservation and associated funding, and with minimal biological implications, while at the same time providing appropriate economic benefits for the industry. These tourism ventures must also be supported by the local community for the development to be socially as well as biologically sustainable.

1.5 New Zealand regulations for whale-watching

Early regulation of whale-watching in New Zealand came about as a result of growing concern by both the public and the government at the effect of whaling, and other anthropogenic sources of stress on cetaceans. Regulations were set out in the Marine Mammals Protection Act (MMPA) which was passed in 1978 and forbade the ‘taking’ (kill/harass/harm/attract/ herd/injure/poison) of marine mammals. In response to the rapid growth of the whale-watching industry more specific guidelines were drafted in the Marine Mammal Protection Regulations (1990), specifically designed for the Kaikoura area. These were later revised in 1992 to regulate tourism in the remainder of the country (Donoghue, 1996). Under the regulations a permit system governed by
conservancies within DOC allows whale-watching on the condition that the animals are not harassed in the process. This system also controls commercial effort by restricting the number of operations and amount and type of activity undertaken by each operator (Orams, 1997). Regulations also require operators to provide ‘sufficient educational value’ to participators and to promote conservation, protection and management. In addition to these nationwide rules, Marine Mammal Sanctuaries have been established at Banks Peninsula, for Hector’s dolphin, and the Auckland Islands, for the southern right whale (*Eubalaena australis*). Such sanctuaries are advantageous in that they are flexible, allowing the creation of guidelines and by-laws specific to a species and locality.

1.6 Hector’s dolphin – a species targeted by tourism ventures in New Zealand

Currently more than 10 cetacean species can be viewed and/or swum with in many locations around New Zealand’s coast (Constantine, 1999). Kaikoura is undoubtedly New Zealand’s whale-watching capital as an abundance of marine mammal life, including sperm whales and dusky dolphins can be found there, and the industry is accordingly well-developed. Commercial viewing of our most-threatened cetacean, Hector’s dolphin, is available at Akaroa, Banks Peninsula, Greymouth, on the West Coast and in Porpoise Bay, the Catlins (Constantine, 1999).

The highly coastal distribution of Hector’s dolphins, together with their attraction to boats and high level of site fidelity, make them highly attractive targets for marine mammal tourism ventures (Baker, 1983; Bejder et al., 1999; Bräger et al., 2002). In addition, their status as a threatened species creates heightened public interest in their ecology and plight. However these same features also make them very vulnerable to disturbances associated with tourism (Bejder et al., 1999). At Akaroa on Banks Peninsula, one of the species’ strongholds, four tourism ventures, with up to four boats each, convey passengers to dolphins within the harbour, one using kayaks. Three of these also allow passengers to enter the water and swim with dolphins. By New Zealand standards Akaroa represents a relatively highly developed example of cetacean tourism, Porpoise Bay on the south-east corner of the Catlins, provides a contrasting example of small-scale cetacean tourism (Fig. 1.1).
At Porpoise Bay, a sole tourist operator runs up to three trips per day taking passengers to view the dolphins. In addition, dolphins, which are commonly found within 30 m of the shore (E. Green, pers. obs.), are targeted by swimmers from the beach who seek an encounter with wild dolphins. While this creates an excellent opportunity for people to experience viewing and even swimming with the dolphins directly off the beach, the small population size (see Chapter 3) means that swimmers in the bay probably interact with the same dolphins on each trip. This is a very different situation to other ventures for example in Kaikoura, where tourist boats interact with pods of non-threatened dusky dolphins that may consist of up to 1,000 dolphins in a single pod (Barr and Slooten, 1999).

Figure 1.1. Map of New Zealand showing the area over which Porpoise Bay Hector's dolphins are known to range.
1.7 The Porpoise Bay/Te Whanga Aihe population of Hector’s dolphins

As evidenced by the albeit inaccurate naming of the bay, a population of summer-resident Hector’s dolphins have utilised Porpoise Bay for more than a century (W. Cooper, pers. comm.). While local knowledge of the dolphins’ presence has existed for a long time, very little detailed information was available about the population until research was conducted in the bay by Bejder in the summers of 1995/96 and 1996/97 (Bejder, 1997). Mark-recapture analysis of photographic data collected in this study estimated that a semi-resident population of 48 dolphins (95 % CI = 44 - 55) used the bay (Bejder and Dawson, 2001). Theodolite tracking revealed that dolphins preferred a very small area at the southern end of the bay confined by a reef system, and that sightings of dolphins drew closer together as the day progressed (Bejder and Dawson, 2001). In addition, it was found that dolphins were accompanied by boats for 12.4 % and by swimmers for 11.2 % of observation time. While swimmers had no detectable effect on pod dispersion, in the presence of boats dolphin pods became significantly more tightly bunched (Bejder et al., 1999). Research indicated that dolphin interest in boats was significantly positive in the initial stages of an encounter but that dolphin interest decreased with time (Bejder et al., 1999).

Since 1997 the number of tourists visiting the Catlins, and Porpoise Bay specifically, has increased enormously. Specifically, numbers to visit the bay have risen approximately 400 % in the last ten years. Concern regarding this increasing level of tourism as well as the possibility that the population was being affected by gill-net mortalities prompted Southland DOC to consider new management options for the population. In 2002 DOC began a consultation process with local people, tangata whenua, commercial and recreational fishers, and other stakeholders regarding the possibility of establishing a Marine Mammal Sanctuary in Porpoise Bay for the dolphins’ protection. While it was apparent that more recent research was needed regarding the finer scale movements of dolphins in the bay and their reactions to the increased tourism presence, it also became clear how little was known about the population’s range when not in the bay. Such information is crucial when deciding on boundaries for any type of reserve and was of direct relevance for the design of any sort of area protection for the Porpoise Bay population of Hector’s dolphins.
It was this combination of factors that provided the impetus for the current research during the summers of 2001/02 and 2002/03. The aims of the study were similar to those of Bejder (1997), focusing on both the biology and effects of tourism on this small population, with the additional aim of documenting the dolphins’ range beyond the bay. Wherever possible, methodology was identical to that used by Bejder (1997) to allow direct comparison of results, with reference to the increased tourism in the area since his research.

Specific aims were to:

1. Quantify tourism within the bay and assess changes in tourism since previous research.
2. Estimate the abundance of Hector’s dolphins using Porpoise Bay.
3. Quantify the spatial and temporal use of the bay by dolphins.
4. Quantify the responses of dolphins to boats and swimmers.
5. Compare findings to previous research.
6. Investigate the range of the population of Hector’s using the bay.
7. Present recommendations to the Department of Conservation for the management of this population in order to aid its conservation.

1.8 Thesis structure

This thesis is comprised of a further six chapters. Chapter 2 discusses the current levels of tourism in Porpoise Bay and presents data collected in this study and by the DOC summer warden on swimmers, beach users and the boat operator in the bay. This chapter presents the regulations governing boat and swimmer behaviour in the bay and goes on to compare and discuss current levels of tourism to those observed by Bejder (1997) and the DOC summer warden in 1995/96 and 1996/97.

Chapter 3 presents data from boat-based photographic-identification surveys of dolphins in Porpoise Bay. The Lincoln-Petersen estimator is applied to photographic data to provide a mark-recapture estimate of the abundance of the population that uses the bay. This estimate is compared to that calculated by Bejder and Dawson (2001).
Chapter 4 is focused on the dolphins’ distribution and movements within the bay as observed from a land-based theodolite station. Principal component analyses (PCA) are used to compare distribution across research summer, month and time of day. In addition a PCA is used to compare dolphin use of the bay in the presence and absence of boats and swimmers. Within the bay distribution observed during this study is compared to that observed by Bejder and Dawson (2001).

Chapter 5 presents data on dolphin responses to swimmers and boats in the bay, using three methods. First, logistic regression models are fitted to dolphin orientations in relation to boats and swimmers, measured using a theodolite, to investigate whether orientation changed as a function of length of exposure. Secondly, pod dispersion is compared between control conditions and in the presence of humans and finally, behavioural states are similarly compared between control conditions and when boats and swimmers were present. Dolphin responses observed in this study are compared with those observed by Bejder and colleagues (1999).

Chapter 6 discusses data from alongshore surveys either side of Porpoise Bay for Hector’s dolphins and discusses the relevance of the results when choosing the area over which management measures areas for conservation of the dolphins should apply. A hypothesis is presented for a seasonal alongshore movement by the study population.

Finally, Chapter 7 summaries the finding of each of the chapters and offers recommendations for appropriate management for the population based on this research. Ideas for future research in the area are put forward.
Chapter 2. Tourism in Porpoise Bay

2.1 Introduction

International visitor arrivals to New Zealand are increasing at a rate that is three times the world's average, making regulation of tourism here of utmost importance (Sage, 1995). Marine mammal tourism is a large part of the tourism industry and in 1998 alone 230,000 people were involved in whale-watching in New Zealand, generating more than NZ $95 million through both direct and indirect means (Hoyt, 2001). While tourism in the Catlins has fallen behind the growth of the industry in other areas of natural beauty within New Zealand such as Fiordland, the attractions of the area are becoming more widely known. Advertising by local businesses and the Catlins Promotions Board, and descriptions of the area in renowned travel guide books such as 'The Lonely Planet' have raised awareness of Porpoise Bay as a travel destination. Commercial bus services such as the 'Bottom Bus' and 'Stray Tours' that cater mainly to international tourists tour the Catlins daily and have helped this growth. In addition, the recent sealing of a stretch of gravel road leading to Porpoise Bay is expected to further increase visitor numbers to the area as rented cars that were formerly not covered by insurance to use the road will now be covered (Fig. 2.1).

Figure 2.1. Porpoise Bay, Curio Bay and the South Heads (New Zealand Department of Survey and Land Information).
Attractions of the Porpoise Bay/Curio Bay area include the petrified forest, described as one of the most extensive fossil forests in the world (Lonely Planet, 1998), and the special wildlife found there including three of the world’s most threatened marine species: hoiho (*Megadyptes antipodes*), the New Zealand sealion (*Phocarctos hookeri*) and Hector's dolphin.

The Hector’s dolphins found during the summer months in Porpoise Bay are an important attraction for tourists visiting the area. Humans have enjoyed a relationship with these dolphins for over a century, with Maori in the past predicting weather patterns by the movements of the dolphins (W. Cooper, DOC, pers. comm.) and local holiday makers and tourists today continuing to enjoy this relationship. In the recent past, visitors to Porpoise Bay were primarily holidaying Southlanders; now a large proportion of visitors are from overseas or from other parts of New Zealand. Numbers accessing the petrified forest at near-by Curio Bay (Fig. 2.1) during the summer months (December to March) of 2001/02, a reasonable indicator of numbers visiting the neighbouring Porpoise Bay, reached 45,000. During the same months in summer 2002/03 this figure dropped to approximately 34,000. Although the latter figure indicates fewer tourists over the whole period, visitor numbers during January and February were greater. Forecasters suggest that Porpoise Bay will experience almost exponential growth in tourist numbers in the next decade, predicting the number of tourists to the bay to reach 180,000 per year by 2012 (Southland Regional Council, 2002).

Part of the increase in visitor numbers to the area may be attributable to an increased desire for personal encounters with marine mammals, a phenomenon that has occurred around the world (Hoyt, 2001). To meet the demand for such encounters a local ex-farmer began offering dolphin-watching tours in the bay in 1994. While in many places such boat-based tourism is the only way to access cetaceans, Porpoise Bay is one of the few places where dolphins are easily accessible from the shore. Thus, rather than choosing a guided trip, many tourists choose simply to view the dolphins from the hillside and beach (Fig. 2.2). Of these people, a large number also

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Presumably the decrease in total numbers seen this year might in part be attributable to world political factors such as the recent America-Iraq war. Thus, it is likely that the decrease observed does not indicate a long-term change in the trend for tourism growth in the area.
enter the water to swim with the dolphins. A bonus for tourists doing this in Porpoise Bay is that the swimming is ‘free’ in two senses of the word. Not only are dolphins easily accessible from the shore in an often sheltered area of the bay for no financial cost, but swimming is less regulated than for those who swim with dolphins from a commercial boat operation.

Figure 2.2. Tourists on the beach in Porpoise Bay experience a close encounter with surfing Hector’s dolphins (photo: E. Green).

While not every visitor coming to the bay swims with dolphins it is logical that the predicted and observed increase in tourist numbers to the bay could have an effect on the Hector’s dolphins there.

The aims of this chapter are to:

1. Briefly review the regulations governing swimmer and boat behaviour in the bay.
2. Provide an overview of current levels of tourism in Porpoise Bay.
3. Compare current tourism levels to those observed during previous research.
2.2 Management regulations for people using the bay

2.2.1 Swimmers and boats

New Zealand’s Marine Mammal Protection Regulations (1992) and Marine Mammal Act (1978) provide national guidelines to manage human interactions with marine mammals and prescribe appropriate behaviours by both commercial operators and others in order to minimise adverse effects on marine mammals. These regulations detail 14 conditions for appropriate interaction with marine mammals and make it illegal to:

- Kill or harass any marine mammal
- Try to feed any marine mammal.
- Swim with pods containing juveniles.
- Travel faster than wake speed within 300 m of a pod, or faster than the slowest animal.
- Separate a mammal from its pod.

Further guidelines specific to Porpoise Bay advising how users of the bay should behave around dolphins have been developed by DOC based on Bejder’s (1997) research on the population. The central theme of these guidelines is ‘Never approach a dolphin: let them come to you’. These guidelines are displayed on interpretation panels at beach access ways as well as being printed on posters and leaflets and delivered to all holiday homes in the area (Fig. 2.3). A local DOC summer warden is employed to help educate the public about these regulations which include the following recommendations:

- Always enter the water at least 50 m away from, and on the Curio Bay (southern side) of, any group of dolphins.
- No boat or kayak should spend more than 40 mins within the ‘5 knot restriction zone’.
- Never surround, follow or pass through a group of dolphins.
A regulation under the Southland District Council’s Coastal Plan limits boats within the ‘dolphin zone’ to a speed of not more than 5 knots (Fig. 2.3).

Figure 2.3. The ‘five knot restriction zone/dolphin zone’ (courtesy of DOC Southland).

In addition to these regulations, boat and swimmer behaviour in the bay is managed locally by a ‘grass roots’ voluntary code of practice which was generated from local desire to both protect the dolphins and limit any guidelines that might affect resident’s rights regarding usage of the bay. This implicitly restricts boats targeting dolphins and the setting of nets in the bay (A. Stronach, pers. comm). While this is arguably effective at the local level, outsiders do not feel bound to such a code, as evidenced by a non-local commercial fisherman setting a net within the bay during January 2002 (E. Green, pers. obs.). After explanations about the code from representatives of the local community, the fisherman reluctantly (and not immediately) removed the net. However, the net was set again later that evening. This highlights the fact that although the behaviour of local people may be guided by protection for the dolphins, visitors may not be prepared to follow these rules.
2.2.2 Tour operator

A commercial whale-watching operator held the only concession issued by DOC to convey passengers to view marine mammals in Porpoise Bay over summer 2001/02. This concession was subject to additional regulations. These included:

- A limit of three trips per day.
- No viewing before 1000.
- No entering the surf zone.
- A limit of one attempt to re-establish contact if the dolphins leave the vicinity of the boat.
- No commercial access to the area behind the South Heads.

This permit was revoked at the end of summer 2001/02 for non-compliance reasons that will be discussed later in the chapter.

2.3 Methods

In order to provide an indication of the number of people using Porpoise Bay during summer 2001/02 and 2002/03 hourly counts were made by the local DOC warden each day during December to March of the number of people on the beach and in the water, on every hour between 1000 and 1700 (unpub. data, DOC, 2003). Swimmers were considered to have entered the water if they were in to waist-height or deeper.

Observations of people using the bay were also made from the theodolite station during all occasions when dolphin tracking was attempted (see Chapter 4 for details of theodolite use and observation hours). In order to investigate the distribution of water users in the bay the position of each swimmer was fixed using the theodolite upon their entry into the water. At the same time, the activity each swimmer was engaged in

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4 For a complete copy of the guidelines the operator was subject to please refer to the Appendix.
5 This guideline was developed on the basis of previous research which suggested that the area may be an important nursery area for the population. As the area is naturally restrictive to swimmers due to the swell and depth, restricting commercial tourist access to the area was implemented with the intention of creating a ‘rest area’ for the dolphins.
was recorded (unaided swimmer, body boarder, or surfer). On occasions when a swimmer left the water and then re-entered to a depth of waist-height, their position was again taken and they were recorded as a new swimmer.

Similarly, data was recorded about each boat to enter the bay, or enter or leave Waikawa estuary, during observation periods. The type of the vessel was noted (fishing vessel, tourism operator, kayak, or other/recreational vessels) and its path was tracked using the theodolite.

In order to estimate the proportion of time dolphins spent in the presence of humans, a distinction was made during tracking of dolphin focal pods (Martin and Bateson, 1993) between ‘control’ and ‘human presence’ conditions on the basis of the presence or absence of tourism activities. These definitions were identical to those used by Bejder et al. (1999) to allow for best comparison between research periods, and were as follows:

- ‘Human presence’: observations when either a) a boat was anywhere in the bay, and/or b) a swimmer(s) came within 200 m of the dolphin pod.
- ‘Control’: observations when both swimmers and boats were absent (as per definitions above), and had been for at least 20 min.

2.4 Analysis

The total number of people observed on the beach during hourly counts was calculated for each month and pooled across the two research seasons, and the mean calculated. The same method was used to calculate the mean daily number of people in the water on each hour between 1000 and 1700. The locations of all swimmers observed entering the water from the theodolite station were plotted on a map of the bay and the proportion of swimmers engaged in each of the swimming-related activities calculated.

Similarly, the proportion of boats in each vessel classification was calculated. Boat fixes were divided into vessel type and were plotted on a map of the bay.
The amount of time dolphins were observed in the presence of boats and swimmers was calculated as a proportion of the observation time (see Chapter 5, p. 74) and was plotted for comparison with the proportion of time dolphins were observed in these conditions by Bejder et al. (1999). A z-test on the proportion of time dolphins spent with a tourism presence between the two periods of research (with data from 1995-97 combined and data from 2001-03 combined) was applied to determine whether any changes observed were statistically significant.

2.5 Results

2.5.1 Swimmers and beach users

The most popular months to visit Porpoise Bay during the research summers were January and February (Fig. 2.4). At any one time, approximately half the numbers of people using the beach were in the water, a relatively high proportion given the cool summertime temperature (max. 12 °C) of the waters of the Catlins coast.

Preferred swimming times were between 1200 and 1600, coinciding with the warmest times of the day (Fig. 2.5). On average, more people were observed in the water on weekends than weekdays, suggesting that people from the near-by regions of Southland and Otago comprised a sizeable proportion of swimmers and beach users.
Figure 2.5. Number of swimmers in the water on the hour (between 1000 and 1700), Porpoise Bay. Data are pooled over summers 2001/02 and 2002/03 (unpub. data, DOC, 2003).

During summers 2001/02 and 2002/03 over 380 hours of observation time, more than 1,400 swimmers were observed entering the water from the theodolite station. At peak visitor times over the Christmas to New Year period, more than 250 people were observed in the water at a time. Swimmers were primarily unaided, followed by body boarders and then surfers (Fig. 2.6).

Swimmers used the southern part of the bay (Fig. 2.7), with use differing according to their activities in the water. Surfers tended to use the area north of Cook’s Creek (Fig. 2.1) as this is where the surf is usually biggest. In contrast, unaided swimmers preferred the southern part of the bay where the surf is minimal due to shelter from the reef system. As this is also the most preferred area for the dolphins, this is where
the majority of interactions take place (Bejder, 1997; this study). Body boarders were spread throughout the bay. Some swimmers were observed as seeking out the dolphins visually before entering the water near where dolphins were present.

![Figure 2.7. Locations of swimmers in Porpoise Bay during summers 2001/02 and 2002/03.](image)

### 2.5.2 Boats

Boat traffic in the study area was comprised of the sole dolphin-watch operator, as well as three commercial and numerous recreational fishing vessels. Other users of the bay included private vessels, namely, kayaks, dinghies, small power crafts, rubber inflatables, windsurfers and a single jet-ski. Boats were documented in the bay on 219 occasions during both research summers (Fig. 2.8).

![Figure 2.8. Types of boats using the bay and surrounding area, as observed from the theodolite station.](image)
Use of the bay differed according to the boat type and function with most boats accessing the bay from the Waikawa estuary. From here, fishing and recreational boats generally headed north-east along the coast, or east past the South Heads, seldom entering the bay itself. The dolphin-watch operator left the estuary and generally travelled first into the northern part of the ‘five-knot dolphin zone’ (Fig. 2.9), heading south until a pod of dolphins was encountered. On occasions when no dolphins were found in the bay, the vessel often headed to the southern side of the South Heads in an attempt to locate them. Kayakers entered the sea from the shore through the surf and generally stayed within approximately 500 m of the coast.

a) Recreational vessels  
b) Commercial fishing vessels

c) Kayaks  
d) Tourism operator

Figure 2.9. Sightings of different types of boats in Porpoise Bay during summers 2001/02 and 2002/03.
2.5.3 Tourism boat effort in the bay

During the first research summer the tourist operator offered 53 trips for the period between 1 December 2001 and 8 March 2002. At the end of this summer DOC revoked the operator’s dolphin-watching permit for non-compliance issues (D. Taylor, pers. comm.). During the same period between December and March in summer 2002/03, 49 trips were undertaken, despite the lack of permit.

