Responses of South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) to vessel activity (including tourism operations) in Akaroa Harbour, Banks Peninsula, New Zealand.

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Marine Biology at Massey University, Auckland, New Zealand

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DEDICATION

Je dédie cette thèse

A ma mère Christine Smagghe,
Ma petite soeur Julie Estève,
Et mon adorable filleul Martin Estève
Pour avoir toujours été là pour moi et avec moi malgrè la distance.

Ainsi qu'à la mémoire de ceux qui nous on quitté trop tôt:
Mon père Joseph Martinez
Mon grand-père Jean Smagghe
Ma grand-mère Suzy Smagghe
Mon arrière grand-mère Simone Brunerie
Mon oncle Jean-Michel Stieber
Et Josette Veray qui fut comme une tante pour moi.

This thesis is also dedicated to
the emblematic Hector's dolphin, special to me in so many ways.

FRONTISPIECE

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He tu te Pahu, He tu te Tai
“If dolphin is well, so too are our coasts”

Māori whakatauaki (proverb)

ABSTRACT

For over 25 years, tour operators have been undertaking view and swim-with-dolphin trips in Akaroa Harbour off Banks Peninsula, east coast South Island, New Zealand. Following the international exponential growth in the commercial dolphin-based tourism industry, Akaroa Harbour is now a key eco-tourism destination in New Zealand with 32 daily permitted trips targeting Hector's dolphin (*Cephalorhynchus hectori hectori*). Such a high number of trips is of particular concern given that this species is not only endemic but also endangered. Our current understanding of the effects of tourism activities on Hector's dolphins in Akaroa Harbour is far from satisfactory. To ensure the sustainability of the economically-important and rapidly-growing dolphin-based tourism industry, there is an urgent need for sound scientific evidence on which to base management decisions.

One of the challenging issues with the assessment of tourism impacts is the lack of baseline data. Prior to beginning the evaluation of the effects of disturbance on this population, data relating to the occurrence and demographics of Hector's dolphins, as well as vessel traffic in Akaroa Harbour, were collected from land-based platforms during three consecutive austral summers (November and March), commencing in 2005. Examination of Sighting Per Unit Effort (here number of dolphin sightings per hour) and the dolphin fine-scale spatial distribution confirmed an inshore-offshore migration and, in the case of the latter, higher density patterns between the Kaik hills and the harbour entrance. However, no specific area was associated with a particular behaviour or nursery groups. The majority of groups consisted of adults only (91.2%, n = 2,000) and comprised mainly 2-5 individuals (83.2%). Group size varied with behaviour, being larger when socialising. Activity budgets within two outer bays were very comparable to Akaroa Harbour, except for socialising.

In the harbour, Hector's dolphins only spent a small proportion (14%) of their day (0600-1800 hr) in the absence of vessels. Vessel traffic in the harbour consisted mainly of recreational vessels (72.9%) although commercial vessels represented 70.4% of observed encounters and interacted twice as long with the dolphins. No displacement was evident and as a result, Hector's dolphins might compensate for high vessel traffic levels by adjusting their behavioural budget.

To determine the effects of tourism activities on Hector's dolphins' behavioural budget, focal-group follows using a scan sample methodology were conducted from land-based stations and analysed using Markov chain models (n = 330 sequences). Vessel presence affected the activity budget of Hector's dolphins by changing transition probabilities, bout durations and the time taken to return to a behavioural state once disrupted. Both diving (inferred foraging) and travelling were significantly disrupted by vessel interactions. The addition of one of more vessels during an encounter further disrupted diving.

Responses of Hector's dolphins to swim attempts were assessed from commercial tourism vessel trips (n = 420). The method of approach and swimmer placement affected the dolphins' behaviour, with a reduction in avoidance when regulations were adhered to, i.e. using *line abreast* and *around* methods. Dolphin responses to swim encounters were also correlated with the number of successive attempts, dolphin group size and initial behaviour. Although Hector's dolphins appear to be more tolerant of the presence of swimmers over time, some level of sensitisation to seasonally high levels of vessel interactions was also detected. The effects of swim encounters could potentially be exacerbated by the use of stones as an auditory stimulant. Specifically, swimmers who used stones had a greater probability of close and sustained approaches by dolphins than those who sang or simply floated on the surface of the water.

Based on opportunistic photo-identification surveys (n = 254), 46% and 44% of the 50 identifiable individuals were infrequently and occasionally recorded interacting with commercial tourism vessels, respectively. It was also estimated that individuals using Akaroa Harbour are exposed to the highest level of cetacean-based tourism in New Zealand. This implies that dolphins that are frequent users of the harbour are likely to be more exposed to intensive tourism pressure. The high resighting rate of some individuals further suggests that frequent users are unlikely to discontinue using the harbour, even though they face increased human disturbance.