2.6 Changes in tourism figures since 1995-97

When research was conducted between 1995 and 1997 in Porpoise Bay, the average proportion of time dolphins were observed in the presence of humans was 13 % and 12 % with boats and swimmers respectively (Bejder et al., 1999; Fig. 2.10). During the 2001/02 summer research the proportion of time dolphins were spending with boats remained much the same, but the amount of time spent with swimmers nearby increased to 32 % (Fig. 2.10). Data from summer 2002/03 suggest that this increase was not a one-off event, but rather that it is a trend that will likely continue.

![Bar chart showing the proportion of observation time dolphins spent in the presence of humans between 1995-97 and 2001-03.](image)

Figure 2.10. The proportion of observation time dolphins spent in the presence of humans (a boat anywhere in the bay and/or a swimmer within 200 m), during summers 95/96, 96/97, 01/02 & 02/03.

A z-test on the proportion of time dolphins spent with a tourism presence between the two periods of research (with data from 1995-97 combined and data from 2001-03...
combined) confirmed that there has been a significant increase in the proportion of
time dolphins spend with swimmers since past research \( (z = 4.57, p < 0.001;\)
Newcombe, 1998). In contrast, the amount of time spent in the presence of boats has
not changed significantly over the past five years \( (z = 0.031, \text{ ns}).\)

The notable increase in swimmer presence in the bay was not only apparent in the
proportion of time dolphins spent with swimmers but in the sheer number of
swimmers dolphins were exposed to over the past two summers. During 2001/02 and
2002/03 a total of 1,429 swimmers were observed entering the water in Porpoise Bay.
Of these, 419 came within 200 m of the focal dolphin pod, and were consequently
classified as swim-with attempts. During the summers of 1995/96 and 1996/97 during
a similar number of observation hours, 56 swim-with attempts were observed. Thus
swim-with attempts have increased approximately 800 % in around five years.

2.7 Discussion

Of the total time Hector’s dolphins were observed from the hilltop in Porpoise Bay in
the past two summers they spent an average 33 % accompanied by a tourist presence.
The amount of time spent with swimmers near-by has increased almost three-fold in
just 5 - 7 years, and is of concern given the extent to which tourism to the area is
increasing. Also of concern is that swimmer number and behaviour are difficult to
regulate. While the majority of swimmers follow the guidelines for swimming with
Hector’s dolphins, there are those who do not. For some, the chance to swim with
dolphins from the shore is a once-in-a-lifetime opportunity, and one that they will take
without consideration of any detrimental effect their behaviour may have on the
dolphins (Anon. tourist, pers. comm.). The lack of enforceable deterrents for
inappropriate behaviour, especially given the predicted and observed increases in
tourism, is of concern.

Another matter of concern is the continued operation of a commercial vessel despite
the operator no longer holding a valid permit. It is understood that the main reason for
DOC’s revocation of the permit involved the failure of the operator to pass on to DOC
information regarding the trips completed and details of the dolphins encountered on
these trips (A. Roberts, pers. comm.). In addition, the operator frequently made more
than one re-approach to dolphins and regularly went into the restricted area behind the South Heads. While the operator clearly breached the regulations by offering unlicensed dolphin-trips during the past summer, the majority of guidelines laid out in the former permit were adhered to. It is understood that the Department may prosecute the operator in order to ensure that the whale-watch industry is properly regulated and that only permitted operators conduct commercial tours to view cetaceans.

Bejder and colleagues (1999) suggested the level of tourism present in Porpoise Bay during the summers of 1995/96 and 1996/97 did not appear to seriously disturb Hector’s dolphins. However, they expressed concern should the level of tourism increase. This chapter documents that in the five to seven years since that study tourism has increased significantly, and that this has dramatically increased the proportion of time dolphins are exposed to swimmers. Given the apparent importance of the bay to these dolphins as a summer habitat and calving area, this should be viewed as a warning. It was acknowledgement of these trends that led to this follow-up study five years after the first research in this area. With increasing tourism trends apparently confirmed, consideration must now be given to how to manage this small and unique population to ensure that it suffers no detrimental effects from tourism in the bay.
Chapter 3. Abundance

3.1 Introduction

The most recent estimate for the abundance of the South Island population of Hector’s dolphin is 7,270 (95% CI = 5303 - 9966; Slooten et al., 2002). This estimate combines the results of four large-scale surveys (three boat-based and one aerial). Most research on Hector’s dolphins has taken place over the last twenty years around Banks Peninsula, with studies investigating aspects of ecology such as survival rates (Slooten and Lad, 1991), movements (Bräger et al., 2002), extent of fisheries-related by-catch (Dawson, 1991) and the effect of the Banks Peninsula Marine Mammal Sanctuary on survival rates (Cameron et al., 1999).

In contrast, research into smaller populations of Hector’s dolphins is relatively recent (e.g. Bejder and Dawson, 2001; Martinez, 2003). Such research can be very useful as a population of few individuals, many of which can be identified, allows for more detailed investigation of residency, group composition and behaviour (Bejder, 1997). Knowledge of small populations is particularly necessary for Hector’s dolphins due to the species’ high site fidelity and the genetic distinctiveness of individual populations (Bräger, 1998; Pichler, 2002). This knowledge can help to establish whether neighbouring populations should be managed separately, depending on the level of mixing that occurs between those populations (Bräger et al., 2002).

Photographic-identification (photo-ID) techniques, using natural markings such as nicks on the dorsal fin to identify individuals, have been employed for understanding many aspects of cetacean ecology, including abundance (e.g. Hammond et al., 1990; Defran, and Weller, 1999). Such techniques have proved highly informative while also having the advantage of being relatively non-invasive when compared with other techniques such as tagging (Würsig and Jefferson, 1990; Slooten et al., 1992). The Porpoise Bay population of Hector’s dolphins was studied intensively during summer 1995/96 and summer 1996/97 using photo-ID. Mark recapture analysis of photographic data was used to estimate a semi-resident population of 48 dolphins (95% CI = 44 - 55; Bejder and Dawson, 2001). Bejder and Dawson’s (2001) research found individuals had differing levels of residency within the bay with some dolphins
clearly residents and others occasional visitors. The current research aimed to provide a more recent assessment of the size of the population currently using Porpoise Bay and to provide data on their residency in the longer term. Methods and analysis used were based upon those employed by Bejder and Dawson (2001) to allow direct comparison of estimates and an assessment of any changes in abundance. The aims were:

1. To estimate, using photo-ID techniques, the abundance of Hector’s dolphins using Porpoise Bay during summer 2001/02 and 2002/03.
2. To compare the current abundance estimate with the estimate for summers 1995/96 and 1996/97.

3.2 Methods

Photography was carried out from a 3.8 m stabi-craft fitted with 15 hp and 40 hp outboard engines during summer 2001/02 and 2002/03 respectively. In accordance with guidelines for boat use in the area, surveys were conducted at a speed of not more than 5 knots within the bay, and up to 12 knots beyond the confines of the bay. The survey route initially followed the beach and then covered, when sea conditions allowed, the remainder of the bay as well as the area on the south-west side of the reef. Upon sighting a dolphin group the research boat was slowed or stopped for photography of the dolphins’ dorsal fins. For each group sighted, the time, group size, and location of the sighting obtained from a Global Positioning System (GPS), were recorded. In addition, the number of calves and/or juveniles present in the group was recorded. Positive identification of a calf was made based on the animal’s close association with an adult, small size, and the presence of foetal folds (pigmentation patterns are present for up to six months after birth). Juveniles were identified as those animals noticeably smaller than adults and also in close association, but lacking foetal folds. Dolphins were considered to be part of the same group if they came within close proximity of one another (< 20 m) during the photography session.

Lateral photographs of the dorsal fins of dolphins were taken using a Nikon F90X camera fitted with a 28-200 mm zoom lens. Photographs were taken randomly in that
any dolphin surfacing within 10 m of the boat was photographed. Fuji 400 colour film was used with a shutter speed of 1/1000 s to reduce blurring. Every attempt was made to photograph all individuals in a group. In order to maximise the chance of photographing all dolphins at least once, 4 photographs were taken per dolphin present, per session (Balance, 1990). Thus, if the group was composed of 3 dolphins, 12 photographs were taken. When a distinctly separate group of dolphins was encountered and photographed within the same session, they were considered a new group and their details were also recorded. Counts of the total number of dolphins seen in the bay on these sessions provided data on which months dolphins made most use of Porpoise Bay.

3.3 Analysis

3.3.1 Photograph and mark categorisation

An essential assumption of mark recapture analysis is that all photographs included in the analysis are of sufficient quality to identify a dolphin, if that dolphin was indeed identifiable. To ensure this assumption was met, thereby reducing the effects of sighting heterogeneity\(^6\), only photographs of a high quality were included in the analysis. This study defined high-quality photos as those lateral or almost lateral to the fin, in which the fin was clearly defined and covered > 20 % of the area of the photograph.

Ratings of dorsal fin marks were made independently of photograph quality. Only those markings that were deemed permanent were included in the group of animals considered ‘marked’ (Lockyer and Morris, 1990). Animals were placed into one of four categories based on the distinctiveness of their marks. Category 1 had very clear and deep marks, and/or obvious discolouration. Category 2 animals had marks that were clear but less deep. Category 3 included animals with marks that could be used to identify an individual reliably, but were more subtle. Finally, Category 4 animals

\(^6\)Sighting heterogeneity occurs when individual animals have a different chance of re-sighting due to the distinctiveness of their marking. Inclusion of only high-quality photos reduces this bias by excluding those photographs of dolphins in which an obviously marked individual would be more likely to be re-identified than a less obviously marked individual (Hammond, 1986; Stevick et al., 2001).
were excluded from the analysis, as their markings were considered too faint for reliable identification\textsuperscript{7}. Given the results discussed in Chapter 6, which suggest dolphins seen along the coast either side of Porpoise Bay comprise the same population, all high quality photographs taken both within and beyond the bay were included in the analysis.

3.3.2 Mark recapture analysis

Using the photographs taken on surveys it was possible to plot a cumulative discovery curve of the number of dolphins identified with time. Plotting these data makes it possible to determine whether the population can be considered open or closed. If a plateau in the rate of dolphin discoveries is reached, it suggests that the majority of distinctive dolphins have been discovered/identified and that the population is closed. Conversely, failure of the rate of discoveries to plateau suggests that the population is open to emigration and immigration. Determining whether the population is open or closed is essential in order to determine whether application of mark recapture analysis is appropriate.

Confirmation of the study population as a closed (see section 3.4.3) meant that it was possible to estimate the number of marked animals in the population using Chapman’s (1951) version of the Lincoln-Petersen estimator (Seber, 1982). The Lincoln-Petersen model, which is frequently used for this type of mark recapture analysis, requires the field season to be divided into a ‘marking’ and a ‘recapture’ period (e.g. Williams et al., 1993; Smith et al., 1999; Gormley, 2002). In cetacean studies an animal is considered ‘marked’ when it is first identified from a distinctive mark. ‘Recapture’ occurs when that animal is re-identified. Here, the first half of the summer 2002/03 research season (December and January) was defined as the ‘marking’ period and the second half (February and March) as the ‘recapture’ period\textsuperscript{8}.

\textsuperscript{7} Slooten et al. (1992) excluded Category 3 and Category 4 animals from their analysis. In large populations, such as that studied by Slooten et al. (1992), the chance of two dolphins having very similar marks is high (Bejder, 1997). Category 3 animals were included in the analysis in the current study as this chance is minimal for smaller populations of dolphins, such as the one present in Porpoise Bay.

\textsuperscript{8} For reasons that will be discussed later, the photographic data from field work in 2001/02 was not included in the analysis.
The formula for calculating an abundance estimate $\hat{N}$ is:

$$N = \left( \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \right) \times M_R$$

where:  
$n_1 =$ the number of distinctive dolphins sighted in the 'marking' period.  
$n_2 =$ the number of distinctive dolphins sighted in the 'recapture' period.  
$m_2 =$ the number of distinctive dolphins sighted in the 'marking' period also sighted in the 'recapture' period.  
$M_R =$ mark rate i.e. the total number of high quality photographs of naturally marked dolphins divided by the total number of high quality photographs.

To account for the fact that the majority of individuals seen in the 'marking' period were also seen in the 'recapture' period, 95% confidence intervals around the abundance estimate were calculated using profile likelihoods (McCullagh and Nalder, 1989). This approach generates a confidence interval that is asymmetrical around the estimate and considers the uncertainty in the measurement of the mark rate, thereby better representing the uncertainty related with estimating the abundance of a small population (Bejder and Dawson, 2001).

### 3.4 Results

#### 3.4.1 Summer 2001/02

Photographic-ID surveys in Porpoise Bay took place during 39 sessions on 44 days between 25 November 2001 and 13 March 2002, one of which was disrupted by the weather. Session duration, on average, was 33 minutes, and ranged between 5 and 105 minutes. Twenty-seven hours and 16 minutes were spent photographing the dolphins, which were encountered on all but one of the trips. In all, photographs were taken of 49 groups (mean = 1.33 groups encountered per outing). Group size ranged between 1
and 15 (mean = 6.5; SE = 4.16; median = 5). More dolphins on average were encountered in February than in the other months (Table 3.1).

### 3.4.2 Summer 2002/03

During summer 2002/03 photo-ID surveys were conducted over 62 sessions on 52 days between 26 November 2002 and 28 March 2003. Photo Session length ranged from 2 to 56 minutes (mean = 23 minutes). A total of 32 hours and 52 minutes were spent photographing dolphins, which were encountered on all but 4 trips, all of which were in November. Three trips were interrupted due to deteriorating weather conditions, namely fog and rough seas, and no photographs were taken. Photographs were taken of 85 groups (mean = 1.52 groups encountered per outing). Group size ranged between 1 and 23 (mean = 8; SE = 5; median = 7). On average, more dolphins were present in the bay during January, February and March than during November and December (Table 3.1).

Table 3.1. The monthly mean number of dolphins encountered on photo-identification surveys in Porpoise Bay during summers 2001/02 and 2002/03.

<table>
<thead>
<tr>
<th>Month</th>
<th>2001/02</th>
<th>2002/03</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of</td>
<td>Mean no. of</td>
</tr>
<tr>
<td></td>
<td>photo-ID</td>
<td>dolphins in</td>
</tr>
<tr>
<td></td>
<td>sessions</td>
<td>bay</td>
</tr>
<tr>
<td>November</td>
<td>3</td>
<td>5.3</td>
</tr>
<tr>
<td>December</td>
<td>8</td>
<td>4.9</td>
</tr>
<tr>
<td>January</td>
<td>14</td>
<td>3.5</td>
</tr>
<tr>
<td>February</td>
<td>14</td>
<td>11.4</td>
</tr>
<tr>
<td>March</td>
<td>8</td>
<td>5.3</td>
</tr>
</tbody>
</table>

During summer 2001/2002 two new calves were sighted, one in December and two simultaneously in March. Three new calves were sighted during summer 2002/03, the first in early January, and three simultaneously on 7 February 2003. Calves were present in 27.1% of the groups photographed.

### 3.4.3 Identifiable dolphins

Analysis of photographs showed that 14 dolphins were identifiable from natural markings on their dorsal fins during summer 2001/02 and 19 during summer 2002/03.
Each of the 14 dolphins identified in the first research season was also identified during 2002/03 (Fig. 3.1). Ten of the distinctive individuals were identified in research conducted during 1995-1997 (Bejder, 1997). It is difficult to know whether the four dolphins identified for the first time in the second season were new individuals or whether they were present during 2001/02 but were not identified. They may have been part of the overall population but did not, for some reason use Porpoise Bay during 2001/02. Similarly, there is no way of knowing whether eight dolphins identified by Bejder (1997), but not identified in the current study were present but not photographed, absent (e.g. due to death), had marks that had changed, or were no longer using the area. All but one of the dolphins identified during this research was sighted at least once in Porpoise Bay itself. Ten were sighted near the township of Fortrose in Toetoe Bay (see Chapter 6 for details of the alongshore range of this population).

Figure 3.1. Individual dolphins identified at a) Porpoise Bay and Toetoe Bay (square nick in top right corner) b) Porpoise Bay and Toetoe Bay (double nick out of base of fin), c) Porpoise Bay only (significant skin discolouration), and d) an unmarked dolphin.
The discovery rate of identifiable dolphins during 2001/02 was very slow, with only 29% of dolphins (5 of 14) identified during the first half of the research season (Fig. 3.2). Figure 3.2 shows that the cumulative discovery of new dolphins continued until the end of the field season. Failure to reach a plateau in new discoveries suggests that not all marked individuals were identified during summer 2001/02. This contrasts with research on the population conducted by Bejder (1997) which identified 13 of 18 dolphins during the first two photographic surveys in 1996/97, and all dolphins by the 40th and 16th field day during 1995/96 and 1996/97 respectively. As with the 2001/02 data, the rate of discoveries of dolphins during 2002/03 was relatively slow. However, a plateau in new discoveries was reached (Fig. 3.2). Research in summer 2002/03 identified no new dolphins after 90 days into the 123 day field season.

Figure 3.2. Discovery curve of naturally marked dolphins in Porpoise Bay and surrounds, summers 2001/02 and 2002/03.

Thus, like research from 1995-97, data from 2002/03 suggest that the population of Hector's dolphins that use Porpoise Bay and the surrounding coast is closed (Bejder and Dawson, 2001). Data from 2001/02 were not conclusive in this respect. However, it seems that the dolphins' pattern of use of the bay during that season was different to what is considered 'normal' and certainly from the other three years of study. During summer 2001/02, dolphins did not begin to use the bay until late December/early January, whereas usually they are regularly present in the bay from late
November/early December. Furthermore, the local DOC warden noted that fewer dolphins used the bay in 2001/02 than in other summers and that they were not present as often as usual. Comparison of the proportion of time dolphins spent in the bay during summer 2001/02 and 2002/03 substantiated this opinion. During the latter season dolphins were present for a much greater proportion of the observation time and were present in greater numbers (Chapter 4). Long term residents of the bay and DOC staff felt that the use of the bay in 2002/03 was similar to most other summers, and different from summer 2001/02.

3.4.4 Sighting frequency and residency

The individual sighting frequency of dolphins during summer 2001/02 ranged from 1 to 14, with an average sighting frequency of 4.3 (SE = 3.9; median = 3). During 2002/03 marked dolphins were seen, on average, many more times. In that season, individual sighting frequency ranged from 1 to 30, with a mean of 10.4 sightings (SE = 7.2; median = 9; Fig. 3.3).

![Figure 3.3. Sighting frequencies of Hector's dolphins in Porpoise Bay and surrounds during summer 2001/02 and 2002/03.](image)

The sighting frequency of individual dolphins identified during both research summers varied from 2 (dolphin positively identified just once each summer) to 35. On average each dolphin was sighted 15.2 times in both seasons (SE = 11.0; median = 11; Fig. 3.4).
The number of days between consecutive sightings of the same individual ranged between 0 and 57 in 2001/02 (mean = 8.1; SE = 10.1; median = 6) and 0 and 68 during 2002/03 (mean = 8.3; SE = 10.1; median = 5). Figure 3.5 shows the mean number of days between consecutive sightings of identifiable dolphins in summer 2001/02 and 2002/03.

Figure 3.5. Mean number of field days between consecutive sightings of marked individuals in summers 2001/02 and 2002/03.
3.4.5 *Mark rate and population estimate*

During summer 2001/02 approximately 1,400 photographs were taken of all dolphins that surfaced near the research vessel. This figure includes photographs of juveniles and adults only. Photographs of calves were excluded from the analysis for two reasons: 1) calves very rarely show any distinctive markings and 2) they are generally boat shy, therefore removing the few photos taken of calves decreases the effect of sighting heterogeneity. Of the 1,400 photos 265 were deemed of suitable quality to include in mark recapture analysis. That is, were a dolphin marked, the photo was of sufficient quality to unambiguously determine that mark’s presence (using the criteria discussed earlier). Of these, 102 were of 14 naturally identifiable dolphins. During summer 2002/03, more than 2,500 photographs were taken of which 914 were high quality photographs of juveniles or adults. Of these, 428 were photographs of one of 19 distinctive dolphins identified that summer. Thus, mark rates of 38.5% and 46.8% were calculated for summer 2001/02 and 2002/03 respectively.

Early attempts at analysis of photographic data from 2001/02 showed that mark recapture techniques were not appropriate as the discovery of new marked individuals did not plateau. Two factors may have contributed to this, 1) that dolphins did not start coming into the bay until late in the summer and 2) that researcher ability to take high quality photographs of dolphins may have improved with experience by the second research summer. In consideration of these factors and given that there were few photos of high quality taken during 2001/02, these data were excluded from the mark recapture analysis.

Chapman’s version of the Lincoln-Petersen estimator was used to estimate the number of marked animals seen in 2002/03. This estimate was scaled up using the mark rate calculated from 2002/03 photographic data:

\[
N = \left( \frac{(14 + 1)(19 + 1)}{(14 + 1)} - 1 \right) \times \left( \frac{428}{914} \right)
\]

\[
N = 19 \times 0.4683
\]
N = 40.57

Thus the estimate of the population using the bay during 2002/03 was 40 dolphins (95 % CI = 37 - 45). In addition, three new calves were sighted simultaneously in February, making the estimate for the whole population 43 dolphins (95 % CI = 40 - 48).

3.4.6 Comparison with 1995-97 research

The sighting frequency of identifiable dolphins was greater during 2002/03 and lower during 2001/02 than in 1995-97 (means: 1995/96 = 7.3; 1996/97 = 9.8; 2001/02 = 4.3; 2002/03 = 10.4). The range in sighting frequencies and in the number of days between consecutive sightings was large for all years over which research was conducted. The average group size observed in summer 2002/03 was higher than was found during summer 2001/02, but lower than during 1995-97 (Table 3.2). Similarly, the range and median of the size of dolphin groups followed the same pattern.

Table 3.2. Comparison of dolphin group statistics between each of the research summers.