Data presented here reveal the nature and the susceptibility of Hector's dolphins to tourism activities, warranting the continuation of a moratorium on new permits. Furthermore, a reduction in daily trip numbers should be considered. Ongoing monitoring of this population's response to tourism activities, combined with an integrated and adaptive approach to management, gives the best chance of ensuring the sustainability of the industry.

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"The road of life twists and turns and no two directions are ever the same. Yet our lessons come from the journey, not the destination" (Don William Jr). There have been an uncountable number of people involved during this journey in one way or another over the past few years, without whom this thesis would have never been completed. "Tēnā rāwā atu koe", thank you everyone, "merci à tous"!!!

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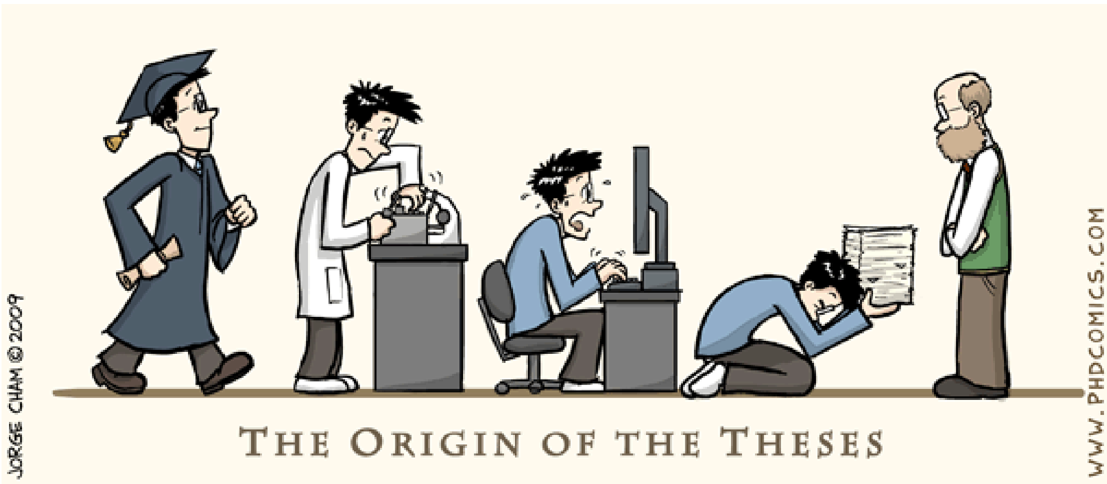

Karen (aka da Boss), your friendship and commitment as a supervisor have no bound and I am eternally indebted. Thanks for bearing with me and my puns. I hope that "flip her" will get "stuck in" your mind even though it might be un-bear-able to admit it! Thanks also for making me apart of the New Zealand Common Dolphin Project and training me in necropsy procedures, although I admit, I prefer them alive than smelly. By the end of this journey, you've almost turned me into a "common" girl, although I still think that the Hector's are the cutest! It has been a privilege to be part of the Coastal-Marine Research Group (C-MRG) and see it grow first under Mark and now your leadership.

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Mere dost, “mein aap ko dhanyavaad deti houn ki aap meri achi se saheli hokar hame hamesha achi achi salaha deti aayi hai. Mei aap aur aap ke bache ko hirday se dhanyavaad deti huon kyuki aap mujhe apni pariwar ki tahara kayi mahine tak apne ghar hame apna saath rakhi. Ye mei hamesha yaad rakhu gi”. Shukriya from DLCB!

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"Some people save stamps or coins.
I save whales."

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LIST OF ABBREVIATIONS

AAGR	Average Annual Growth Rate
AEI	The Acoustic Ecology Institute
AHHD	Akaroa Harbour Hector’s Dolphin catalogue
AIC	Akaike’s Information Criterion
A.R.E.V.A.	Akaroa Research on the Effect of Vessel Activity project
BPHDPC	Banks Peninsula Hector’s Dolphin Photo-ID Catalogue
BPMMS	Banks Peninsula Marine Mammal Sanctuary
BWR	Bow riding
BSS	Beaufort Sea State
ca.	*circa*, approximately
C.I.	Confidence Interval
CJS	Cormack-Jolly-Seber (model)
cm	Centimetre
COC	Code of Conduct
COM	Commercial
C.V.	Coefficient of Variation
d	Days
Dec	December
d.f.	Degrees of freedom
DIV	Diving
DOC	Department of Conservation
DW	Dolphin-Watching
e.g.	*exempli gratia*, for example
EIA	Environmental Investigation Agency
et. al.	*et alii*, and others
etc.	*et cetera*, and other things
Feb	February
Fig.	Figure
GIS	Geographic Information System
GLM	Generalised Linear Model
GOF	Goodness Of Fit
GPS	Global Positioning System
hr	Hour
ID	IDentification
i.e.	*id est*, in other words
IFAW	International Fund for the Animal Welfare
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
Jan	January
kHz	KiloHertz
kg	Kilograms
km	Kilometre
km^2	Square kilometre
km/hr	Kilometre/hour
kts	Knots
LAC	Limit of Acceptable Change

LR	Logistic Regression
Ltd.	Limited
m	Metre
min	Minute
Mar	March
MFish	Ministry of Fisheries
MIL	Milling
MMPA	Marine Mammals Protection Act
MMPR	Marine Mammals Protection Regulations
MPA	Marine Protected Area
MRA	Marine Reserves Act
MSR	Maritime Safety Regulations
NGOs	Non-Governmental Organisation
NIWA	National Institute of Water and Atmospheric research
n	Sample size
nm	Nautical mile
Nov	November
NRC	National Research Council
s	Second
S	South
SIHD	South Island Hector's Dolphin
S.E.	Standard Error of the mean
SOC	Socialising
SPUE	Sighting Per Unit Effort
SST	Sea Surface Temperature
SW	Swim-With-dolphins
TMP	Threat Management Plan
TRAV	Travelling
UNCED	United Nations Conference on Environment and Development
UK	United Kingdom
USA	United States of America
UTM	Universal Transverse Mercator
vs.	*versus*, against

CHAPTER I

The South Island Hector's dolphin (*Cephalorhynchus hectori hectori*), a major tourist attraction in Akaroa Harbour, Banks Peninsula

Photo: A.R.E.V.A. Project © 2005.

1.1. Cetacean-watching

Cetacean-watching is defined here as viewing or swimming with wild cetaceans (whales, dolphins, and porpoises) in their natural environment and does not include captive and/or trained animals. This type of activity consists of vessel-based (*e.g.* kayaks, sailing vessels, small- and medium-sized powerboats, and cruise ships), aerial-based (*e.g.* small planes or helicopters), and land-based (*e.g.* vantage points) methods or platforms. The term encompasses both formal (commercial) and informal (recreational) cetacean-watching.

1.1.1. On a global-scale

Commercial cetacean-watching first started in the 1950s in San Diego, California, in the United States of America (USA) and began to increase in the late 1980s across the world (Hoyt, 1995). Responsible cetacean-watching is currently perceived as the most sustainable, environmentally friendly, and economically beneficial "use" of whales in the 21st century, at a time when the future of whaling is still being debated (O'Connor *et al.*, 2009). Over the past 30 years, cetacean-watching as a commercial endeavour has witnessed a spectacular growth (Hoyt, 1995, 2001; O'Connor *et al.*, 2009), at an estimated average rate of 12.1% per annum between 1991 and 1998 (Hoyt, 2001). Even though over the subsequent decade (1998 - 2008), the annual growth rate slowed to 3.7%, it compared well against global tourism growth of 4.2% per annum over the same period (O'Connor *et al.*, 2009).

Since the early 1990s, the number of countries and overseas territories engaging in cetacean-watching has approximately quadrupled from 31 in 1992 to 119 in 2008 (Fig. 1.1). Simultaneously, the number of watchers has increased from *ca.* four million in 1991 to almost 13 million in 2008, generating an estimated US$2.1 billion in total revenues (Hoyt, 1995; O'Connor *et al.*, 2009). In most countries, cetacean-watching is a tourism activity predominantly engaged in by international visitors. Overall, there is still scope for growth given that in most parts of the world, cetacean-watching is still in its infancy.

The most common method of cetacean-watching (72%) is vessel-based, followed by shore-based (28%). Helicopters or planes represent less than 0.001% of the tours

(Hoyt, 2001). From these platforms, the majority of 90 cetacean species are the focus of viewing and/or swimming tours (increasingly popular since the 1990s), with the exception of almost all of the beaked whales species (Hoyt, 1995, 2001). The most common whales targeted by the industry include the following species: humpback (*Megaptera novaeangliae*), sperm (*Physeter macrocephalus*), grey (*Eschrichtius robustus*), northern and southern right (*Eubalaena* sp.), and blue (*Balaenoptera musculus*) whales. The most common focal delphinid species are short-finned pilot whales (*Globicephala macrorhynchus*), killer whales (*Orcinus orca*), and bottlenose dolphins (*Tursiops* sp.) (Hoyt, 2001; O'Connor *et al.*, 2009).