<table>
<thead>
<tr>
<th></th>
<th>1995/96</th>
<th>1996/97</th>
<th>2001/02</th>
<th>2002/03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean no. dolphins/group</td>
<td>11 ± 0.85</td>
<td>11.6 ± 0.89</td>
<td>6.5 ± 4.16</td>
<td>8 ± 5.45</td>
</tr>
<tr>
<td>Median no. of dolphins/group</td>
<td>11</td>
<td>11</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Range</td>
<td>1-26</td>
<td>1-26</td>
<td>1-15</td>
<td>1-23</td>
</tr>
<tr>
<td>No. new calves</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>No. of dolphin IDs</td>
<td>16</td>
<td>18</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>No. of re-identified dolphins since 1995-97</td>
<td>-</td>
<td>12</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>No. of re-identified dolphins since 2001/02</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Mark rate</td>
<td>-</td>
<td>36.88 %</td>
<td>38.49 %</td>
<td>46.83 %</td>
</tr>
<tr>
<td>Abundance estimate</td>
<td>48</td>
<td>41</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>95 % Confidence interval</td>
<td>45 – 55</td>
<td>40 – 48</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

More than half of dolphins identified in research during 1995-97 were re-identified in the current study. The mark rate of dolphins calculated in this study was higher than during previous research (Table 3.2). In contrast, the abundance estimate calculated here for the population, 43 dolphins, is lower than the one calculated in 1995-97 of 48 dolphins (Bejder and Dawson, 2001). While the 95 % confidence interval calculated
in 1995-97 does not include the abundance estimate of 43 dolphins calculated during this study, it does overlap the 95% confidence interval calculated here.

3.5 Discussion

The photographic data collected during 2002/03 provided a much better picture of the Porpoise Bay population of Hector’s dolphins than that provided by 2001/02 field work. Greater knowledge of the population’s range gathered during the course of this research suggests dolphins seen along the coast are part of the Porpoise Bay population, therefore photographs of dolphins seen beyond the bay were included in the analysis (see Chapter 6). Thus, the estimate provided here relates to the population of dolphins using the southern coast between Dummy’s Beach and Toetoe Bay.

The mark rate used to calculate this estimate was comparatively high when compared to other studies of Hector’s dolphins (e.g. Slooten et al., 1993). Unbiased use of more subtle marks in the analysis was possible because of the population’s small size. The population appears to fit the definition of ‘closed’ as the discovery of new identifiable dolphins reached a plateau during the research season. However, in contrast to previous research in Porpoise Bay, discovery rate was relatively slow (Bejder and Dawson, 2001).

The slow rate of discovery probably indicates that individual dolphins use the bay differently. Increased experience photographing dolphins may have partially contributed to the higher rate in the second research summer, however, this difference is mostly likely the result of the dolphins’ differing use of the bay over the two summers. Individual sighting frequencies of dolphins using the bay were very different, with some dolphins seen just once and others seen up to 30 times during a single summer field season. Similarly, there was great variability of the number of days between consecutive sightings of dolphins. Residency patterns appeared similar to those found by Bejder and Dawson (2001), and show that while some dolphins are clearly residents, others appear to visit the bay occasionally. No obvious pattern was apparent in the use of the bay by residents compared to visitors. More data on the population’s entire range is desirable for protection measures to be effective (see Chapter 6). Differing residency is problematic when applying mark recapture methods.
and affects robustness of the abundance estimate. Variability in site fidelity is not limited to the current study and is a problem common to many mark recapture studies. For example humpback whales in the Gulf of Mexico were shown to use different areas within their range which in turn affected their chance of being photographed ('captured'; Hammond, 1986). It is possible that individuals within this population also had differing chances of being photographed, however this would be more likely attributable to variations in responsiveness to the research vessel rather than to differing ranges within the bay.

Of 18 distinctive dolphins identified by Bejder (1997), 10 were re-identified in the current study. Therefore conclusive evidence exists to show that the population is seasonally resident in the long term. This finding is consistent with other studies investigating site fidelity in Hector's dolphins elsewhere. For example Bräger and colleagues (2002) sighted marked individuals within the same small areas around Banks Peninsula over a 12 year period.

Though the average group size has decreased since 1995-97, this does not necessarily indicate that fewer dolphins are using Porpoise Bay. Rather, it simply shows that groups during this past summer contained fewer individuals. Comparison of the population estimates for each of the research seasons gives a better indication of trends in abundance. The abundance estimate calculated for 1995-97 was 48 (95 % CI = 44 - 55 (Bejder and Dawson 2001). The estimate calculated for summer 2002/03 was 43 (95 % CI = 40 - 48), including three new calves. While the abundance estimate of 43 animals calculated here does not fall within Bejder and Dawson’s (2001) 95 % confidence interval, their interval does overlap with the 95 % confidence interval calculated in this study. Therefore one cannot conclude that there has been a change in abundance since 1997. Although the abundance estimates show that there has not been a decline, any statistical change would be very difficult to detect given the small size if the population and the relatively short time since previous research.

A precautionary approach to management of this small population is essential given the threatened status of this species and its low potential for growth. Research is required to investigate what might be affecting the mortality of dolphins in this area on the southern coast. This could include documenting set-netting effort in the area to
assess by-catch risk. In considering management options for these dolphins, sound knowledge of the population’s home range is of utmost importance. Findings investigating where ‘visiting’ dolphins go when not in Porpoise Bay are presented in Chapter 6.
Chapter 4. Distribution within Porpoise Bay

4.1 Introduction

Hector's dolphin distribution has been studied on a large-scale via boat and aerial surveys around the coast of New Zealand (Dawson and Slooten, 1988; Clement et al., 2001; DuFresne et al., 2001; Slooten et al., 2002), and on a smaller scale around the shores of Banks Peninsula (Slooten et al., 1992). Research indicates a seasonal preference for shallow and turbid coastal waters with low water clarity (Bräger et al., 2003). Their distribution around Banks Peninsula, further offshore during winter and inshore during summer (Dawson and Slooten, 1988), is thought to correspond to the dolphins' summer calving and the distribution of their prey, further inshore in the summer months.

Hector's dolphins demonstrate high site-fidelity with populations showing patchy and localised distributions (Pichler et al., 1998; Bräger et al., 2002). Combined with genetic distinctiveness between populations this means that it is very important to understand the small-scale movements of each population (Pichler et al., 1998; Pichler and Baker, 2000). One method that has been successfully used in the study of small-scale cetacean movements is theodolite tracking (Kruse, 1991). Because theodolite stations are land-based this method of study poses no threat to the animals being studied nor does it provide a source of potential disturbance. For these reasons, theodolite tracking has been effectively used to measure cetacean reactions to boats (e.g. Corkeron, 1995; Barr and Slooten, 1999; Williams et al., 2002), responses to acoustic alarm devices (e.g. Koschinski and Culik, 1997; Culik et al., 2001), for measuring the effectiveness of Porpoise Detectors (PODs; e.g. Rayment, unpub. data.) and documenting habitat use (e.g. Harzen, 1998; Bejder and Dawson, 2001). Research has found that a tourism presence around cetaceans has led to changes in habitat selection (e.g. Jones and Swartz, 1984; Driscoll-Lind and Östman-Lind, 1999).

During the summers of 1995-97 a theodolite was used to study the small-scale movements of Hector's dolphins in Porpoise Bay. Dolphins used the bay in a similar way during each of the months, showing a high preference for a small area in the southern part of the bay (Bejder and Dawson, 2001). At that time, dolphins were not
displaced from the bay by the presence of boats or swimmers. The only apparent
difference in distribution was dependent on the time of the day, with dolphins
becoming more congregated in successive time periods from morning to afternoon
(Bejder et al., 1999).

Since previous research, tourism to the area has increased markedly (Chapter 2). In
light of the documented increase and the period of time elapsed since the previous
study in Porpoise Bay, this study had two specific aims, the results of which would
form the basis for recommendations on the management of dolphins and humans in the
bay. They were:

1. To investigate whether dolphins exhibit any temporal or diurnal changes in
distribution within the bay.
2. To compare distribution over summers 2001/02 and 2002/03 to that
documented in previous research, given the increase in tourism to the area since
then.

4.2 Methods

Data were collected from a land-based theodolite station situated on the car park of the
South Heads Public Reserve (46°39'52" E, 169°06'23" S, elevation 27.85 m above
mean sea level). Unfortunately, grading on the top of the hill where the theodolite
station was located in previous research meant that the exact location could not be
used. However, this site was located as close as possible to that used in earlier research
(Bejder et al., 1999; Fig. 4.1).
Collection of data involved taking fixes of dolphin positions in the bay using a T1000 electronic theodolite fitted with a 30 x telescope. A theodolite is a device that measures vertical and horizontal angles simultaneously (Trutmann, 1972). By working from a known position and 'zeroing' the theodolite to a distant trig station of known position and elevation one can later translate recorded angles into absolute positions. This process can also incorporate tidal fluctuations. Fixes can then be plotted onto maps and analyses carried out. In addition, comparisons can be made regarding relative positions of dolphins compared to other features (e.g. Würsig and Würsig, 1980; Smith, 1993). The precision of individual fixes depends upon theodolite height above sea level and is inversely proportional to the distance of the fix from the theodolite. At Porpoise Bay, a 20 cm inaccuracy in theodolite height would result in a position error of 7 m at a range of 1000 m (Würsig et al., 1991; Bejder et al., 1999).

Custom written software on a Hewlett-Packard 200LX palmtop computer was used to record fixes of dolphin positions (software written by D. Coup and modified by J. Jenkins). This software also allowed users to enter environmental data such as sea-state, wind direction and strength, and notes on dolphin behaviour. In addition, the user could record data about the type of fix (dolphin, boat or swimmer) and details about that fix (for example, for a dolphin pod the size of the group, presence of calves/juveniles and behavioural state was recorded).
Methodology for tracking was based on that used by Bejder (1997). At the beginning of each tracking session the study area was scanned thoroughly using a pair of 18 x binoculars. This area included all of the sea visible from the theodolite station. If dolphins were present, the largest pod was tracked. Like Bejder (1997), if dolphins were not present, the area was scanned for a 15 minute period every half-hour in an attempt to locate them. Tracking of dolphins occurred under two conditions defined by Bejder and Dawson (2001):

- 'Human presence': observations when either a) a boat was anywhere in the bay, and/or b) a swimmer(s) came within 200 m of the dolphin pod.
- 'Control': observations when both swimmers and boats were absent (as per definitions above), and had been for at least 20 min.

Fixes of dolphin pods were taken approximately once per minute. In order to reduce observer fatigue as much as possible, tasks (binocular tracking, theodolite operating and data entry) were swapped every hour and each tracking shift was limited to a maximum of 5 hours. Generally, theodolite observations were made over 4 hour periods. Fixes were taken according to focal group sampling procedure with fixes taken as close to the centre of the group as possible (Martin and Bateson, 1993). While every attempt was made to track the same group throughout the shift, this was often made difficult by the dolphins’ habit of group fission-fusion. On occasions when groups split, the larger of the two resulting groups was tracked. To ensure that tracking was continuous, observations were made only when the Beaufort sea state was lower than 3⁹, and when visibility was not impaired by fog.

4.3 Analysis

To investigate the overall use of Porpoise Bay by Hector’s dolphins over the two research summers, a z-test was used to test for a significant difference between the

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⁹ The Beaufort Sea State is a scale used to assess sea conditions. Under its criteria a flat sea surface is scored ‘0’, a surface broken by ripples is ‘1’ and small wavelets on the sea are scored ‘2’. When the score became ‘3’, scattered whitecaps, it could no longer be guaranteed that every surfacing was visible and thus tracking was ceased.
proportion of observation time dolphins were present in the bay during 2001/02 with that observed in 2002/03 (Newcombe, 1998).

Theodolite fixes (positions) were plotted and analysed to investigate the small-scale use of Porpoise Bay by dolphins. As the 1 minute intervals at which fixes were taken were estimated by theodolite users, there was often more than one fix per minute taken of the focal group. In order to reduce these data to be identical to collection methods used by Bejder and Dawson (2001) fix data were sub-sampled so that just one fix per dolphin group per minute remained. Fixes were separated into those taken during human presence situations and those taken during control situations. Fixes taken in the 20 m period following a human presence near the dolphins (see definition p. 45) were discarded from the analysis.

Although methodology for data collection was identical to that used by Bejder and Dawson (2001), analysis of the data was different. Bejder and Dawson (2001) used two methods of data presentation from which they drew conclusions about dolphin utilisation of the bay. The first method involved plotting all fixes taken of dolphins as dots on a map of the bay. While this effectively shows the areas of the bay used by dolphins it is problematic in that one fix in a position is represented in the same way as ten overlapping fixes in that identical spot. To account for this, Bejder and Dawson (2001) produced contour plots of distribution for each condition of interest (month and time of day), with isopleths which encompassed 10% of all dolphin positions within that condition (e.g. January). While this shows spread of distribution in each of the conditions from the theodolite, it does not effectively show where the dolphins are concentrated in relation to the layout of the bay. Also, conclusions are based on visual inspection rather than statistical analysis. The current study aimed to more effectively present data on dolphin utilisation of the bay and to apply analyses to test whether any differences noted were statistical.

In order to do this, fix data were imported into the computer programme iSITE (v.4.7 ©) on a shift-by-shift basis. For example fixes taken during a 4 hour tracking shift on the morning of 1 December 2002 were imported separately to fixes taken during a 2 hour shift in the afternoon of that day. This way each shift could be treated as an individual data set, thus reducing any effects of autocorrelation. iSITE software was
used to translate files into the appropriate format for importing to the programme TurboCAD (v.10.2 ©IMSI, 2000), a design and mapping programme. In TurboCAD fixes taken during each shift were plotted on to a map of Porpoise Bay’s coastline.

A 100 m by 100 m grid was then fitted over the bay encompassing all dolphin fixes. This allowed counts of the number of fixes taken of dolphins (2001/02 n = 2,924; 2002/03 n = 5,703) in each grid for each shift (2001/02 n = 63; 2002/03 n = 137). For example, the number of fixes in each grid during a control situation between 1000 and 1400 in January 2002. These counts were standardised by calculating the proportion of time spent in each grid per shift so that habitat use in one shift could be directly compared to another. Tracks with fewer than 20 fixes (i.e. tracks of less than 20 min duration, 2001/02 n = 16; 2002/03 n = 27) were deleted from the data set as were data collected after 1800 as they contained too few shifts (2001/02 n = 1; 2002/03 n = 2).

It was then possible to calculate means across the shifts for each of the conditions of interest, namely month, time of day and human presence versus control situations. These means were used to shade grids according to the average proportion of time dolphins spent in each area in each condition, thus creating a visual presentation of distribution for each of the conditions of interest. The advantage of using shaded grids to present data rather than plotting all fixes is that shading takes account of more than one fix in the same position by deepening the shade of that grid.

In order to detect which changes in distribution were statistically significant between the different conditions of interest a technique called Principal Component (PC) Analysis was employed. This analysis is a multivariate method that takes a large set of variables $X_1$, $X_2$, ..., $X_p$, and from this forms a smaller set of new indices called principal components, $Z_1$, $Z_2$, ..., $Z_p$, each of which explains a decreasing proportion of the data (Jolliffe, 1986). During analysis the software looks for correlation between several variables at once to explain variation in the data that is independent from that which is generated by that variable’s position relative to others. These new variables are uncorrelated which is useful as each PC measures a different dimension of the data (Manly, 1994). Therefore, in addition to reducing the number of variables required to explain a data set, PC analysis also removes autocorrelation between grids by identifying patterns in the data that do not depend on distribution (Townend, 2002).
Principal component analysis is commonly employed when taking, for example, a number of measurements of individual animal. Manly (1994) provides as example of a number of measurements of female sparrows’ bodies, namely; total length, alar length, length of beak and head, length of humerus, and length of keel of sternum. In these analyses, the aim of the analysis is to determine which two or three of the measurements can be used to explain the great majority of the variation in the data, and with which you could make relatively accurate predictions of the other variables. Commonly, more than 20 variables can be reduced to just two or three principal components. Application to the data gathered in this research was somewhat different to its typical application. Here, the shifts of theodolite tracking were the objects of interest, and were used where an individual animal is usually used, and the \( X \) variables were measurements of the proportion of time spent in each grid for each tracking shift. In this analysis the grids (primary variables) were designed to encompass all fixes of dolphins. Dolphin distribution in the bay was highly concentrated in the southern corner of the bay. To reduce the number of zeros in the matrix, outlying grids were grouped into larger areas to increase the number of fixes in them (Fig. 4.2). There was no need to account for the different areas covered by the inner grids compared to the outer, grouped grids, as the analysis compared the mean for each condition (e.g. months) for each grid to itself.

![Figure 4.2. Grouping of grids used for the principal component analysis of distribution data.](image)

While this reduced the number of zeros in the matrix, it was still sparse when compared to typical matrices used in PC analyses. The result of this was that many
PCs were needed to explain the data, with each explaining a relatively small amount of variation. This type of analysis was used on a similarly sparse data set to investigate the relationship between a number of variables present in burial sites of men, women and children in Thailand (Manly, 1994). For that analysis, 15 components were needed to explain 90% of the variance, and Manly (1994) acknowledged that much of the variation present in the original variables was not accounted for. However, the aim of the analysis was not to explain all the data but to look for more general trends between different burial sites. Application to distribution data here was similar, in that rather than attempting to define two or three variables that explained most of the variation in the data, the intent was to find trends in the data.

Detecting these trends involved applying an ANOVA or t-test to the scores generated by the PC analysis between the conditions of interest. Significantly different values for a PC indicated that the grids that composed that PC were different over the condition being investigated, say month. Examination of the standardised means for the months then made it possible to tease out specific differences. Such an analysis provides statistical support to trends indicated by visual presentations. However, the approach is highly exploratory and interpretation of results must consider whether they make biological sense (J. Harraway, pers. comm.). For the purposes of this analysis PCs that explained less than 5% of variation were not presented, as they were not deemed very important to the dolphins' overall use of the bay10.

As the current study used different methods to those used by Bejder and Dawson (2001) to assess changes in distribution in different conditions, direct comparison of results was not possible. Thus visual inspection of the plots produced in Bejder and Dawson’s (2001) study with those produced in this study was carried out in an attempt to compare dolphin distribution between the two studies.

While the vast majority of the bay was visible from the theodolite station, a portion was obscured from view by land. This included the area within the bay close to the reef

10 Deciding which PCs should be commented on is fairly arbitrary process and depends largely on what the researcher hopes to achieve with the analysis. Manly (1994) chose to comment on the first four PCs, as he felt these were the most important in explaining the data.
system and the area behind the reef on the south-east side (Fig. 4.3). Theodolite tracking of dolphin groups in this area was therefore not possible.

![Figure 4.3. Area behind the reef system not visible from the theodolite station (photo: E. Green).](image)

In order to document dolphin use of these areas in front and behind the reef, GPS locations of dolphins were taken of each group encountered on photo-identification surveys (Chapter 3). These locations were plotted to demonstrate use of the area obscured from the theodolite station and give a broader view of dolphin distribution in Porpoise Bay.

### 4.4 Results

#### 4.4.1 Tracking

Theodolite observations were made on 48 days between 2 December 2001 and 17 March 2002 and 56 days between 3 December 2002 and 28 March 2003, from 0600 to 2030. Dolphins were absent for the entire shift on 12.3 % (n = 57) and 3.8 % (n = 78) of occasions when tracking was attempted during the first and second research summer respectively. Observations were made over 189 hrs and 190 hrs during which time 8,048 and 8,856 theodolite fixes of dolphins, boats and swimmers were taken during each summer respectively.
While weather conditions affected tracking opportunities, every attempt was made to spread theodolite tracking effort evenly through different time periods (0600-1000, 1000-1400 and 1400-1800; Fig. 4.4) and months (December through March; Fig. 4.5). In addition to the standard 4-hour shifts between 0600 and 1800, a small amount of time was spent tracking dolphins after 1800 in the evening.

Figure 4.4. Hours of theodolite observation, sorted by time during summer a) 2001/02 and b) 2002/03.

Figure 4.5. Hours of theodolite observation, sorted by month during summer a) 2001/02 and b) 2002/03.

Of the total time spent at the theodolite station looking for dolphins, successful tracking took place for 66.5 and 146.2 hours during summer 2001/02 and 2002/03 respectively. Length of tracking time ranged from 5 to 240 minutes with a mean tracking time of 96 and 29 minutes per group (2001/02 median = 90, SE = 63.6; 2002/03 median = 19, SE = 29.4). For an additional 32.3 hours in the first research season and 13.4 hours in the second research season, dolphins were known to be present in the bay but could not be tracked as they were not visible from the theodolite
station (i.e. were in the shaded area in Fig. 4.1). Many more groups were tracked in summer 2002/03 (n = 344) compared with summer 2001/02 (n = 51). This was possibly because there were more dolphins present in the bay in the second research season and thus the rate of social interactions, including group fission-fusion was high.

4.4.2 Use of the bay

The proportion of observation time during which dolphins used the bay in summer 2002/03 was significantly different to the proportion found during summer 2001/02. Specifically, dolphins were present in the bay for a much higher proportion of observation time in the second research summer when compared with summer 2001/02 (z = 7.244, p < 0.001). In addition, dolphins were found very close to shore on the northern side of the South Heads (out of sight from the theodolite station) for a much greater proportion of the observation time during 2001/02 (z = 3.267, p < 0.001; Fig. 4.6).

4.4.3 Distribution

4.4.3.1 Comparison of distribution during 2001/02 and 2002/03

During summer 2001/02 and 2002/03 dolphins spent the majority of tracking time in the southern part of the bay in an area approximately 1.3 km along the coast by 600 m from the shore (Fig. 4.7). This preferred summer habitat has remained much the same.
since 1995 (Bejder and Dawson, 2001). Within this area dolphins demonstrated a strong preference for a 400 m by 200 m strip in the south part of the bay, close to shore and sheltered from the swell by the reef system (Fig. 4.7).

Figure 4.7. Dolphin distribution within Porpoise Bay during summers a) 2001/02 and b) 2002/03. Shading of grids shows the average proportion of tracking time dolphins spent in each grid.

To investigate whether usage differed between the two research summers a principal component analysis of all data was conducted. A t-test was then carried out on the scores generated by the analysis to test whether they were different for each of the PCs between the two years of research. This analysis needed 23 PCs to explain 80% of the variation in the data. Of these, seven were statistically different between the research summers (p < 0.05), and three explained more than 5% of the variation in the data.

The first significant PC explained 7.38% of variation, and was composed of 35 grids (with eigenvalues > 0.2\textsuperscript{11}; Fig. 4.8). Each of the grids had either a positive or a negative value that represented the degree of contrast between the mean scores in the two research seasons (Fig. 4.8). The mean of the PC scores was −0.273 for summer 2001/02 and 0.144 for summer 2002/03. Interpretation of the mapped PCs (Fig. 4.8) involved comparing the sign of the mean for each year (+ or −) to the sign shown in each grid. A matching sign shows higher presence of dolphins in the condition and conversely, a differing sign shows less use.

\textsuperscript{11} While each grid has a corresponding eigenvalue, only variables (grids) > 0.2 are usually commented on as these are considered most important to the analysis.
Figure 4.8. An example of a PC that was significantly different between the research seasons. Here, + represents eigenvalues > 0.2 and – represents eigenvalues < -0.2. The direction of the sign is irrelevant, and simply represents a contrast in use between the test conditions, here the research summers; 2001/02 and 2002/03.

Figure 4.8 then, shows that dolphins were present more in the southern part of the bay during 2001/02 than 2002/03 and that the area north of Cook’s Creek was used more in 2002/03. It also suggests that dolphins were found further offshore more often in 2002/03 compared to 2001/02. These changes were also apparent in maps of the other significant principal components that explained > 5 % of variation in the data. Figure 4.8 is an example of how a PC can be mapped and interpreted. For the remainder of this chapter, having demonstrated how the technique works, the significant changes in distribution identified by the PC analysis will be discussed rather than a map of each analysis presented.

Given these differences in overall distribution between summers 2001/02 and 2002/03 the data sets have been analysed, presented and discussed separately. In the PC analysis of 2001/02 data, 13 PCs were needed to explain 80 % of the variation in the data, with the top seven PCs explaining 17.6, 10.2, 8.4 6.7, 6.6, 5.8 and 5.1 % of the variation each. In 2002/03, 19 PCs were needed to explain 80 % of the variation in the data, with the first six PCs explaining 9.8, 8.3, 7.2, 5.9, 5.6, and 5.2 % of the data each. Comparison between dolphin distribution in each of the conditions of interest, namely month, time of the day, and human absence/presence are presented and discussed below.
4.4.3.2 Summer 2001/02

a) Months

An ANOVA on the scores generated by a PC analysis on 2001/02 distribution data showed that there were no significant changes in distribution between the months of research. Visual comparison of the plots suggests that dolphins were slightly more concentrated in the southern part of the bay during December, February and March than during January (Fig. 4.9).

Figure 4.9. Plot of the proportion of tracking time dolphins spent in areas within the bay during summer 2001/02 classified according to month.
b) Time periods

Comparison of the means of the PC scores found that the grids composing two PCs were statistically different during different times of the day. These showed that dolphins were further north in the bay during the early morning and that they tended to be closer to the shore during the middle of day and in the afternoon, and further south in the afternoon ($p < 0.05$, Fig. 4.10).

Figure 4.10. Plot of the proportion of tracking time dolphins spent in areas within the bay during summer 2001/02 classified according to time.
c) Human presence vs control situations

To investigate whether a human presence altered dolphin distribution, a t-test on the PC scores between control distribution and distribution in the presence of both boats and swimmers was undertaken. There were so few occasions when boats were present without swimmers near-by that these two conditions were combined to increase sample size. Distribution in the presence of swimmers only was excluded from the analysis as it was highly predictable given the definition of swimmer presence (within 200 m of dolphins) because swimmers seldom venture far beyond the surf\(^{12}\). The analysis showed no significant differences in dolphin distribution in the presence of boats and swimmers compared to the control situation (Fig. 4.11).

![Diagram showing dolphin distribution](image)

Figure 4.11. Percentage of tracking time dolphins spent in areas of the bay during summer 2001/02 a) in the absence of humans b) in the presence of swimmers and c) in the presence of boats and swimmers.

\(^{12}\) Distribution data in the presence of boats and swimmers was not as predictable as in the presence of swimmers only. This was because boats could access dolphins anywhere in the bay, and interactions where a swimmer was within 200 m of the focal pod at any stage during a boat-dolphin encounter were categorised as occurring in the presence of both boats and swimmers.
4.4.3.3 Summer 2002/03

a) Months

An ANOVA test on the means generated from the PC analysis on 2002/03 distribution data showed that dolphin use of the bay differed according to month. Specifically, dolphins used the area of the bay north of Cook’s Creek more in December and January and were found slightly more offshore in the southern part of the bay during March (p < 0.05; Fig. 4.12).

Figure 4.12. Plot of the proportion of tracking time dolphins spent in areas within the bay during summer 2002/03 classified according to month.
Changes in distribution were also detected with the progression of each day during summer 2002/03 (Fig. 4.13). The first of these significant differences was the change from fairly even use of the whole preferred area in the morning and middle of the day, to a strong preference for a small area at the southern end of this preferred habitat in the afternoons (p < 0.05; Fig. 4.13).

In the evenings dolphins were seen further north and further offshore (Fig. 4.13). However low effort after 1800 meant that there was no way of knowing whether or not evening data was truly representative of dolphin habitat use after 1800 (Fig. 4.13).

Figure 4.13. Plot of the proportion of tracking time dolphins spent in areas within the bay during 2002/03 classified according to time.
c) *Human presence vs control situations*

A t-test of the PC means showed that dolphins were sighted further offshore during control situations ($p < 0.05$). In contrast, in the presence of boats and swimmers dolphins were found further inshore in the northern part of their range. Another visually apparent trend, though not statistically significant, was higher use of the southern part of the bay in the presence of boats and swimmers (Fig. 4.14). As with 2001/02 data, distribution in the presence of swimmers was not commented on due to its predictability.

Figure 4.14. Percentage of tracking time dolphins spent in areas of the bay during summer 2001/02 a) in the absence of humans b) in the presence of swimmers and c) in the presence of boats and swimmers.
In order to test whether higher use of the small area in the southern part of the bay during afternoons was the simply because this was the time that most people preferred to swim (Chapter 2) a comparison of data gathered in control situations and in the presence of boats and swimmers in 2002/03, during afternoon shifts only was carried out. This comparison showed that the dolphins' distribution closer to shore in the southern part of the bay when around boats and swimmers was still apparent in the absence of boats and swimmers. No significant difference was found when 2001/02 afternoon data were compared. However, sample size was small (n = 15) compared with 2002/03 (n = 36).

4.4.4 Comparison of distribution data with Bejder and Dawson (2001)

Visual comparison of plots of distribution produced in this study with those produced by Bejder and Dawson (2001) showed that overall dolphin distribution within the bay was similar to distribution observed during 1995-97. That is, dolphins were spread throughout the bay but spent the great majority of time in the southern end, in an area between Cook's Creek and the South Heads, sheltered by the reef system. The finding that dolphins used a larger area during January 2002 and were less concentrated in the southern end of the bay than in the other study months of 2002 was also observed by Bejder and Dawson (2001). This pattern was visually apparent also in 2002/03 but the effect was not significant. Bejder and Dawson's (2001) observation that dolphin sightings became more closely congregated throughout the day was a pattern also observed in this study. However, while this study showed the dolphins moving from use of the southern half of the bay in the mornings to concentrating in the very south end of the bay by the afternoons, this effect was not observed in 1995-97 (Bejder and Dawson, 2001). Unfortunately, plots of dolphin distribution in the presence and absence of humans were not presented by Bejder and Dawson (2001). This meant that comparison of distribution in these conditions with results found in the current study were not possible.

4.4.5 Locations of dolphins sighted from the research boat

GPS locations of dolphin groups encountered when conducting photo-ID field work (Chapter 3) during 2001/02 (n = 36) and 2002/03 (n = 68) were plotted onto a map of
Porpoise Bay (Fig. 4.15). This map shows that dolphins used similar areas within the bay during both research summers. Also apparent during both summers was the dolphins’ use of the area on the south side of the reef system, not visible from the theodolite station. Dolphin sightings were more spread out in 2002/03 compared to 2001/02, when dolphins were most often found close to the shore in the southern end of the bay (Fig. 4.15).

![Dolphin sightings](image)

**Figure 4.15.** Dolphin sightings made from the research boat during photo identification surveys in summer 2001/02 and 2002/03.

During summer 2002/03 newborn calves were sighted in nursery groups of, on one occasion, three calves and three mothers, and on another, two calves and two mothers. While such nursery groups are common at Banks Peninsula, they were not seen in summer 2001/02 in Porpoise Bay, nor were they observed by Bejder (1997) in previous research. Instead, calves were incorporated in larger, mixed groups. Interestingly, on both occasions nursery groups were seen on the south east side of South Heads (Fig. 4.3). At the same time, larger groups were present within the bay in the southern corner, on both occasions with a large number of swimmers nearby.
4.5 Discussion

4.5.1 Distribution differences between 1995-97 and 2001-03

Visual comparison of distribution plots produced in this study with those presented by Bejder and Dawson (2001) show that dolphin use of Porpoise Bay was very similar in the summers 1995-97 and 2001-03. While these studies are effectively only two points in time, they suggest that dolphin use of the bay is fairly consistent, with dolphins exhibiting a strong preference for the southern end of the bay. That some of the minor changes in distribution observed in the previous study were also observed in this study suggest that fine scale use of the bay may also be similar across years.

4.5.2 Distribution differences between summer 2001/02 and 2002/03

Dolphin use of Porpoise Bay during summer 2001/02 and 2002/03 was quite different. In the first research season dolphins were absent from the bay for almost half the time theodolite tracking was attempted, compared to just 16% of the time during 2002/03. In addition, when present, there tended to more dolphins in summer 2002/03 than during 2001/02 (Chapter 2). As a result of this, many more groups were tracked in the second season and groups tended to split and merge more often. The reason dolphin use of the bay was greater during summer 2002/03 is unknown. However other studies on cetaceans have shown that a number of factors influence distribution, including the presence of other species, environmental factors and resource availability (e.g. Selzer and Payne, 1988; Harzen, 1998; Davis et al., 2002). Prey distribution is presumed to be the main factor in Hector’s dolphin, and cetaceans’ generally, habitat choice (Theile et al., 2000; Garcia von Imhof, 2002).

It is possible that the low use of Porpoise Bay by Hector’s dolphins observed during 2001/02 may have been related to prey distribution, however, it was beyond the means of this study to attempt to assess this. In fact, linking distribution to the distribution of prey is notoriously difficult, and has not been successfully attempted with dolphins. In contrast, studies on larger cetaceans have been able to make this link. For example, Jaquet and Gendron (2002) showed that the abundance of jumbo squid (Dosidicus gigas) affected the distribution of sperm whales in the Gulf of California. A decline in
squid stocks was reflected in a fairly even spread of whales throughout the gulf during that year. When stocks recovered, whales were concentrated in areas of high squid biomass. In another study marked variability in the distribution of gray whales off Vancouver Island was found, with some feeding areas used on an annual basis, and others used at more than 10 year intervals (Darling et al., 1998). Porpoise Bay is obviously an important annual habitat for the Hector's dolphins studied in this research, but perhaps for unknown reasons another area is more attractive during some summers, and was so during 2001/02.

Another reason dolphins did not use Porpoise Bay extensively during 2001/02 might be related to environmental factors. Bräger and colleagues (2003) attempted to relate the distribution of Hector's dolphins to three such factors, namely sea surface temperature, water depth and water clarity, and found that all of these affected the distribution of dolphins (preferred SST > 14 °C; preferred depth < 39 m; preferred visibility < 4 m). Thus, annual changes in one or all of these factors may have affected dolphin distribution in Porpoise Bay during the research summers. In New Zealand in summer 2001/02 and 2002/03 rainfall was much lower than usual. In 2001/02 there were far more easterly winds than normal and temperatures were warmer than average. In contrast, in 2002/03, winds were mostly westerlies and average temperatures were the lowest since 1996/97. Research on gray whales in Magdalena Bay, Mexico showed whale presence was inversely related to water temperature with whales extending their migration paths to head further south to warmer waters in the cooler temperatures associated with a La Niña event (Gardner and Chávez-Rosales, 2000). Like these whales, Hector's dolphins in Porpoise Bay may have used another area in 2001/02 where environmental conditions were preferable. Or perhaps, differing weather conditions affected the distribution of prey, which in turn affected the distribution of dolphins.

4.5.3 Distribution by month, time of day and tourism presence

Small-scale differences in use between the two most recent research summers were detected by mapping the proportion of time dolphins spent in 100 m² grids in the bay. In 2001/02 dolphins congregated more in the southern part of the bay whereas in 2002/03 dolphins were found regularly north of Cook's Creek. In addition, in the first
research season, dolphins not visible from the theodolite station spent more time close to the reef system on the north west side of the South Heads. In contrast, when dolphins were not visible, but were present during 2002/03, they were usually found on the south east side of the South Heads. Application of principal component analysis to distribution data was an exploratory but informative technique used to determine whether dolphins showed statistically significant differences in habitat use according to time, month and the presence of humans.

Comparisons of utilisation of the bay between different months showed that dolphins occupied a very similar area during the two summer seasons. However, within 2002/03 two changes were discernible. First, in March dolphins were found further south and further from the shore and secondly, in December and January dolphins were found north of Cook’s Creek more often. Dolphins are regularly sighted in Porpoise Bay from December through to March each year, but are seldom seen through the winter months. Although small in scale, the distributional change documented here may show dolphin movement into the bay in December and January and the beginnings of dolphin movement out of the bay to another area for winter; either offshore or alongshore (see Chapter 6).

Utilisation of the bay was also found to differ as a function of the time of day. During both summers dolphins became more congregated with successive time periods from morning to afternoon, showing particularly high use of a small area in the southern part of the bay during the afternoons. This confirms the patterns of dolphin distribution during summer 1995/96 and 1996/97 documented by Bejder and Dawson (2001). Changes in distribution over the course of a day have also been observed in other species such as bottlenose dolphins in Portugal. There, dolphins were observed to move into an estuary in the mornings with the flood tide and then leave again in the afternoons and with the ebb tide (Harzen, 1998). When compared to these dolphins, the diurnal movements of Hector’s dolphins in Porpoise Bay are very small. However, these differences, regardless of scale can be used to guide management actions. High use of a very small area within the bay in the afternoons generally, suggests that this area is of great importance to the dolphins. Dolphins seen there were commonly observed to be socialising and resting.
Dolphin distribution was also affected by the human presence in the bay. During summer 2002/03 dolphins were found closer to shore and further south in the bay while in the presence of boats and swimmers. No significant difference in distribution was detected during 2001/02. The majority of the time dolphins spent in the presence of boats was in the afternoons, as this is the warmest, most appealing time to swim and take a boat-trip to see the dolphins. Thus it was possible that the high use of this small area in the presence of tourists may have been an artefact of the time of day these boat and swimmer interactions occurred. However, comparison of data gathered in control situations and in the presence of boats and swimmers in 2002/03, during afternoon shifts only, showed that this distribution pattern was apparent irrespective of the presence of boats and swimmers. In addition, during photo-ID surveys from the research boat, dolphins were observed on occasions to move into the surf when the research vessel came near. Attempts at photographing dolphins became impossible because it was too dangerous to move the boat into the surf. This movement was also observed in reaction to the tourist vessel. These observations provide support for the finding apparent from the plots that dolphins were found closer to the shore in the presence of boats. In regard to swimmers, near-shore distribution is most likely a function of the definition of swimmer presence.

4.5.4 *Dolphin sightings from the boat*

Plotting of boat-based sightings of dolphin groups in addition to theodolite sightings was effective in showing that dolphin distribution extended beyond the bay to the area behind the reef system of the South Heads where tracking was not possible. Further evidence for the importance of this area during summer 2002/03 came from the sighting of nursery dolphin pods in the area. On both days nursery pods were sighted there, the tourism presence in the bay was high. Whether the mothers of this pod were keeping the calves from interacting with humans in the bay or whether the area behind the reef provided more food, necessary for lactating mothers, is impossible to say. However, on the basis of this evidence, and given the higher susceptibility of calves to boat strikes, it seems appropriate that this area be subject to speed and behaviour restrictions similar to those currently in place within the confines of the bay.
4.5.5 Conclusion

Comparison of the maps of dolphin distribution presented in this chapter with the maps of swimmer and boat presence in Chapter 2, show the distinct overlap between the preferred area of swimmers with that of dolphins, and the accessibility of dolphins to boats. Despite the large increase in tourism presence since previous research in 1995-1997, the distribution of Hector’s dolphins in Porpoise Bay has not been significantly altered, as has been observed with other cetacean species (e.g. Jones and Swartz, 1984; Driscoll-Lind and Östman-Lind, 1999). However, this may not remain so given that tourism in the bay is continuing to increase rapidly. Estimating the level of tourism these dolphins will tolerate before finding another area to use during summer months was beyond the scope of this study. However, findings presented in this chapter can be used to assist managers on how to manage human use of the bay in order to reduce dolphin exposure to humans should it be found to be problematic in the future. The immediate responses of dolphins to boats are swimmers were assessed, and these are discussed in the following chapter (Chapter 5).
Chapter 5. Responses to Boats and Swimmers

5.1 Introduction

Although marine mammal watching is growing enormously around the world, research into assessing the effects of such tourism has not grown to nearly the same extent (Higham, et al., 2001). Studies that have investigated the interactions between humans and cetaceans have documented directional changes, altered behaviours, and shown the displacement and vessel avoidance of the cetaceans being studied (e.g. Watkins, 1986; Janik and Thompson, 1996; Barr and Slooten, 1999; Nowacek et al., 2001; Williams et al., 2002). Noticeable behavioural changes include differing; diving times, blow intervals, vocal behaviour, swimming speed, group dispersion and behavioural budgets (e.g. Kruse, 1991; Norris, 1994; Barr and Slooten, 1999; van Parijs and Corkeron, 2001; Richter et al., 2002).

Research on the effects of tourism on cetaceans consists largely of studies investigating short-term behavioural changes. These studies, while informative, tend also to be very specific in that their findings pertain only to a certain species, in a certain location and under a specific level of tourism presence. This specificity can relate even to the individual level, as seen with sperm whales at Kaikoura, which demonstrate varying levels of tolerance among individuals, probably as a result of habituation to the tourism vessels operating there (Gordon et al., 1992; Richter et al., 2002). Similarly, different sexes can demonstrate differing responses to vessels. For example, killer whales in Johnstone Strait, B.C., showed different boat avoidance strategies according to gender; males maintained speed while swimming in a variable direction while females swam faster and increased their angle to the boat during successive dives (Williams et al., 2002). This variability in response to a human presence means that management regulations cannot easily be generalised from one population to another and emphasises the necessity of studying each cetacean population that is subject to tourism.

Also apparent from the literature is the lack of long-term studies on the effects of the short-term changes observed. It seems likely that such changes disrupt the energy
budgets of cetaceans and may have long-term effects; however these are largely unknown. Long-term studies are needed so that trends, for example in habitat use, abundance and responses to boats can be investigated. Such research and subsequent implementation of the appropriate management actions can ensure that the educational and economic potential of a tourism venture is not compromised by negative effects upon the cetaceans being targeted (Archer and Cooper, 1995).

Previous research on Hector’s dolphins’ responses to tourism in Porpoise Bay was conducted by Bejder and colleagues (1999) during the summers of 1995-97. This research showed that dolphins approached boats more often than was expected for the first 40 minutes of an encounter, and less often than expected beyond 70 minutes. In addition, Bejder and colleagues (1999) found that while swimmers appeared to have very little effect on the dispersion of pods in the bay, that in the presence of boats, dolphins became more tightly congregated. Of 56 swim-with attempts observed, 57% were classified as successful (dolphins stayed within 200 m of swimmers for > 5 minutes).

This chapter investigates the responses of Hector’s dolphins in Porpoise Bay to the presence of boats and swimmers during the austral summers of 2001/02 and 2002/03. Consistency in field and analytical methods with those used by Bejder et al. (1999) allowed direct comparison of the results to those of 1995-97. In turn, this made it possible to evaluate management actions adopted as a result of previous research and discuss trends in responses exhibited by dolphins given the increase of tourism in the bay in the intervening five years (as discussed in Chapter 2). Thus, the aims of this chapter were:

1. To investigate Hector’s dolphin responses to the presence of boats and swimmers in Porpoise Bay.
2. To compare these responses with similar research conducted five years ago on the population as described by Bejder et al. (1999).
5.2 Methods

Research methods employed in this study were as close as possible to those used by Bejder et al. (1999) to allow for best comparison between results. Dolphins were tracked continually with a theodolite with a distinction made between ‘control’ and ‘human presence’ situations on the basis of the presence or absence of tourism activities:

- ‘Human presence’: observations when either a) a boat was anywhere in the bay, and/or b) a swimmer(s) came within 200 m of the dolphin pod.
- ‘Control’: observations when both swimmers and boats were absent (as per definitions above), and had been for at least 20 min.