Fig. 1.1: Map of the global distribution of cetacean-watching countries (marked in black) in 2008 (O'Connor *et al.*, 2009).

1.1.2. On a national scale, New Zealand

The Oceania, Pacific Islands and Antarctica regions have followed the global trend, showing a continually growing cetacean-watching industry over the past two decades (O'Connor *et al.*, 2009). Between 1998 and 2008, the annual growth for the region was estimated at 9.8%, accounting for 20% of the world watchers or 2.5 million people (O'Connor *et al.*, 2009). New Zealand and Australia are the two largest regional industries, being two of the six countries in the world with over 500,000 cetacean-watchers, representing 4% and 13% of the total global watchers in 2008, respectively (O'Connor *et al.*, 2009).

Cetacean-watching only started in 1985 in Akaroa and 1987 in Kaikoura (Hoyt, 1995; Allum, 2009) but is now one of New Zealand's largest earner of foreign exchange with US$80 million in total expenditure in 2008 (O'Connor *et al.*, 2009; Table 1.1). Following a remarkable expansion in the 1990s (Table 1.1), the growth of the industry is now stabilising. However, it could be expected to continue to expand, subsequent to the forecast increase of inbound tourism (IFAW, 2005; Ministry of Tourism, 2010).

Table 1.1: The cetacean-watching industry in New Zealand between 1994 and 2008, including the number of watchers, average annual growth rate (AAGR), the number of operators and total expenditure (O'Connor *et al.*, 2009).

Year	Number of watchers	AAGR (%)*	Number of operators	Total expenditure (US$)
1991	40,000	n/a	n/a	8,400,000
1994	90,000	31	n/a	12,500,000
1998	230,000	27	> 50	48,736,000
2004	425,432	11	90	72,338,157
2008	546,445**	6.5	86	80,918,541

* AAGR is calculated as the average percentage of a series of percentage growth rates that allows the data to grow steadily from the first survey period and achieve the result specified in the next survey period ('interpolated growth').

** This number includes opportunistic dolphin-watching during general nature and scenery cruises, particularly in Fiordland.

The New Zealand wilderness and remoteness, as well as the ability to interact with wild marine mammals, have been a strong focus of Tourism New Zealand, with their marketing of "100% Pure New Zealand" using images of whales and dolphins. Cetacean-watching in New Zealand has an outstanding potential (Hoyt, 1995). Many species can be sighted year-round and provide a competitive advantage within the Pacific Region (Orams, 2003). The main focal species include sperm whale, Bryde's whale (*Balaenoptera brydei*), dusky dolphin (*Lagenorhynchus obscurus*), bottlenose dolphin (*Tursiops truncatus*), common dolphins (*Delphinus* sp.), and the South Island Hector's dolphin (*Cephalorhynchus hectori hectori*). In addition, New Zealand is one of the few countries allowing swimming with delphinids (Carlson, 2008).

The major centres for cetacean-watching in New Zealand include the Bay of Islands and Bay of Plenty on the North Island, as well as Kaikoura and Akaroa on the east coast of the South Island (Fig. 1.2). The South Island, however, supports the majority of cetacean-watching opportunities (Table 1.2), with approximately 72% of the country's watchers. In 2008, an estimated 40% of the total trips in the country occurred in Kaikoura and Akaroa (O'Connor *et al.*, 2009). Kaikoura is the only location where aerial whale-watching can be undertaken. In Akaroa, a large industry is based on the South Island Hector's dolphin, specialising in swim-with-dolphin trips.

Table 1.2: The cetacean-watching industry in New Zealand in 2008, including the number of watchers, percentage of international visitors, average annual growth rate (AAGR), the number of operators and total expenditure (O'Connor *et al.*, 2009).