Dolphins were tracked as described in Chapter 4, with two changes. First, when the tracking situation changed from ‘control’ to ‘human presence’, fixes were taken alternately of the dolphin focal pod and the tourist presence (boat/swimmer). Secondly, fixes were taken to the dolphin closest to the tourist presence (rather than to the centre of the pod). When more than one boat or swimmer was present, fixes were taken alternately between the dolphin pod, and each swimmer/boat. For example a track might consist of the fixes; dolphin, swimmer 1, dolphin, swimmer 2, dolphin, swimmer 1, and so on.

5.2.1 Measurement of dolphin orientations in relation to boats and swimmers

The computer software PYTHAGORAS (©Gailey and Ortega-Ortiz, 2000) was used to analyse movement of dolphin pods in relation to boat/swimmer movements. The programme considered three targets: dolphin, boat and swimmer, and made calculations by considering two consecutive fixes of the same target. Interpolation was used to account for the theodolite only being able to take fixes of one target at a time. This process controlled for time differences between fixes of each target in order to calculate the angle between the orientation of the dolphin pod in relation to the boat or swimmer (Fig. 5.1).
The programme then provided calculations of distances between targets as well as classifying the angle ($\alpha$) of the dolphin pod heading according to one of four quadrants. That is, 'towards', 'equivocal' or 'away', depending on the angle of the leg of dolphin movement compared to the boat/swimmer (Fig. 5.2). Here, the dolphin pod is considered to be in the middle of the circle and the boat or swimmer at 0°.

---

**Figure 5.1.** An example of the calculation of dolphin orientation ($\alpha$) in relation to boat/swimmer position. The number in brackets indicates the order the fixes/positions were taken by the theodolite operator (Bejder, 1997).

**Figure 5.2.** Classification of dolphin/boat and dolphin/swimmer orientation (Bejder, 1997).
Dolphin responses to boats and swimmers were assessed with regard to dolphin pod orientation compared to that presence using logistic regression models. These models predict the probability of a dolphin group heading towards a boat or swimmer based on the proportion of headings classified into the top quadrant in Figure 5.2. From these analyses the study aimed to determine 1) whether responses made by dolphins changed as a function of time into an encounter and 2) whether dolphin responses were consistent across the different years over which research was undertaken.

5.2.2 Classification of swim-with attempts

To investigate the effect of the increased number of swim-with attempts (swimmer/s entering the water < 200 m from dolphins) on dolphins, each dolphin-swimmer interaction was classified following the criteria described by Bejder et al. (1999). That is, ‘non-disturbing’ when dolphins remained within 200 m of swimmer/s for > 5 minutes, ‘potentially disturbing’ when dolphins moved > 200 m away within 5 minutes of swimmer/s entering the water and ‘disturbing’ if the dolphin pod immediately (within 2 min) left the 200 m vicinity.

5.2.3 Pod dispersion methods

The dispersion of the dolphins within the focal pod was assessed once per minute throughout each tracking session. Following Bejder et al.'s (1999) definition for comparative reasons, dispersions were categorised into one of four states, based on the average distance between individuals within the focal pod:

- State 1: dolphins 0 – 2 dolphin body lengths apart
- State 2: dolphins > 2 – 5 dolphin body lengths apart
- State 3: dolphins > 5 – 10 dolphin body lengths apart
- State 4: dolphins > 10 dolphin body lengths apart

These data were analysed to determine whether dolphin group dispersion changed depending on the presence of boats or swimmers.
5.2.4 Collection of behavioural data

To investigate whether the presence of boats or swimmers affected the behavioural budget of dolphins, assessments of behavioural states were made every three minutes during all the time dolphins were being tracked. In addition, behavioural recordings were made on occasions when dolphins were present in the bay but were not visible from the theodolite station. The decision to record states rather than behavioural events was made because of the variability in distance from the theodolite station. On some occasions dolphins were within 150 m of the theodolite station, while in others they were more than 2 km away. The ability to detect individual events was thus biased by distance. In contrast, assessment of states was made on the basis of the focal pod’s overall movements, which are more easily discerned from a distance. Definitions of states were similar to the categorisation used by Lusseau (2003b). However, the ‘resting’ category was not included as the distinction between ‘milling’ and resting was considered too difficult to make, especially at a distance (Table 5.1):

Table 5.1. Definitions used to classify the behaviour of the focal pod.

<table>
<thead>
<tr>
<th>State</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diving</td>
<td>The direction of the group varies. Dives are synchronous and long (1 - 2 mins). It is sometimes possible to see dolphins arching their backs at the surface just before diving. It is likely that dolphins are feeding.</td>
</tr>
<tr>
<td>Milling</td>
<td>The group shows no net movement. Individuals face differing directions. Dives tend to be short (&lt; 20 secs).</td>
</tr>
<tr>
<td>Socialising</td>
<td>Many types of behavioural events are observed including aerial behaviour, body contacts, lob tailing (slapping the water with the lower half of the body and tail) weeding (playing with pieces of weed) and tail slaps (slapping of just the tail on the water). The rate of group fission and fusion is high. Behaviours may be directed towards other dolphins, boats or swimmers.</td>
</tr>
<tr>
<td>Travelling</td>
<td>The pod moves in a steady direction, at speed. Active surfacing (breaking out of the water while travelling at speed) may be observed. Dives are short (&lt; 20 secs).</td>
</tr>
</tbody>
</table>
5.3 Analysis

5.3.1 Logistic regression modelling of dolphin orientations

To reduce autocorrelation, data were thinned so that just one dolphin fix per minute remained. Also, fixes of dolphin pods more than 180 seconds apart were discarded from the analysis in order to ensure that the same focal pod was being tracked for the entire length of the interaction\(^\text{13}\). In a further attempt to reduce the effect of autocorrelation of the data, dolphin responses were pooled into 10 minute categories within the interaction. For dolphin interactions with boats, this meant that for 2001/02 data there were 5 intervals of 10 minutes each. A 6\(^{\text{th}}\) interval of 20 minutes comprised responses observed in the 50 - 70\(^{\text{th}}\) minutes, pooled to increase sample size. In 2002/03 there were 4 intervals of 10 minutes and a 6\(^{\text{th}}\) interval of pooled responses between the 40\(^{\text{th}}\) and 70\(^{\text{th}}\) minutes. For all swimmer data there were seven 10 minute categories, and one category of 20 minutes with data collected between the 70\(^{\text{th}}\) and 90\(^{\text{th}}\) minutes pooled.

Scoring of response data was made in a cumulative fashion to investigate the effect of multiple swimmers or boats on dolphins. For example, for swimmers, time into the encounter was scored based on whether that dolphin group had already been within 200 m of a swimmer before a new swimmer entered the water. In this case, the dolphin pod's response to the new swimmer was entered into the interval of elapsed time since the first swimmer's presence. When the dolphin pod moved beyond 200 m of a swimmer presence for more than 20 minutes the clock was reset to zero, and responses in the presence of new swimmers were allocated into the 0 – 10 minute time interval.

SPSS software was used to fit logistic regression (LR) equations to heading data, that is, to the observed proportion of heading responses in the binomial form (Harraway, 1995). In order to make results directly comparable to Bejder et al.'s (1999) study the

\(^{\text{13}}\) Whereas in other studies this time threshold has been lower, 180 seconds was chosen here for the reason that alternating between a boat/swimmer target and a dolphin target, and the consequent movement of the theodolite, meant that a pod's surface could easily be missed. The theodolite operator would then have to wait for the next surface to take the dolphin fix, a wait of sometimes up to 2 minutes.
'towards' headings exhibited by dolphins were modelled to investigate the effect of encounter duration on dolphin responses.

The LR models fitted were in the form:

\[
\pi = \frac{\exp(\beta_0 + \beta_1 T + \ldots + \beta_p T)}{1 + \exp(\beta_0 + \beta_1 T + \ldots + \beta_p T)}
\]

where \( \pi \) is the probability of movement towards the boat/swimmer.

The LR models involved either a constant only (\( B \)), or modelled the probability of movement towards the boat/swimmer as a function of the time since the beginning of the encounter (\( T \)), as follows:

Model 1: Constant only.
Model 2: Constant plus linear term in Time (\( T \)).
Model 3: Constant plus linear and quadratic terms in \( T \).
Model 4: Constant plus linear, quadratic and cubic terms in \( T \).

Before carrying out this analysis however, it was necessary to determine whether dolphin responses to a tourism presence were consistent between the research summers. To do this the variable, 'year', was introduced to the model. In the case of dolphin responses to boats, this involved comparing data gathered during 2001/02 with data gathered during 2002/03. Improvement of the model fit by the addition of this new variable 'year', as indicated by a significant deviance difference, would show that the responses were different between the years (Harraway, 1995). Similarly, dolphin responses to swimmers over the two summers were compared by introducing the same variable 'year'. Significant improvement of the models including 'year' was considered justification for analysing the data sets separately. Conversely, failure to improve the predictive value of the models with the addition of the new factor provided the grounds for combining data gathered over both research seasons for analysis. The same technique was used for determining longer-term trends in dolphin responses to a tourism presence. Data from dolphin-boat headings observed in 1995-97 were pooled and compared to pooled headings from 2001-03. Here, the variable
‘research period’ was introduced to investigate any differences in headings in the 5 years since previous research. Comparison of swimmer data with research carried out in 1995-97 was not possible, as encounters with swimmers were not tracked. Thus the models were as follows:

- Model 1: Constant only
- Model 2: Constant plus year (Y) or research period (P)
- Model 3: Constant plus Y or P and linear term in T
- Model 4: Constant plus Y or P, linear and quadratic terms in T
- Model 5: Constant plus Y or P, linear, quadratic and cubic terms in T

All models selected were further tested for goodness of fit by calculating and summing the Pearson residuals.

5.3.2 Pod dispersion analysis

Data on pod dispersion were pooled to aid comparison with past research and to increase sample size. States 1 and 2 were combined into a ‘tight’ state, and States 3 and 4 into a ‘dispersed’ state. To account for the possibility of pod dispersion being affected for some period after exposure to tourism, data collected during the 20 minute period after a human presence left the dolphins were discarded from the analysis. As pod dispersion states were collected sequentially from the same pod, analyses of the data had to consider the likelihood that they were correlated. Markov chain models have been used successfully in studies for ecological assessments as they consider such potential autocorrelation between successive data points (e.g. Hill and Caswell, 2001). These models quantify the degree to which preceding events affect succeeding events. With a Markov chain model there are many possibilities for the level of dependence (Caswell, 2001). The simplest form is the 0-order chain, which describes data in which each event is independent of others. The 1st-order chain fits data in which an event depends on the event immediately preceding it. A 2nd-order chain describes events that depend on the two events preceding it, and so on.

To determine whether it was appropriate to use Markov chain models to test for differences in group dispersion between control and human presence situations, it was necessary to test whether the data met the assumptions of the analysis, namely:
1. That transitions remain stable over time i.e. that the chances of one dispersion state preceding/succeeding another is the same over time.

2. That sample size is sufficiently large.

In order to determine which type of relationship best represents the data, the fit of each Markov chain model (0-order, 1st-order, etc.) is compared using a Bayes Information Criterion (BIC). A high BIC for a chain indicates good fit to the model whereas low BIC for a chain indicates poor fit (Katz, 1981).

After ensuring that data satisfied the assumptions it was then possible to calculate maximum likelihood estimates (MLEs), of dolphins remaining in either a tight (t) or dispersed (d) state, or changing from one to the other (Fig. 5.3).

![Diagram of possible transitions in dispersion state](image)

**Figure 5.3.** Representation of the possible transitions in dispersion state, tight (t) or dispersed (d), for dolphin pods. Here, \( P_{tt} \) = MLE dolphins stay in a tight state. \( P_{dd} \) = MLE dolphins stay in a dispersed state, \( P_{td} \) = MLE dolphins change from a tight state to a dispersed state. \( P_{dt} \) = MLE dolphins change from a dispersed state to a tight state.

5.3.3 *Behavioural state analysis*

To investigate any changes in behavioural budget in the presence and absence of boats and swimmers, the proportion of time spent in each of the behavioural states was compared between the control condition and each of the states of human presence. Like pod dispersion data, behavioural observations gathered for the 20 minute period following a boat or swimmer interaction were discarded from the analysis to account for any lasting effects of an interaction.
5.4 Results

During the first summer of research, observations were made over 98.92 hours on 52 days between December 2001 and March 2002. In the second research summer, observations were collected for 146.18 hours on 56 days between 3 December 2002 and 28 March 2003. All observations were made between 0600 and 2030. Dolphins were absent on five and four occasions when tracking was attempted during 2001/02 and 2002/03 respectively. Boats and swimmers were ‘present’ within the distances defined earlier (p.66) of dolphins for 39 % of the total time spent tracking during the first research season and 32 % during the latter (Table 5.2 and Chapter 2, p.24).

Table 5.2. The proportion of observation time dolphins spent with boats in Porpoise Bay and with swimmers within 200 m during summer 2001/02 and 2002/03.

<table>
<thead>
<tr>
<th>Type of interaction</th>
<th>Summer 2001/02</th>
<th>Summer 2002/03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boat</td>
<td>2h 24m (4 %)</td>
<td>8h 46m (6 %)</td>
</tr>
<tr>
<td>Swimmer</td>
<td>14h 12m (21 %)</td>
<td>28h 14m (19 %)</td>
</tr>
<tr>
<td>Both (boat &amp; swimmer)</td>
<td>7h 0m (11 %)</td>
<td>9h 56m (7 %)</td>
</tr>
<tr>
<td>Control (boats &amp; swimmers absent)</td>
<td>42h 54m (64 %)</td>
<td>99h 16m (68 %)</td>
</tr>
<tr>
<td>Total observation time</td>
<td>66h 30m (100 %)</td>
<td>146h 12m (100 %)</td>
</tr>
</tbody>
</table>

5.4.1 Dolphin responses to boats

During the research period encompassing summer 2001/02 and 2002/03 the sole tourist boat operator in Porpoise Bay conducted 52 and 69 trips to the dolphins respectively. On average the vessel spent 35 and 23 minutes within the 5 knot ‘dolphin zone’ (Fig. 2.3; unpub. data, DOC, 2003). However, as dolphins were often beyond the boundaries of the zone, a significant amount of dolphin-boat interaction time was spent outside the ‘dolphin zone’. A more accurate estimate of the total time dolphins spent with boats would be based on an estimate of 40 minutes spent with the dolphins per trip, as sanctioned in the operator’s former permit. Of the trips, 35 tourist boat-dolphin interactions were tracked from the theodolite station. Interactions between dolphins and 23 kayaks, one private dinghy with a small outboard and one rubber inflatable were also tracked. Time spent tracking dolphin-boat interactions totalled 9.4 hours during summer 2001/02 and 18.68 hours during 2002/03.
An example of a typical boat-dolphin interaction is depicted in Figure 5.4. Modelling of dolphin responses was based on the assumption that if dolphin movements in relation to the boat were random, you would expect the proportion of ‘towards’ responses exhibited by dolphins to be 0.25 (Fig. 5.2).

![Graph showing dolphin orientation in relation to the boat]

Figure 5.4. An example of a typical boat-dolphin interaction also depicting dolphin orientation in relation to the boat: ? = Towards, \( \downarrow \) = Equivocal, ? = Away.

\[ a) \quad 2001/02 \text{ vs } 2002/03 \]

The first Logistic Regression analysis was undertaken to determine whether the data collected during each of the two research summers should be analysed as one data set or separately. Results of this analysis including the variable ‘Year’ are presented in Table 5.3.

Table 5.3. Analysis of deviance for assessing goodness-of-fit of the different models for dolphin responses during 2001/02 compared to 2002/03 (where T = Time and Y = Year). (ns) = non-significant when compared with chi-square distribution. * = significant at the 5 % level when compared with the chi-square distribution. ** = significant at the 1 % level when compared with the chi-square distribution (NB this key is applicable to all similar tables in this chapter).

<table>
<thead>
<tr>
<th>Model</th>
<th>Deviance</th>
<th>DF</th>
<th>Deviance Difference</th>
<th>DF Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Constant only</td>
<td>1630.787</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 Constant + Y</td>
<td>1621.495 **</td>
<td>5</td>
<td>9.292 **</td>
<td>1</td>
</tr>
<tr>
<td>3 Constant + Y + T</td>
<td>1621.374 (ns)</td>
<td>4</td>
<td>0.121 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>4 Constant + Y + T + T^2</td>
<td>1621.323 (ns)</td>
<td>3</td>
<td>0.051 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>5 Constant + Y + T + T^2 + T^3</td>
<td>1616.530 *</td>
<td>2</td>
<td>4.793 *</td>
<td>1</td>
</tr>
</tbody>
</table>
Using Logistic Regression techniques, the size of the deviance difference can be used to indicate how well a model fits the data. A significant deviance difference indicates that the predictive value of the model has been significantly improved by the addition of the new factor. This analysis showed that dolphins’ responses to boats were significantly different between the years during which the research was conducted ($p < 0.01$; Table 5.3)\textsuperscript{14}. Given this result it was decided that it was most appropriate to analyse data gathered during the two research summers separately.

\textit{b) 2001/02}

Responses recorded during 2001/02 boat-dolphin interactions, pooled into 10 minute intervals, with the final two intervals combined to increase sample size, are presented in Table 5.4.

Table 5.4. Bearings towards boats classified by time for the 2001/02 season.

<table>
<thead>
<tr>
<th>Time into encounter (mins)</th>
<th>Total (n)</th>
<th>Frequency of towards responses to boat</th>
<th>Proportion of towards response to boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10</td>
<td>151</td>
<td>42</td>
<td>0.27</td>
</tr>
<tr>
<td>10 - 20</td>
<td>105</td>
<td>38</td>
<td>0.36</td>
</tr>
<tr>
<td>20 – 30</td>
<td>78</td>
<td>18</td>
<td>0.23</td>
</tr>
<tr>
<td>30 – 40</td>
<td>41</td>
<td>10</td>
<td>0.24</td>
</tr>
<tr>
<td>40 – 50</td>
<td>20</td>
<td>5</td>
<td>0.25</td>
</tr>
<tr>
<td>50 – 70</td>
<td>13</td>
<td>5</td>
<td>0.38</td>
</tr>
</tbody>
</table>

The regression models of dolphin responses to boats during 2001/02 tested for goodness-of-fit are presented in Table 5.5.

\textsuperscript{14} While neither the linear nor quadratic components of time had any effect on the predictive value of the model, the cubic had a significant effect. However, examination of the raw data shows that the final value used for the analysis (50 to 60 minutes) had a very small sample size ($n = 13$), and came from just one dolphin-boat interaction. When this value was removed from the analysis the cubic of time had no significant effect. Given this finding it was concluded that the statistical significance of the model incorporating $T^3$ warranted no further comment.
Table 5.5. Analysis of deviance for assessing goodness-of-fit of the different models for dolphin responses during 2001/02 (where $T = \text{Time}$).

<table>
<thead>
<tr>
<th>Model</th>
<th>Deviance</th>
<th>DF</th>
<th>Deviance Difference</th>
<th>DF Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Constant only</td>
<td>490.781</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Constant + $T$</td>
<td>490.738 (ns)</td>
<td>4</td>
<td>0.043 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>3 Constant $T + T^2$</td>
<td>490.316 (ns)</td>
<td>3</td>
<td>0.422 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>4 Constant $T + T^2 + T^3$</td>
<td>487.924 (ns)</td>
<td>2</td>
<td>2.393 (ns)</td>
<td>1</td>
</tr>
</tbody>
</table>

Analysis of these data show that the addition of time did not significantly improve the constant only model, that is, that time had no significant effect on dolphin responses to boats during 2001/02. Thus, the model using the constant only (Model 1) was selected as the best predictor of the probability of a dolphin pod heading towards a boat during the first research summer (Fig. 5.5), where the constant was:

$$\pi = \frac{\exp(-0.899)}{1 + \exp(-0.899)}$$

$$p = 0.29$$

Figure 5.5 shows the proportion of 'towards' responses made by dolphins to boats as a function of time into an encounter. “Expected” proportions are what we would expect to see under the null hypothesis that dolphin movements are random. The “Predicted” line represents the proportions as estimated by the model (shown here with 95 % confidence intervals).

![Figure 5.5](image)

Figure 5.5. The probability of a dolphin group heading towards a boat with time during summer 2001/02. Error bars are 95 % confidence intervals and numbers above the bars show sample size.
Here, the value predicted by the selected model, incorporating the constant only, is only slightly higher than what would be expected if dolphin movements around boats were random. That the confidence intervals around the values predicted by the model overlapped the 'Expected' value of 0.25 for all time intervals indicates that one could not conclude the dolphins were behaving significantly differently towards boats than if their responses were entirely random.

To provide another means of assessing how well the model fitted the data the goodness-of-fit of Model 1 was tested using an analysis of the Pearson residuals between the observed proportions of towards headings and those predicted by the model. The residuals showed no evidence of a lack of fit, thereby confirming that the model using the constant only was a good predictor of probability of dolphins heading towards a boat during summer 2001/02 (p < 0.001).

c) 2002/03

Data collected during 2002/03, also pooled into 10 minute intervals (here, with the final three intervals grouped to increase sample size) for separate analysis are presented in Table 5.6.

Table 5.6. Bearings towards boats classified by time for the 2002/03 season.

<table>
<thead>
<tr>
<th>Time into encounter (mins)</th>
<th>Total (n)</th>
<th>Frequency of towards responses to boat</th>
<th>Proportion of towards responses to boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 10</td>
<td>359</td>
<td>128</td>
<td>0.36</td>
</tr>
<tr>
<td>10 – 20</td>
<td>241</td>
<td>106</td>
<td>0.44</td>
</tr>
<tr>
<td>20 – 30</td>
<td>139</td>
<td>44</td>
<td>0.32</td>
</tr>
<tr>
<td>30 – 40</td>
<td>76</td>
<td>30</td>
<td>0.39</td>
</tr>
<tr>
<td>40 – 70</td>
<td>39</td>
<td>13</td>
<td>0.33</td>
</tr>
</tbody>
</table>

The regression models tested for goodness-of-fit to the observed dolphin responses to boats during 2002/03 are presented Table 5.7.
Table 5.7. Analysis of deviance for assessing goodness-of-fit of the different models for dolphin responses to boats during 2002/03 (where $T =$ Time).

<table>
<thead>
<tr>
<th>Model</th>
<th>Deviance</th>
<th>DF</th>
<th>Deviance Difference</th>
<th>DF</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Constant only</td>
<td>1130.714</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Constant + $T$</td>
<td>1130.636 (ns)</td>
<td>3</td>
<td>0.078 (ns)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3 Constant $T + T^2$</td>
<td>1129.897 (ns)</td>
<td>2</td>
<td>0.738 (ns)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4 Constant $T + T^2 + T^3$</td>
<td>1128.379 (ns)</td>
<td>1</td>
<td>1.519 (ns)</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Like responses during the previous summer, dolphin responses to boats during 2002/03 were unaffected by the duration of the encounter and were best predicted by the model including a constant only. Thus the equation that best predicts dolphin ‘towards’ responses to boats during the second research summer was simply the constant (Model 1; Fig. 5.6):

$$\pi = \frac{\exp(-0.51)}{1 + \exp(-0.51)}$$

$$p = 0.38$$

Figure 5.6 shows dolphins do not appear to change their approach response to boats as a function of time and that for the first 40 minutes of an encounter dolphins head towards boats more often than they would be expected to if they were making random movements. Responses beyond 40 minutes into an encounter did not occur at a higher rate than they would if movements were by chance.

![Figure 5.6. The probability of a dolphin group heading towards a boat with time during summer 2002/03. Error bars are 95% confidence intervals and numbers above the bars show sample size.](image-url)
The goodness-of-fit of this model was also tested using the Pearson residuals test. This test showed that the residuals showed no lack of fit to the constant only model (p < 0.01) and thus confirmed its choice as a good predictor of dolphin movement.

5.4.2 Dolphin responses to swimmers, 2001/02 and 2002/03

The same logistic regression procedure was used to analyse dolphin orientations with regard to swimmers. In order to account for the effect of continued ‘human presence’ situations on the dolphins, swimmer data, like boat data, was scored in a cumulative manner. Such scoring was deemed particularly necessary for swimmer data as 39% of all dolphin-swimmer encounters began when another swimmer was already within 200 m of the focal pod \((n = 417)\). This is much higher than that observed for dolphin-boat interactions where just 7% began during an existing boat interaction \((n = 67)\). As with boat data the first LR analysis undertaken compared dolphin responses over the two research summers and tested for goodness-of-fit to determine whether or not these data should be combined for analyses (Table 5.8).

<table>
<thead>
<tr>
<th>Model</th>
<th>Deviance</th>
<th>DF</th>
<th>Deviance Difference</th>
<th>DF Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Constant only</td>
<td>7248.145</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Constant + Y</td>
<td>7247.998 (ns)</td>
<td>7</td>
<td>0.147 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>3 Constant + Y + T</td>
<td>7247.880 (ns)</td>
<td>6</td>
<td>0.117 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>4 Constant + Y + T + T^2</td>
<td>7242.674 *</td>
<td>5</td>
<td>5.206 *</td>
<td>1</td>
</tr>
<tr>
<td>5 Constant + Y + T + T^2 + T^3</td>
<td>7239.761 (ns)</td>
<td>4</td>
<td>2.914 (ns)</td>
<td>1</td>
</tr>
</tbody>
</table>

Unlike the LR models comparing boat responses between the research years, dolphin responses to swimmers between the years were not found to be significantly different. On this basis it was decided that the data from the two seasons should be combined and pooled into 10 minute intervals for analysis. The pooled, cumulative proportions of ‘towards’ responses by dolphins to swimmers during both summer 2001/02 and 2002/03 are presented in Table 5.9.
Table 5.9. Bearings towards swimmers during summers 2001/02 and 2002/03, classified by time.

<table>
<thead>
<tr>
<th>Time into encounter mins</th>
<th>Total (n)</th>
<th>Frequency of towards responses to boat</th>
<th>Proportion of towards responses to boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 10</td>
<td>2090</td>
<td>835</td>
<td>0.40</td>
</tr>
<tr>
<td>10 – 20</td>
<td>1310</td>
<td>555</td>
<td>0.42</td>
</tr>
<tr>
<td>20 – 30</td>
<td>758</td>
<td>307</td>
<td>0.41</td>
</tr>
<tr>
<td>30 – 40</td>
<td>474</td>
<td>201</td>
<td>0.42</td>
</tr>
<tr>
<td>40 – 50</td>
<td>283</td>
<td>116</td>
<td>0.41</td>
</tr>
<tr>
<td>50 – 60</td>
<td>169</td>
<td>96</td>
<td>0.57</td>
</tr>
<tr>
<td>60 – 70</td>
<td>134</td>
<td>45</td>
<td>0.34</td>
</tr>
<tr>
<td>70 – 80</td>
<td>110</td>
<td>39</td>
<td>0.35</td>
</tr>
<tr>
<td>80 – 90</td>
<td>23</td>
<td>6</td>
<td>0.26</td>
</tr>
</tbody>
</table>

As with boat-dolphin data, LR models were fitted to the swimmer-dolphin data and tested for goodness of fit (Table 5.10).

Table 5.10. Analysis of deviance for assessing goodness-of-fit of the different models for dolphin responses to swimmers during 2001/02 and 2002/03 (where T = Time).

<table>
<thead>
<tr>
<th>Model</th>
<th>Deviance</th>
<th>DF</th>
<th>Deviance Difference</th>
<th>DF Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Constant only</td>
<td>7248.145</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Constant + T</td>
<td>7247.996 (ns)</td>
<td>7</td>
<td>0.149 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>3 Constant T + T^2</td>
<td>7242.979 *</td>
<td>6</td>
<td>5.017 *</td>
<td>1</td>
</tr>
<tr>
<td>4 Constant T + T^2 + T^3</td>
<td>7240.410 (ns)</td>
<td>5</td>
<td>2.569 (ns)</td>
<td>1</td>
</tr>
</tbody>
</table>

In contrast to the analysis of boat heading data, dolphin orientations in the presence of swimmers were affected by the duration of the encounter. Table 5.10 shows that while the addition of a quadratic component of time improved the fit of the model to the data, the addition of the cubic failed to improve the model further. Thus the best model for predicting dolphin responses to swimmers during both seasons was Model 3 (Fig. 5.7):

\[
\pi = \frac{\exp(0.013 - 0.713)}{1 + \exp(0.013 - 0.713)}
\]

As with boat encounters, the probability of a dolphin group heading towards a swimmer should be 0.25 if relative movements were random. Figure 5.7 shows that dolphins demonstrated significant attraction towards swimmers for the first eight time intervals (95% confidence intervals were above the expected value of 0.25). However, Model 3 suggests that these probabilities change, that is, decrease, as a function of time into the encounter. This decrease is apparent from the plot in Figure 85.
5.7, as ‘towards’ orientations increase during the first 30 minutes of an encounter, and then begin to decrease. After the 80\textsuperscript{th} minute into a cumulative encounter, dolphins showed no more orientations towards swimmers than would be expected if they were moving by chance.

![Graph showing the probability of a dolphin group heading towards swimmers with time during summer 2001/02 and 2002/03. Error bars are 95% confidence intervals and numbers above the bars show sample size.](image)

**Figure 5.7.** The probability of a dolphin group heading towards swimmers with time during summer 2001/02 and 2002/03. Error bars are 95% confidence intervals and numbers above the bars show sample size.

5.4.3 *Success of swimmer interactions*

During both research years 419 swim-with-dolphin attempts were tracked from the theodolite station. Of these, 76 were discarded from the analysis as the tracks were incomplete. Incomplete tracking occurred on days when many swimmers used the bay at the same time and sustained tracking of all swimmers within a 200 m range of the focal pod became impossible. This left 343 fully tracked swim-with attempts during 2001/02 and 2002/03, of which 262 (77%) were considered ‘successful’, that is, interactions were sustained for more than five minutes. A further 64 (19%) were considered ‘potentially disturbing’, and 15 (4%) were judged ‘disturbing’, as dolphins moved away from swimmers within 2 minutes.
5.4.4 *Pod dispersion*

During summers 2001/02 and 2002/03, 6,132 observations were made of dolphin focal pod dispersion, and 5,269 transitions were observed. The proportion of time spent in tight and dispersed states was different between control situations and time when dolphins were exposed to humans. It appeared that all human interactions had the same effect on pod dispersion, that is, dolphins were more dispersed in the presence of humans (Fig. 5.8).

![Proportion of time spent in tight and dispersed states](image)

Figure 5.8. The proportion of time spent in tight and dispersed states in the control situation and with different types of human presence. Error bars are 95% confidence intervals.

Dispersion data fitted both assumptions of Markov chain analysis. First, transitions were stable over time and secondly, sample size was sufficiently large (at least 20 to 40 transitions; Table 5.11).

<table>
<thead>
<tr>
<th>Chain order</th>
<th>Control</th>
<th>Human presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3720</td>
<td>2412</td>
</tr>
<tr>
<td>1</td>
<td>3185</td>
<td>2084</td>
</tr>
</tbody>
</table>

Comparisons of the BIC for each of the chain orders showed that the 1st-order chain provided more information than the 0-order chain (control BIC difference = 451.72, human presence BIC difference = 362.55; Table 5.12).
Table 5.12. Bayes Information Criterion for 0- and 1st-order chains during control and human presence situations.

<table>
<thead>
<tr>
<th>Chain order</th>
<th>K*</th>
<th>Control</th>
<th>Human Presence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>l(θ</td>
<td>data)</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>-816.203</td>
<td>-1648.85</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-590.499</td>
<td>-1197.13</td>
</tr>
</tbody>
</table>

Maximum likelihood estimates (MLEs) of the probability of dolphins staying in one state or changing from one to another were calculated for the control state and for all types of human interactions (Table 5.13). These data show that the presence of humans decreased the likelihood of dolphins remaining in a tight state (Ptt) and increased the likelihood they would change from a tight state to a dispersed one (Ptd; Table 5.13). Conversely, the presence of humans decreased the probability of dolphins staying in a dispersed state (Pdd) and decreased the likelihood they would change from a dispersed state to a tight state (Pdt).

Table 5.13. The MLEs of probabilities of dolphins staying in one state or changing from one to another in control situations and in the presence of humans. Ptt = MLE dolphins stay in a tight state. Pdd = MLE dolphins stay in a dispersed state, Ptd = MLE dolphins change from a tight state to a dispersed state. Pdt = MLE dolphins change from a dispersed state to a tight state.

<table>
<thead>
<tr>
<th>MLE</th>
<th>Control</th>
<th>Boat presence</th>
<th>Swimmer presence</th>
<th>Boat and swimmer presence</th>
<th>All human interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ptt</td>
<td>0.8824</td>
<td>0.8788</td>
<td>0.8375</td>
<td>0.7665</td>
<td>0.8058</td>
</tr>
<tr>
<td>Pdd</td>
<td>0.5837</td>
<td>0.7000</td>
<td>0.6572</td>
<td>0.6464</td>
<td>0.6527</td>
</tr>
<tr>
<td>Ptd</td>
<td>0.1176</td>
<td>0.1212</td>
<td>0.1625</td>
<td>0.2335</td>
<td>0.1942</td>
</tr>
<tr>
<td>Pdt</td>
<td>0.4163</td>
<td>0.3000</td>
<td>0.3428</td>
<td>0.3536</td>
<td>0.3473</td>
</tr>
</tbody>
</table>

Given that dolphin responses to humans were consistent, regardless of whether the presence was boat-based, swimmer-based or a combination of the two, tests for the significance of differences in the MLE compared the control situation to all (pooled) human interactions. The likelihood ratio test was based on a Markov chain model and showed that dolphin groups were significantly more dispersed in the presence of humans than during control situations (Ptt z = 6.463, p < 0.001; Pdd z = -6.463 p < 0.001; Ptd z = 2.645, p = < 0.01, Pdt z = -2.645 < 0.01, all 1 df). These differences can be seen clearly in Figure 5.9, which shows the effect of human presence on the transition probability of spacing. In Figure 5.9 effect size is calculated by subtracting transition probabilities observed in the presence of humans from control probabilities.
A positive value therefore represents a decrease in transition probability during transitions in the presence of humans, and conversely a negative value represents an increase in transition probability.

![Bar graph showing the effect of human presence on the transition probability of spacing for dispersion states.](image)

Figure 5.9. The effect of human presence on the transition probability of spacing for dispersion states.

5.4.5 Behavioural states

During the two research summers 3,239 assessments of behaviour were made at three minute intervals. Of these, 1,917 were collected during control situations and 1,322 in the presence of humans. The proportions of time spent in different states for each of the conditions are presented in Figure 5.10.

![Bar graph showing the behavioural budget of dolphins during control and human presence situations during summers 2001/02 and 2002/03.](image)

Figure 5.10. The behavioural budget of dolphins during control and human presence situations during summers 2001/02 and 2002/03. Budgets are the proportion of time spent in a given state (total = 1). Error bars are 95% confidence intervals.
These data show that the percentage of time spent ‘diving’ is reduced (from 69% during control situations) in the presence of humans. This decrease is most apparent in the presence of boats (13%) and is less so in the presence of swimmers (43%) and both boats and swimmers (45%). The proportion of time spent ‘milling’ increases in situations in which humans are present. Again, this effect is especially apparent in the presence of boats. Like milling behaviours, socialbehaviours increased in a tourism presence. ‘Travelling’ was the only behavioural category that was apparently unaffected by the presence of humans.

5.4.6 Comparison of results from dolphin-tourist encounters to the previous research (Bejder et al., 1999)

It was also possible using LR techniques to investigate long-term changes in dolphin responses to boats by comparing responses observed in the current research to those observed by Bejder and colleagues (1999). A summary of the analysis of deviances assessing the goodness-of-fit of various models to all boat data from both research periods is presented in Table 5.14. Here, the first factor introduced was research period (P), which was the dummy variable used to determine whether there were differences between the data gathered during each research period.

Table 5.14. Analysis of deviance for assessing goodness-of-fit of the different models for dolphin responses during 1995-97 (pooled) compared to 2001-03 (pooled; where T = Time and P = Research Period).

<table>
<thead>
<tr>
<th>Model</th>
<th>Deviance</th>
<th>DF</th>
<th>Deviance Difference</th>
<th>DF Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Constant only</td>
<td>2694.147</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Constant + P</td>
<td>2691.603 (ns)</td>
<td>7</td>
<td>2.544 (ns)</td>
<td>1</td>
</tr>
<tr>
<td>3 Constant + P + T</td>
<td>2684.761 **</td>
<td>6</td>
<td>6.842 **</td>
<td>1</td>
</tr>
<tr>
<td>4 Constant + P + T + T^2</td>
<td>2677.135 **</td>
<td>5</td>
<td>7.626 **</td>
<td>1</td>
</tr>
<tr>
<td>5 Constant + P + T + T^2 + T^3</td>
<td>2676.708 (ns)</td>
<td>4</td>
<td>0.427 (ns)</td>
<td>1</td>
</tr>
</tbody>
</table>

The figures in Table 5.14 indicate that the dummy variable ‘research period’ added no predictive value to the model including the constant only. This suggests that dolphin responses to boats were not significantly different between the research conducted previously in the bay and those observed in the current study. In contrast, the addition of time and time squared significantly improved the model that predicts dolphin
responses to boats (Fig. 5.11). Hence, the model selected as best predicting dolphin movements to boats during both research periods was Model 4:

$$\pi = \frac{\exp(0.011 - 0.463)}{1 + \exp(0.011 - 0.463)}$$

Figure 5.11 shows that the model including the linear and quadratic components of time predicts that for the first 40 minutes of an encounter with a boat during 1995-97 and 2001-03, dolphins were attracted to the boat. After 40 minutes into an encounter the proportion of headings towards the boat decreased with time. Confidence intervals show that responses beyond this time were no different than one would expect if dolphins were moving by chance.

Figure 5.11. The probability of a dolphin group heading towards a boat with time with summers 1995-97 pooled and 2001-03 pooled. Error bars are 95% confidence intervals and numbers above the bars show sample size. Due to regulatory changes since research in 1995-97, the majority of data used to plot responses beyond 40 minutes into an encounter came from 1995-97 (Bejder et al., 1999).

Analyses of pod dispersion data between each of the research periods yielded very different results. Bejder and colleagues (1999) found dolphins to become more tightly grouped in the presence of both boats and swimmers, though the effect was significant only when around boats. However, in this study the effect of boat and swimmer presence was the reverse, with pods becoming significantly tighter in the presence of both boats and swimmers. Comparison of the number of successful swim-with
attempts with previous research shows that a greater proportion of observed interactions were successful in this study (1995-97 = 57 %; 2001-03 = 77 %). This represents not only a larger proportion but also a much higher total number of successful interactions (1995-97 n = 32; 2001-03 n = 262). The proportion of attempts deemed ‘disturbing’ decreased from 12.5 % in 1995-97 to 4 % (15 %) in 2001-03.

5.5 Discussion

Research during the summers of 2001/02 and 2002/03 showed that whereas the proportion of time dolphins spent in the presence of boats has remained much the same over the past 5 – 7 years, dolphins are spending an increasing proportion of time with swimmers near-by. Specifically, over the months of summer 2001/02 and 2002/03 dolphins spent, on average, 32 % of observation hours in the presence of tourists (Chapter 2). This has increased from 24 % in five years. However this increase may not be linear as the two studies discussed here show data collected at just two points in time. Although Hector’s dolphins in Porpoise Bay have experienced a significant increase in their exposure to tourism, it remains small when compared with the presence faced by other species in other locations. For example resident sperm whales off Kaikoura were accompanied by at least one boat approximately half of the total time they spend surfacing (Richter et al., 2002).

5.5.1 Dolphin heading in response to boats

In contrast to findings from past research on the study population the current study showed that the length of a dolphin encounter with boats had no significant effect on dolphin headings in relation to those boats. In this sense, dolphin responses during 2001/02 and 2002/03 were similar; both logistic regression models selected as best fitting heading in the two summers included a constant only. However, the value of the constant was very different between the seasons. During 2001/02 dolphins did not head towards boats any more often than they would if their movements were entirely random, irrespective of the time into an interaction. In contrast, headings observed during 2002/03 contained a higher proportion of ‘towards’ responses than was expected for the first 40 minutes of a boat-dolphin encounter. Beyond this time, there were very few data, and dolphins headed towards boats no more than if their
movements were random. Pod dispersion data showed dolphins were more dispersed in the presence of boats. In addition, dolphins spent less time diving when around boats and more time milling and socialising. These data suggest that although dolphins did not actively avoid interactions with boats, pod composition and behavioural budgets were disrupted, which may have long-term effects. In addition, data on dolphin headings presented in this study may have been somewhat biased by the sampling methods. In this study in order to replicate Bejder and colleagues' (1999) methodology, during 'human presence' situations the position of the dolphin closest to a boat or swimmer was taken. This is likely to have meant that in both studies bold animals were sampled. As a consequence results presented here may show the responses of bold animals to boats and swimmers, rather than being representative of the pod’s response. Future studies on the population should consider taking dolphin positions in the presence of humans to both the animal closest to the boat or swimmer, to allow comparison with past research, as well as to the centre of the focal pod for more objective methods.

Comparison of dolphin responses to boats during the past two summers to those observed during 1995-97 showed the data were not dissimilar. The model that best predicted all combined data showed that dolphins approached boats for the first 40 minutes of an encounter after which time their approaches were no different than random. However, the predictive value of this model is somewhat limited due to the imposition of a 40 minute limit on boats using Porpoise Bay implemented after research in 1995-97. The result of this time limit is that the great majority of response data used to calculate the model beyond 40 minutes came from Bejder and colleagues’ (1999) work. Thus while it appears that dolphin responses for the first 40 minutes of boat encounters were not statistically different to what they were five years ago, it would be unwise to make any conclusions about similarities in their behaviour beyond 40 minutes based on extrapolations from previous research.

In both the current study and Bejder and colleagues’ (1999) study, only headings towards boats were analysed. Headings deemed neutral and away from boats were lumped together and were not modelled to test for changes with length of an encounter. Future research should address this gap by specifically modelling avoidance responses.
5.5.2 *Altered dispersion*

Bejder and colleagues (1999) observed dolphin groups becoming significantly tighter in the presence of boats. Such a response has been observed in other species and has been explained as providing higher protection for individuals within a group (e.g. Au and Perryman, 1982; Blane and Jaakson, 1994). However, in this study, the reverse was found. That is, dolphins were found to be significantly more dispersed in the presence of boats. On occasions when invasive boat interactions were observed in Kaikoura, dusky dolphins became similarly scattered (Barr and Slooten, 1999). However, these dolphins became more congregated when exposed to boats for long periods. Both responses are almost certainly disruptive in the longer-term. The reason for the altered response observed in Porpoise Bay is unclear. Perhaps some dolphins are more habituated to boats and are generally more attracted to them. Others, possibly with higher energy requirements (e.g. nursing mothers) or possibly those that are less habituated, may avoid boats. Thus the group may spread according to their willingness to interact with boats. It is also possible that dispersion is affected by behavioural state of the pod at the time. For example when travelling, dolphins tend to form relatively tight groups whereas when diving, dolphins are usually spread further apart from one another.

5.5.3 *The consequences of interactions*

The lack of effect of encounter duration on dolphin approaches to boats could lead one to conclude that boats are currently having no negative effects on dolphins in Porpoise Bay. However, positive responses to boats do not necessarily equate to the lack of any negative consequences of the interaction for the dolphins. If dolphins spend large proportions of time with a boat, it leaves less time for crucial behaviours such as feeding and caring for young. Increased pod dispersion in the presence of boats, and less time spent ‘diving’, which is probably associated with feeding, must also be having some effect on the pod’s functioning. Surprisingly, the decrease in time spent diving in the presence of boats appeared to be mitigated by the concurrent presence of swimmers. The reasons for this effect are not apparent. Assessing the biological significance of behavioural changes is notoriously difficult and was beyond the scope of this study. However, this research does suggest that the limit of 40
minutes on boats using the bay, implemented since previous research, has been effective in that the decrease in boat-positive responses with time reported by Bejder et al. (1999) no longer occurs.

While this is a positive finding, the current level of boat regulations in the bay should not be interpreted as sufficient for the future. Although there is now a time limit for boats in the bay, there remains no limit on the number of boats that can use the bay and approach dolphins with their vessel. Should the population size of the local community increase significantly in the future, there would be no regulation to prohibit every person taking their private vessel out to view the dolphins throughout the day. In disturbing examples of this elsewhere, killer whales in Johnston Straight, British Colombia, were commonly observed to be followed by up to four boats at a time (Williams et al., 2002). Furthermore, bottlenose dolphins off the northern coast of Bali, Indonesia have been observed with more than 70 boats at a time actively targeting them (E. Green, pers. obs.).

5.5.4 Dolphin heading in response to swimmers

Unlike dolphin-boat interactions, dolphin-swimmer encounters were found to be similar during summers 2001/02 and 2002/03. Also in contrast to their responses to boats, dolphin responses to swimmers were found to change as a function of time. For the first 30-40 minutes of an interaction, the chance of a dolphin pod heading towards a swimmer increased, after which time it decreased. ‘Towards’ headings were more common than expected for the first 80 minutes of an encounter after which time dolphins approached swimmers no more than they would be expected to by chance.

5.5.5 Altered behaviour and the consequences

When compared with boats, swimmers are less mobile and are thus unable to effectively follow dolphins when a pod chooses to leave an area. It would seem then that the high proportion of time dolphins spent near swimmers was a reflection of the dolphins’ choice. This is supported by the finding that the majority of swimmer-dolphin interactions fitted the study’s definition of ‘non-disturbing’, and the observed increase in both the number and proportion of ‘successful’ swim attempts. Part of this
increase may be attributable to habituation by dolphins to swimmer presence after many years of exposure. However, one must be careful when interpreting the fact that swimmers apparently do not displace these dolphins. Instead the question should be posed: do these dolphins choose to interact with swimmers or is the area the swimmers occupy simply the dolphins' most preferred habitat? The latter suggestion is supported by the finding that swimmer presence alters both pod dispersion and the proportion of time spent in each behavioural state. However, results presented in this study are somewhat contradictory as although dolphins were shown to use their preferred area irrespective of swimmer presence they were also shown to be attracted to swimmers in the first stage of encounters. Further research is needed to determine why Hector’s dolphins use Porpoise Bay like they do.

Recent research in Fiordland, New Zealand, showed that female and male bottlenose dolphins reacted differently to boats, with males avoiding boats as soon as they were present whereas females avoided them only when an interaction became intrusive (Lusseau, 2003a). Perhaps the benefits for Hector’s dolphins in Porpoise Bay of staying in an area used by tourists currently outweigh the costs associated with using another area. What is difficult to determine from this research is the level of tourism these dolphins will tolerate before they are displaced. Such displacement may have occurred in spinner dolphins (Stenella longirostris) in Hawaii where use of a bay was found to be 21% lower after the onset of tourism to the area (Forrest, 1999). Forrest (1999) proposes that the suitability of the bay for resting may have been reduced, she notes, however, that other explanations are possible. In the same bay, dolphins were noted to be more interactive with humans during the mornings and afternoons, when the number of swimmers and kayaks in the bay was much lower (Green and Calvez, 1999). If the presence of swimmers generally means that, with time, dolphins begin to avoid the swimmers, there are inevitably metabolic costs associated with this, as animals have to travel further to rest and find places to socialise.

### 5.5.6 Conclusion

Although this study has considered the effects of continued encounters with boats and swimmers by scoring dolphin responses cumulatively, no attempt was made to investigate the effect of differing intensities of swimmer and boat presence. In
Williams and colleagues’ (2002) study on tourism effects on killer whales in British Columbia, they found that avoidance strategies differed according to the number of vessels near-by. While the whales’ paths became more erratic in the presence of one boat, as the number of vessels increased, paths became more predictable. The authors hypothesise that the use of a horizontal avoidance response to a single boat is effective but that when there is more than one vessel this approach does not work, as evading one boat may lead directly to the path of another. So, when there were many vessels near, whales avoided boats vertically (Williams et al., 2002). It would be interesting to investigate the effect of not just the duration of an encounter, but the intensity of an interaction, to determine whether differing tactics were used in Porpoise Bay by Hector’s dolphins in the presence of both boats and swimmers.

It would also be informative to investigate how swimmer and boat behaviour around the dolphins affected their responses. In one study of southern right whales in South African waters, whales demonstrated few short-term behavioural changes when approached by slow moving vessels (Findlay, 1999). In contrast, when approached more aggressively for biopsy attempts, individuals increased their swimming speed and changed headings to evade the boat (Findlay, 1999). Another study by Lusseau (2003a) in Doubtful Sound, New Zealand, showed the swimming behaviour of bottlenose dolphins to become increasingly erratic when boat interactions became invasive. Such effects were minimised when boat operators closely followed guidelines formulated to protect the dolphins. While these findings are expected, consistent with many studies (e.g. Blane and Jaakson, 1994), and almost certainly apply to the study population, no study has investigated the how swimmers can be least intrusive (for a review on swim-with literature see Samuels, et al., 2000). Research by Constantine and Baker (1997) found that people entering the water from tourist vessels in an attempt to swim with bottlenose and common dolphins caused the least avoidance responses when the vessels approached from the side of the pod.

At the moment the observed level of boat and swimmer tourism in Porpoise Bay appears to be having no serious effects on individuals within the population. However, the potential cumulative effects it may be having are difficult to measure (Watkins, 1986). The observed and predicted increase of tourism, particularly swimmer-based in the last few years, combined with the lack of regulations limiting
the number of boats and swimmers using the bay should be cause for significant
cconcern. Even if the effects of tourism at the current level are not conclusively
problematic, the characteristics of the population being targeted exacerbate any
negative effects. Hector's dolphins in Porpoise Bay comprise a small population that
potentially faces loss of individuals in fishing-related mortalities. In addition, the
nearest large population of Hector's is more than 100 km to the west, which may
mean the population has little gene-swapping. Thus while another population of
Hector's dolphins may not be affected by vessel or swimmer disturbance, for the
Porpoise Bay dolphins, it may be an obstacle to population growth in the long-term.
6.1 Introduction

In order to minimise the effects of human interactions with marine mammals, such as manatees (*Trichechus manatus*), killer whales and humpback whales (e.g. Williams et al., 2002) many areas of water around the world have been given sanctuary or refuge status. Accurate knowledge of the range and distribution of a species is crucial when formulating such management strategies. An example of this can be seen with the establishment of the 1170 km$^2$ Banks Peninsula Marine Mammal Sanctuary (Dawson and Slooten, 1993). This sanctuary, established in 1988, aimed to reduce by-catch of Hector’s dolphins in the area by effectively banning commercial gillnetting and placing restrictions on amateur set net use (Dawson and Slooten, 1993). While fisheries-related mortalities within the sanctuary have undoubtedly decreased since its implementation, survival rates of dolphins in the area have not shown a detectable increase (Cameron et al., 1999). Better knowledge of the dolphins’ alongshore and offshore range has since become available and suggests that the boundaries of the reserve are not sufficient to adequately protect the population throughout the entire year (Clement unpub. data; DuFresne, unpub. data). This case study shows that it is essential to have an understanding of a population’s range to design a sanctuary that will protect it effectively.

While no estimate of the extent of fisheries related by-catch on the southern coast of the South Island is available, overlap of set net areas with the population’s range, combined with anecdotal evidence suggest that, as with dolphins around Banks Peninsula, fisheries-related mortalities may also be affecting the Porpoise Bay population (Anon, pers. comm.). Carcasses recovered on beaches in Colac Bay and Te Waewae Bay suggest that entanglement is problem in this area (S. Dawson, pers. comm.). In addition, dolphins in Porpoise Bay are exposed to tourism, which has been shown to affect their behaviour (Bejder and Dawson, 2001; Chapters 2 and 5). Though past research in the area has documented small-scale use of the bay itself, no attempt has been made to document the range of these dolphins beyond the bay (Bejder and Dawson, 2001). Recently however, a proposal has been put forward by the Department of Conservation regarding the possibility of establishing a Marine
Mammal Sanctuary at Porpoise Bay. Data on the range of the dolphins were therefore urgently needed so that an appropriate scale for management could be established.

Hector’s dolphin use of Porpoise Bay is highly seasonal with dolphins found there regularly during the summer months but rarely through the remainder of the year (N. Gee, pers. comm.). Little is known about the distribution of dolphins outside of summer. However, sightings of dolphins beyond the bay reported by local people stretch from the Mataura River-mouth in the west to Dummy’s Beach in the east (B. Gee, pers. comm.; I. McIntosh, pers. comm.). Local people suggested dolphins were occasionally sighted in Toetoe Bay during the winter months. On a single survey to Toetoe Bay during research in 2001/02 dolphins were found in the surf at the mouth of the Mataura River. One dolphin photographed there matched with a dolphin later identified in Porpoise Bay, suggesting that this population’s range may extend at least this far. No further surveys investigated this range in 2001/02 due to limited resources. During the second season of field work in 2002/03, this study attempted to fill this information gap, aiming specifically:

1. To document the alongshore range of the population of Porpoise Bay dolphins.
2. To investigate whether the dolphins exhibited a seasonal shift in preferred habitat.
3. To provide recommendations regarding the spatial scale for management of this population.

6.2 Methods

Boat surveys to look for dolphins were conducted along the coast in either direction from Porpoise Bay. Surveys were run in one direction close to the coastline (c. 100 m), and then, on the return, slightly further from the coast (c. 200 m). However, when conditions deteriorated during surveys, for example due to sun glare, they were only run either ‘leaving’ or ‘returning’ to the bay. When this happened, only the closer survey line (c. 100 m) was run, as dolphins were most often seen within 100 m of the coast. Sighting range included the area in an approximate 200 m radius of the vessel between 270 ° and 90 °. Each survey was undertaken with the intent of reaching either
Long Point in the east or Waituna Lagoon in the west (Fig. 6.1), however many surveys were curtailed due to deteriorating weather conditions. The decision to survey this stretch of coast was based on advice from residents of the area and as this was the distance that could be practically surveyed from the research vessel in a day.

Surveys were undertaken in sea-states of Beaufort 2 or lower. In order to maximise the likelihood of detecting dolphins, surveys were conducted at a speed of 10 – 12 knots. This speed allowed observers to survey the inshore area relatively quickly while the vessel remained at a speed at which dolphins were observable if surfacing at the time they were passed (Clement et al., 2001). Three people, including the boat driver, were present as observers on surveys. On sighting a dolphin group, the boat was slowed and an attempt was made to approach the dolphins. The GPS location, size of each group, and presence of calves and identifiable individuals was recorded and the same photographic procedure followed as used within Porpoise Bay (see Chapter 3). Four photographs were taken for each dolphin in the group, with the aim of maximising the chance of photographing all individuals at least once. The research boat stayed with each group until the required numbers of photographs were taken or until the dolphins moved away and could not be relocated, at which time the boat continued on the survey route. A short burst of speed was made when leaving a group to reduce the chance of double-counting.
6.3 Analysis

Determining whether or not dolphins seen in other areas along the coast were part of the population that used Porpoise Bay entailed simply comparing photographs taken of dolphins sighted on surveys outside Porpoise Bay to the catalogue of dolphins identified within Porpoise Bay. To indicate where Hector’s dolphins were sighted during surveys a map showing location of GPS sightings was produced. The opportunistic nature of these surveys, which was a result of the unsettled weather patterns common in this part of New Zealand, meant that survey effort was unequal along the coast. Plotting of absolute values of dolphin sightings would therefore have given a false picture of dolphin presence in different areas. To standardise data, survey findings were re-plotted as dolphin density (mean number of dolphins sighted per survey) along five kilometre stretches of coastline.

If dolphins were exhibiting an alongshore shift from Toetoe Bay before summer to Porpoise Bay in the summer as local opinion held, one would expect a significant negative relationship between numbers of dolphins in the two bays. To determine the degree of linear association between the two, the correlation coefficient $r_{yx}$ was calculated. This analysis tests whether there is an association between two variables, that is, if the number of dolphins in Porpoise Bay and Toetoe Bay are interdependent.

6.4 Results

6.4.1 Survey effort

The first survey, conducted on 10 December 2001, was undertaken from the tourism vessel operating in Porpoise Bay. No further surveys were conducted that summer. More regular boat surveys were conducted along the coast in either direction from Porpoise Bay during summer 2002/03. An initial five surveys were conducted between 25 November 2002 and 1 December 2002, in ‘Cetos’ (a 6.6 m rigid hulled inflatable) in a relatively intensive effort to investigate dolphin range at the time they were known to start using Porpoise Bay. A further 16 surveys were conducted in a 3.8
m stabi-craft on an opportunistic basis throughout the remainder of the research season, between 5 December 2002 and 27 March 2003. Four surveys were run east of Porpoise Bay (two as far as Long Point) and 13 west (Figure 6.1). Acknowledgement of local advice on dolphin distribution coupled with limited financial resources and weather opportunities resulted in lower survey effort to the east than to the west. Four surveys were carried out by launching and landing the boat at the township of Fortrose in the estuary of the Mataura River-mouth. On these occasions only Toetoe Bay was surveyed (Table 6.1).

Table 6.1. Details of survey effort along the southern coast, across month and area, in summer 2002/03.

<table>
<thead>
<tr>
<th>Month</th>
<th>Date</th>
<th>East/ West</th>
<th>Start point</th>
<th>Turn point</th>
<th>Return/one way</th>
<th>Dolphins sighted?</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>25/11/02</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Waipapa Pt.</td>
<td>Return</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>26/11/02</td>
<td>East</td>
<td>Porpoise Bay</td>
<td>Long Pt.</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>27/11/02</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Waipapa Pt.</td>
<td>Return</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>28/11/02</td>
<td>East</td>
<td>Porpoise Bay</td>
<td>Long Pt.</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>30/11/02</td>
<td>East</td>
<td>Porpoise Bay</td>
<td>Tautuku</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td>December</td>
<td>1/12/02</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Beyond Waituna</td>
<td>Return</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>5/12/02</td>
<td>West</td>
<td>Mataura RM</td>
<td>Beyond Waituna</td>
<td>One way</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>9/12/02</td>
<td>West</td>
<td>Mataura RM</td>
<td>Beyond Waituna</td>
<td>One way</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>18/12/02</td>
<td>West</td>
<td>Mataura RM</td>
<td>Beyond Waituna</td>
<td>Return</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>21/12/02</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Weir’s Beach</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td>January</td>
<td>30/01/03</td>
<td>West</td>
<td>Mataura RM</td>
<td>Beyond Waituna</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td>February</td>
<td>7/02/03</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Waipapa Pt.</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>18/02/03</td>
<td>West</td>
<td>Mataura RM</td>
<td>Beyond Waituna</td>
<td>Return</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>25/02/03</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Weir’s Beach</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>26/02/03</td>
<td>West</td>
<td>Waituna Lgn.</td>
<td>Porpoise Bay</td>
<td>One way</td>
<td>Yes</td>
</tr>
<tr>
<td>March</td>
<td>9/03/03</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Slope Pt.</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>10/03/03</td>
<td>West</td>
<td>Waituna Lgn.</td>
<td>Porpoise Bay</td>
<td>One way</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>19/03/03</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Weir’s Beach</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>20/03/03</td>
<td>East</td>
<td>Porpoise Bay</td>
<td>Tautuku Pen.</td>
<td>One way</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>22/03/03</td>
<td>West</td>
<td>Porpoise Bay</td>
<td>Waipapa Pt.</td>
<td>One way</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>27/02/03</td>
<td>West</td>
<td>Waituna Lgn.</td>
<td>Porpoise Bay</td>
<td>One way</td>
<td>Yes</td>
</tr>
</tbody>
</table>

On 8 occasions both Porpoise Bay and Toetoe Bay were surveyed on the same day. Half of these times Porpoise Bay was surveyed first and the other half Toetoe Bay was surveyed first. The bays were surveyed in a similar fashion, however surveys were conducted at a slower speed in Porpoise Bay due to the speed restriction there.
6.4.2 Distribution of dolphin sightings

Hector’s dolphins were encountered on 42% of all coastal surveys (n = 21). Dolphins were sighted east of Porpoise Bay on one of the four surveys in that direction, 200 m offshore from Dummy’s Beach on 10 March 2003. Unfortunately these two dolphins were very boat shy and were sighted only twice, at some distance from the boat, before disappearing. Sightings of another eight dolphins, over four occasions, were also made between Porpoise Bay and Toetoe Bay. Like those sighted east of the bay, these dolphins avoided the research vessel making identification impossible. In contrast to these relatively sparse sightings east of Porpoise Bay, and for 20 km west, dolphins were sighted on 8 of 9 of surveys covering Toetoe Bay. There, dolphins were found in, or just behind, the surf-zone within 3 km of the outflow of the Mataura River (Fig. 6.2).

During research in summer 2002/03 a total of 59 Hector’s dolphins were sighted in Toetoe Bay (mean group size = 7). Two groups of 18 and 2 dolphins were also sighted on the only survey there in summer 2001/02. The number and distribution of Hector’s dolphins sighted during all boat surveys of the coastline west and east of Porpoise Bay are presented as dolphin densities in Figure 6.3.
Figure 6.3. Distribution of Hector’s dolphins along the southern coast around Porpoise Bay. Shadings show dolphin density in that area, and numbers represent the number of times that area was surveyed. While alongshore distances are accurate, the distance of the survey limit from the shore is exaggerated for the purposes of the diagram. In reality, the distance dolphins could be observed with reasonable certainty extended to approximately 200 m either side of the research boat.
6.4.3 Photographic identification of dolphins sighted during surveys

The boat-shy nature of dolphins sighted outside the two ‘hot-spots’ of Porpoise Bay and Toetoe Bay meant that no high-quality photographs were taken of these dolphins. Of 18 identifiable dolphins sighted in Porpoise Bay, nine were also sighted approximately 35 km along the coast in Toetoe Bay. In addition, a new marked dolphin was seen on five occasions near Toetoe Bay, but was not sighted in Porpoise Bay. That half of identifiable dolphins seen in Porpoise Bay were also sighted in Toetoe Bay provides strong evidence that dolphins comprise the same population.

6.4.4 The relationship between Hector’s dolphins of Toetoe Bay and Porpoise Bay

a) Dolphin movements

The low number of surveys conducted combined with uneven survey effort per month meant that detecting any shift in the dolphins’ range between seasons was difficult. This was especially so given that the research period covered only the summer months. Whereas dolphin movement into the bay for summer was observed at the start of the research season in December 2002, in late March 2003 dolphin use of Porpoise Bay was still high. Thus, while the research season appeared to encompass the movement of the dolphins to the bay from their winter habitat, it did not encompass their shift from the bay at summer’s end. Movements of individual dolphins between Porpoise Bay and Toetoe Bay were deduced through photographs. The time interval between sighting a dolphin in one bay and then sighting it in the other ranged between 2 and 45 days. Of the 9 dolphins sighted in both bays during the surveys, 4 were first sighted in Toetoe Bay, and then later in Porpoise Bay, and 5 were first sighted in Porpoise Bay. The last sighting of 5 of the 9 dolphins was in Toetoe Bay. Figure 6.4 is a diagrammatic representation of the movements of dolphins sighted in both bays. Bars are shaded if an identifiable dolphin was positively identified in Toetoe Bay and Porpoise Bay during that month of research. However, continuous shading of a bar does not mean that a dolphin stayed in a bay continuously but rather, that no sighting of that dolphin was made in the other bay then.
Figure 6.4. Movements of dolphins identified along the southern coast. Shading of each bar represents the sighting of an individual dolphin (names in left column) in Porpoise Bay (PB = blue) and Toetoe Bay (TB = orange) during the months of summer 2002/03. Numbers below months show the number of times Toetoe Bay was surveyed that month. Numbers near arrows show the number of days between the last sighting of that dolphin in one bay and the first in the other. Numbers in bold on the right show the total number of days that dolphin was sighted.
Two dolphins were documented to move back and forth between the bays during the summer. These two dolphins were sighted on 15 and 10 occasions each, thus they were sighted more times than many of the dolphins identified in both bays. It is possible then, that higher survey effort would have shown more of these back and forth movements by other dolphins. Seven dolphins were documented to move both into Porpoise Bay and out of it at the end of summer, or just into the bay at the start of summer or out at its conclusion. Two of these were sighted on more than twenty occasions. One dolphin was sighted in Toetoe Bay only, during three of the four months of research (Fig. 6.4).

\[b) \text{Dolphin numbers}\]

Numbers of dolphins seen in Porpoise Bay and in Toetoe Bay were negatively correlated \((r = -0.71, p < 0.05; \text{Fig. 6.5})\). That is, when there were many dolphins in Toetoe Bay, there were few in Porpoise Bay, and conversely when there were many dolphins in Porpoise Bay there were few dolphins in Toetoe Bay.

![Figure 6.5. Numbers of Hector's dolphins sighted in Porpoise Bay and Toetoe Bay on selected days during summer 2002/03 (regression line indicated).](image)

The results presented above should be interpreted with caution as, though the correlation was found to be significant, Toetoe Bay and Porpoise Bay were surveyed
on the same day on only eight occasions, and thus few data were used to calculate the correlation coefficient.

6.5 Discussion

Knowledge of a population's range is essential in deciding how to manage and protect that population effectively. For the summer-resident population of Hector's dolphins in Porpoise Bay this is a particularly pressing issue given that discussions are underway to create a Marine Mammal Sanctuary in the area. Until now very little information was available on the extent of the population's range. For example, a boat survey conducted by DuFresne et al. (2001) sighted just one dolphin between Oamaru and Te Waewae Bay, demonstrating the need for finer-scale studies. Such a lack of information in many conservation matters has meant that a smaller area, rather than a precautionary larger one, was protected (e.g. the Banks Peninsula Marine Mammal Sanctuary).

6.5.1 Alongshore range

This research shows that dolphins are found along the southern coast of the South Island on either side of Porpoise Bay. Although only one sighting of dolphins was made east of the bay this does not necessarily equate to low dolphin density there, but could be a product of low survey effort to the east. Further fine-scale surveys are required along this stretch of coast before stronger conclusions about density can be made. Sightings west of the bay were more common and extended almost as far as the Waituna Lagoon. Higher survey effort along this coast means that it can be concluded with reasonable confidence that there is comparatively high dolphin density in Toetoe Bay and low density between Porpoise Bay and Toetoe Bay.

Half of the identifiable population from Porpoise Bay were also sighted in Toetoe Bay. Thus there is strong evidence that the same population uses both areas. That nine dolphins sighted in Porpoise Bay were not sighted in Toetoe Bay could be explained by two factors. First, survey effort might have been too low to allow the opportunity to photograph every identifiable dolphin from Porpoise Bay at Toetoe Bay. Alternatively, individuals within the population might utilise different habitats within
the population’s overall range, a phenomenon documented in Hector’s dolphins elsewhere (Bräger et al., 2002). The latter hypothesis is supported by the finding that one dolphin, sighted on five occasions in Toetoe Bay, was never sighted in Porpoise Bay. High photographic survey effort within Porpoise Bay and the generally boat-positive nature of that individual mean that it is unlikely that its home range included Porpoise Bay.

6.5.2 Seasonal shift hypothesis

Preliminary evidence suggests that this population may be demonstrating an overall alongshore shift with different seasons, from Toetoe Bay to Porpoise Bay at the beginning of summer (November/December) returning at the end of summer (March). Survey effort was too sparse to confirm this robustly. In addition, surveys were only conducted from November to March during one summer.

Further evidence for an alongshore shift is provided as a negative correlation was found between dolphin numbers in Porpoise Bay and numbers in Toetoe Bay. A single boat survey conducted by the Department of Conservation on 29 July 2003 found a pod of 23 dolphins at the outflow of the Mataura River (R. Cole, pers. comm.). One of these dolphins was positively identified as a dolphin seen in Porpoise Bay during the summer months. It seems likely that improved photographic technique may have identified more known dolphins. These data, along with local knowledge, provide limited evidence that the population may spend part of the year in this area. However, although local knowledge can be very effective in suggesting where dolphins are found, it is less reliable in documenting where they are not found. Also, given that five dolphins were last identified in Toetoe Bay it would seem that dolphin numbers observed in Porpoise Bay should have shown a decrease if an alongshore seasonal shift were indeed occurring. This decrease was not observed. If dolphins were demonstrating such a shift, it would be the first documented for this species. Further research, especially survey effort during the winter months, is needed to investigate the validity of this hypothesis. Perhaps, like Hector’s dolphins at Banks Peninsula, these dolphins are not making a seasonal alongshore shift, but are concentrated further inshore in summer and so are sighted more often in both areas. It is possible that dolphins use both Toetoe Bay and Porpoise Bay during the summer.
months and that they move offshore from both these areas during winter. That dolphins can move between the bays in just two days and that two marked dolphins were sighted moving back and forth between the two bays throughout the summer provides support for this theory.

6.5.3 Boundaries of a Marine Mammal Sanctuary at Porpoise Bay

The results of these surveys are highly relevant to the establishment of a Marine Mammal Sanctuary in Porpoise Bay. It can now stated conclusively that the alongshore range of Porpoise Bay Hector's dolphins extends west from Porpoise Bay to the Waituna Lagoon. In addition, it is highly likely that dolphins sighted east of the bay were also part of this population. However unlike the behaviour of dolphins seen in Porpoise Bay and Toetoe Bay, dolphins seen between the two bays, and east of Dummy's Beach, were very boat shy. Perhaps this was because dolphins in larger groups are generally more boat-positive and dolphins seen outside Porpoise Bay and Toetoe Bay were in small groups on all occasions (range = 1 – 4). It is also possible that the dolphins are, for some reason, more vulnerable in this area and try to move through it quickly, choosing not to interact with boats there if approached.

These data suggest that the minimum alongshore boundaries of a Mammal Sanctuary in the area should extend from Waituna Lagoon in the west to Dummy's Beach in the east. While no data were gathered during this research on the dolphins' offshore range, it seems appropriate to use information from other studies to provide recommendations for offshore boundaries.

At Banks Peninsula, recent aerial surveys conducted by Rayment and colleagues (unpub. data) that provided uniform and intensive coverage of the waters out to 15 nmi suggest that an offshore boundary of 4 nmi is insufficient to protect dolphins from fisheries-related mortality during the winter months. In fact, during winter 2002, 65 % of sightings were outside the Marine Mammal Sanctuary, compared to just 21 % in summer. There, the furthermost distance from shore a dolphin was sighted was at the boundary of the survey, at 15 nmi. In contrast, in similar surveys on the West Coast during winter 2003, 8 % of dolphins were found beyond 4 nmi and 10 % in summer, and the furthermost sighting from the coast was 5.3 nmi. Comparison of
seasonal distribution with the bathymetry of the area suggests that depth may be a better indicator of seasonal distribution than distance from the shore. At Banks Peninsula 83% of sightings during 2002 summer aerial surveys were in waters less than 60 m deep. In winter, 67% of sightings were in depths less than 60 m. Overall, dolphins were found in deeper waters during winter. On the West Coast the following year, aerial surveys found 99% of sightings were in 50 m or less water during winter, and in summer this figure was 100% (Rayment et al., unpub. data). Unfortunately, bathymetry data for the west and east coasts shows contours at different depths, therefore it was not possible to compare proportions within the same contour. On the West Coast, there was little change in the dolphins’ depth distribution between the seasons.

These data show that depth, rather than distance from the shore, is a better indicator of Hector’s dolphin seasonal distribution. Based on these data it seems appropriate that a Marine Mammal Sanctuary in Porpoise Bay extend to a depth of at least 50 m.

6.5.4 What a sanctuary in the area might involve

This research has shown that the potential for tourism related disturbance on Porpoise Bay Hector’s dolphins is increasing. In addition, there are almost certainly fisheries-related mortality along this coast. Clearly, tourism and fisheries impacts are two very different problems, in terms of both the geographic area affected and in the regulations that might best reduce that impact. An advantage of establishing a Marine Mammal Sanctuary is that the regulations imposed under a sanctuary are designed to meet the conservation needs of a specific area. While the exact regulations a sanctuary in Porpoise Bay might involve will come from a long process of consultation with all interested groups including local people, tangata whenua, scientists, recreational and commercial fishers and environmental groups, data provided here can guide management action. As noted by Martien and colleagues (1999) often the ‘burden of proof’ in implementing management options lies with those who seek protection of a species or environment, with the result that action may come too late.

With regard to fisheries impacts then, regulations on set-net use that would provide effective protection for the Porpoise Bay dolphins must consider that the range of
these dolphins extends to at least Toetoe Bay. Set-net restrictions are the most effective way to limit mortalities. Although the simplest regulations would involve a year-round ban, consideration could be given to protecting different areas seasonally. For example, were an alongshore shift confirmed, fishing practices in Toetoe Bay and immediate surrounds could be limited during the winter months, and in summer regulations could apply instead to Porpoise Bay. More data would be required in order to do this, and until then a precautionarily large area should be protected.

Tourism impacts could be managed by formalising dolphin-watching guidelines already in place in Porpoise Bay so that those not following guidelines could face legal consequences. In addition, thought should be given to restricting swimmer and boat access to certain parts of the bay at certain times. Concern by both researchers and tourism operators regarding the high proportion of time dusky dolphins in Kaikoura were spending in the presence of boats led to such a restriction there. Research showed that the middle of the day appeared to be important for the dolphins for resting (Barr and Slooten, 1999). This finding was used to provide the support for a ‘rest-period’ between 1100 and 1400 during which time no commercial operators are permitted access to the dolphins. This approach could be used in Porpoise Bay. Chapter 4 shows the importance of the southernmost part of the bay to the dolphins during the afternoons. In this area dolphins were regularly observed to be socialising and making few directed movements (an indication of resting). Thus a Marine Mammal Sanctuary could be used to restrict swimmer and boat access south of Cook’s Creek during mid-afternoon. Similar restriction of access to boats based on the behavioural importance of an area has been recommended for the protection of bottlenose dolphins in Doubtful Sound (Lusseau and Higham, in press).

6.5.5 Implementing a sanctuary

In implementing specific conservation actions it is essential to gain local support for the guidelines to be enforced. Given the political situation in New Zealand at present with regard to marine issues particularly the extensive debate surrounding ownership and access to the foreshore and seabed, local reaction to government-imposed environmental management is highly variable but often negative. This has been seen with many reserve processes around the world, with environmental groups giving
support, but local people objecting to protected areas. Often, it seems that confusion about what a sanctuary might involve and what restrictions it will place on human use, lead to a general lack of local support (Tilt, 1989). A process of consultation in Porpoise Bay is needed to ensure stakeholders and interested parties have a role in decision-making and do not feel that the area has been unnecessarily ‘locked up’ (see Hughey, 2000). The key here seems to be keeping people informed with accurate information. In designing the management of the area it would seem wise to include combinations of different management strategies including perhaps Taiapure, marine reserves and Mataitai in order to both gain support for the project and aid in policing of regulations. However, in doing so, it is essential that the aim of the project, that is, conservation of Hector’s dolphins is not lost amongst the interests of different parties.
Chapter 7. Summary, Management Recommendations and Future Research

7.1 Introduction

The extensive growth of the whale-watching industry around the world provides increasing economic benefits for communities associated with the industry, as well as being a potential platform for conservation education. However, there is also potential for disturbance to targeted cetacean populations. Hector’s dolphins’ highly coastal distribution, boat-positive nature, and high site fidelity make them natural targets for whale-watching operations.

This thesis reports on research conducted on a small semi-resident population of Hector’s dolphins in Porpoise Bay, the Catlins. Since the population was studied during the summers of 1995-97 (Bejder, 1997; Bejder et al., 1999; Bejder and Dawson, 2001) the number of tourists visiting Porpoise Bay has increased enormously. Concern regarding the increasing level of tourism as well as the possibility that the population was being affected by gill-net mortalities prompted Southland DOC to consider new management options for the population, such as the establishment of a Marine Mammal Sanctuary. While it was apparent that more recent research was needed regarding the finer scale movements of dolphins in the bay and their reactions to the increased tourism presence, it also became clear how little was known about the population’s range when not in the bay; information crucial when deciding on boundaries for any type of management area. It was this combination of factors that provided the impetus for the current research during the summers of 2001/02 and 2002/03. To allow for best comparison between results, methods utilised in this study were as similar as possible to those used in previous research.

7.2 Tourism

Visitor numbers to Porpoise Bay are estimated to have increased approximately 400% in the last ten years. The result of this increase for dolphins in Porpoise Bay is that whereas the amount of time dolphins spend with boats in the bay has remained much the same in the past 5 – 7 years, the amount of time spent with swimmers near-
by has increased almost three-fold. Of the total time Hector’s dolphins in Porpoise Bay were observed during summers 2001/02 and 2002/03 they spent an average 33% in the presence of tourism. This increase is of concern given the difficulty in regulating swimmer numbers and behaviour, and the continued operation of an unpermitted tourism vessel, combined with the apparent importance of the bay to the dolphins as a summer habitat and calving area.

7.3 Abundance

Analysis of photographic data from summer 2002/03 showed that the population of Hector’s dolphins that use Porpoise Bay and the surrounding areas is closed. As very few high quality photographs were taken during summer 2001/02, these data were excluded from analysis. Nineteen dolphins were identified from natural markings. Ten of these distinctive animals had been identified in the bay five years earlier, indicating that dolphins are seasonally resident in the long term. The slow discovery rate of identifiable dolphins combined with highly variable sighting frequencies suggest some dolphins are resident in the bay whereas others visit the bay only occasionally. Application of the Chapman mark recapture estimate indicates that a population of 43 dolphins (95% CI = 40 - 48), including three new calves, currently use the bay. This estimate is lower than the estimate of 48 dolphins (95% CI = 44 - 55) calculated in a 1995-97 study (Bejder and Dawson, 2001). Overlapping confidence intervals mean that this decrease cannot be considered statistically significant. Notably however, this does not mean that a change in abundance has not occurred, but that none could be demonstrated statistically.

7.4 Distribution within Porpoise Bay

Dolphin use of Porpoise Bay during summer 2001/02 and 2002/03 was quite different, with dolphins present less often and in lower numbers during 2001/02. The explanation for this is unclear but is most likely related to prey distribution, environmental conditions or a combination of these factors. When present in the bay dolphins showed a strong preference for the southern corner of the bay, a preference also documented during 1995-97. During 2002/03 dolphins tended to be further north than during 2001/02. Small, but significant, changes were observed in monthly
distribution during 2002/03, but not during 2001/02. During both summers dolphins were found to congregate in the southern corner of the bay during successive times of the day, from morning to afternoon. Similar movements were observed in previous research. Resting behaviour observed in a small area of the southern part of the bay suggests that this is a particularly important area to dolphins. In conclusion, despite the large increase in tourism presence since previous research in 1995-1997, the distribution of Hector’s dolphins within Porpoise Bay has not been altered significantly.

7.5 Responses to boats and swimmers

Logistic regression analyses on dolphin orientation in relation to boats and swimmers showed that dolphin responses to boats did not change as a function of time, but that dolphins became less interested in swimmers as the duration of cumulative encounters increased. In the presence of both boats and swimmers, dolphins became more dispersed. This contrasts with previous research, which found that dolphin groups became tighter in the presence of boats and swimmers. Assessment of behavioural states showed that dolphins decreased the proportion of time spent ‘diving’ in the presence of boats and swimmers, and spent more time ‘milling’ and ‘socialising’. A higher number and proportion of ‘swim-with’ attempts were deemed successful in this research compared to research conducted five years before. These data all suggest that while dolphins are not exhibiting extensive avoidance behaviour towards boats and swimmers in Porpoise Bay that their presence does result in altered behaviour, which inevitably has metabolic costs. Even if the effects of tourism at the current level are not conclusively problematic, the characteristics of the population being targeted will almost certainly act to exacerbate any negative effects.

7.6 Alongshore range

Boat surveys conducted along the coast either side of Porpoise Bay in this study involved the first attempt to document this population’s range beyond the bay. Dolphin sightings along the coast show that Toetoe Bay to the west of Porpoise Bay is also an area of relatively high dolphin density. Low survey effort east of the bay meant that few conclusions could be drawn regarding density in this area. Analysis of
photographic data showed that dolphins at Toetoe Bay comprise the same population that uses Porpoise Bay and that individuals have differing home ranges within the population’s overall range. Data presented here suggest that dolphins may shift alongshore during different seasons, from Porpoise Bay in summer to Toetoe Bay for the remainder of the year, however more data are required to confirm this hypothesis.

The proposal for a Marine Mammal Sanctuary must consider the known range of “Porpoise Bay” dolphins, and should extend at least from Toetoe Bay in the west to Dummy’s Beach in the east for effective protection of the population. Studies elsewhere suggest that offshore boundaries should extend to a minimum depth of 50 metres. Implementation of a sanctuary should involve extensive consultation with all interested parties in order to gain input and support. However, the primary goal of the conservation of this unique population must be kept foremost.
7.7 Management recommendations

This study shows that Porpoise Bay is an important summer habitat for a small population of Hector's dolphins. When in the bay these dolphins favour a very small area at the southern end, within which they spend most of their time. The importance of the bay seems to vary among individuals, with the home range of the population as a whole extending beyond Toetoe Bay in the west, and probably to Dummy's Beach in the east. This range must be given careful consideration when considering management options, especially when choosing the boundaries and conditions of a Marine Mammal Sanctuary, should one be implemented. The following management recommendations are based both on results from this research and on the precautionary management principle. This principle effectively shifts the burden of proof and requires that an activity be shown to have no negative effects before it is permitted, which contrasts to most environmental management in the past whereby harm had to be proved before management was implemented to mitigate negative effects (Archer and Cooper, 1995; Lien, 2000). It is recommended that:

- Action should be taken to establish a Marine Mammal Sanctuary in the area and that findings presented in this thesis regarding the dolphins' range be used as the minimum alongshore distance for its boundaries.

- Effort be put into quantifying the extent of fisheries-related mortality on the south coast and measures be implemented to decrease such mortalities (e.g. set-net restrictions via a Marine Mammal Sanctuary).

- Commercial tourism in the area be restricted to one operator that is permitted to spend no longer than 40 min per day with the dolphins.

- Kayakers be encouraged to use the area of the bay north of Cook's Creek to avoid overlap with the dolphins' most preferred area.

- Renting of kayaks in Porpoise Bay be prohibited so as not to encourage higher use of the bay by boaters.
• Measures be taken to remove, as much as possible, advertising of Porpoise Bay as a place to swim with wild dolphins at no cost.

• Consideration be given to restricting access to part of the dolphins’ most preferred habitat for parts of the day when dolphins use it most.

• Increased educational material be made available to the public regarding the conservation needs of Hector’s dolphins and how to behave around dolphins, if approached when swimming. This could include educating the drivers of tourist buses in the area. The campaign should focus not on how a tourist should swim with dolphins, but rather on how to behave if a dolphin swims near a tourist.

• The population continue to be monitored in the long-term to better understand trends in abundance, habitat use, and responses to tourists.
7.8 Future research

Although the current study helped to address a number of important questions, it also made clear the need for future research to:

- Determine how far the dolphins known to use Porpoise Bay range east and west and to ascertain whether home ranges overlap between this population and dolphins in Te Waewae Bay. This would also provide data on any seasonal shifts in distribution.

- Document the extent of fisheries-related mortality along the southern coast.

- Investigate the factors that make Toetoe Bay and Porpoise Bay preferred areas over other bays along the coast (e.g. prey distribution, sea surface temperature).

- Survey the dolphins’ offshore range during different seasons to determine whether they are exhibiting an offshore shift in winter as observed with Hector’s dolphins around Banks Peninsula.

- Investigate whether the behaviour of swimmers near the dolphins affects how dolphins respond to their presence.

- Predict how continued exposure to boats and swimmers will affect the dolphins in the long-term, and attempt to assess the metabolic cost of interactions with these tourists.


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Appendix: Marine Mammal Viewing Regulations for the Tourism Operator in Porpoise Bay

- The tour operator is allowed up to three trips per day between eastern tip of South Head reef (Porpoise Bay) and Brothers Point, South Catlins Coastline to view Hector’s Dolphins, NZ Fur Seals and NZ Sealions.
- A maximum of 40 minutes per trip for Dolphin Cruises is permitted in the Southland Regional Council 5 knot restriction zone as highlighted in Fig. 3.7.
- A maximum of 20 minutes per trip for Twilight Cruises is permitted in the Southland Regional Council 5 knot restriction zone as highlighted in Fig. 3.7.
- Of these trips, the combination of trips can be either: Two Dolphin Cruises (1 hour 30 minutes) and one Twilight Cruise (2 hours 30 minutes), or three Dolphin Cruises (1 hour 30 minutes per trip).
- Dolphin Cruise: as well as Hector’s Dolphin viewing, the first part of this trip is spent in the Waikawa Harbour where NZ Sealions and NZ Fur Seals are occasionally sighted (and in Porpoise Bay). Trip times are 1000, 1300 and 1500.
- Twilight Cruise: Viewing of a seal colony in the Brothers Point area and viewing of Hector’s Dolphins. Trip time is 1730.
- Marine mammal viewing activity is not permitted before 1000.
- All marine mammal viewing during the above detailed trip is vessel based only.
- The vessel shall not enter the surf zone. The surf zone is defined as the area between the beach and margin of the furthest breaking wave of the surf.
- At no point when seeking, undertaking or breaking off an encounter with Hector’s dolphins shall the vessel’s motor be put in reverse, except in an unavoidable emergency. An unavoidable emergency does not constitute the placing of the vessel into a situation where rapid evasive action would be required for safety.
- No touching, handling or feeding of marine mammals is permitted.
- If any marine mammal(s) choose to leave the vessel be it stationary or moving, then that vessel may make one attempt to re-establish contact with that/those marine mammal(s) during that trip.
- A copy of any permit granted shall be prominently displayed on board the vessel.
- Swimming with Hector’s dolphins at Porpoise Bay shall not be facilitated.
- Koramika Charters will report, as soon as possible, to DOC any illegal activity in relation to marine mammals and wherever possible the names and addresses of any persons carrying out such acts and will provide the Department with details of the circumstances surrounding any such incidents.
- Koramika Charters will provide a monthly return to the Conservator, Southland, on the form attached as Schedule I in each and every year of the term of any permit granted, listing details of all encounters with marine mammals including the date, trip departure time, duration of encounter, total number of adult and juvenile dolphins seen, behaviour, boat course taken, number of passengers and any concerns regarding marine mammals. The Department reserves the right to request further or different activity related information in order to best monitor and determine any effects of the marine mammal viewing activity on the marine mammals.