Region	Number of watchers	International visitors (%)	AAGR (%)*	Number of operators	Total expenditure (US$)
North Island	147,364	85.0%	5.8	34	28,681,622
South Island	399,080	80.0%	6.8	52	52,236,920
Total	546,445**	82.5%	6.5	86	80,918,541

1.1.3. On a local scale, Akaroa Harbour

1.1.3.1. The importance of tourism to the Akaroa community

Akaroa has had a relatively long association with tourism, which has in part shaped the township for much of the 20th century (Coleman *et al.*, 2003; Shone *et al.*, 2003). Over the years, Akaroa has evolved from a farming community to a community with an increased reliance on tourism. Akaroa and Banks Peninsula are now popular destinations for recreational activities for both domestic and international tourists (Coleman *et al.*, 2003). The historic Akaroa township is located approximately 82 kilometres (km) away or a 90 minute (min) drive from Christchurch (the second largest city in the country with an international airport) and, therefore, within acceptable distance for day-trippers (Fig. 1.3).

Tourism in Banks Peninsula has been evolving steadily over the past 30 years. In recent years, tourism has been one of the fastest growing sectors of the New Zealand economy and has become particularly important in some smaller communities, like Akaroa. Between 1981 and 2001, the tourism industry had increased by more than 150%, compensating jobs lost in the farming and fishing industries (Butcher *et al.*, 2003; Baines, 2005).

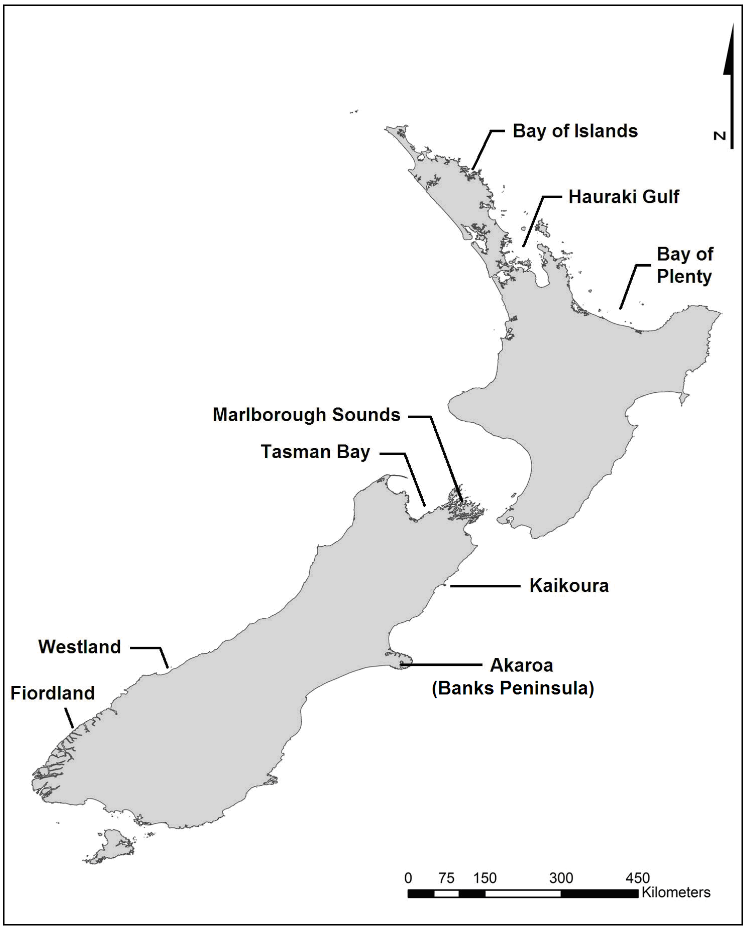


Fig. 1.2: Map of the primary locations providing cetacean-watching opportunities in New Zealand.

Fig. 1.3: Map of Banks Peninsula, New Zealand, in relation to Christchurch (Source: © 2010 TerraMetrics and © 2010 MapData Sciences Pty Ltd.). Yellow lines represent the main highways (with an associated number) and roads.

Tourism now plays a major part in the local economy of Akaroa (Fountain, 2002), being necessary to maintain the township and its resident population (Shone *et al.*, 2003). This sustained growth is partly due to the development of a commercial dolphin-based tourism industry. The South Island Hector's dolphin has become one of the main attractions that bring people to the region.

1.1.3.2. The development of a dolphin-based tourism industry

The focus of the cetacean-watching tourism industry around Banks Peninsula has essentially been in Akaroa Harbour, where commercial dolphin-viewing and swimming trips began in 1985 and 1990, respectively, and to a lesser extent in Lyttelton Harbour (Allum, 2009). Akaroa is also the only place where commercial swimming permits targeting Hector's dolphins have been granted, allowing commercial operators to provide a unique experience.

The local dolphin-based commercial tourism industry, like any other in New Zealand, is regulated by a permit system, administered by the Department of Conservation (DOC; refer to section 1.3. for further details). In Akaroa, the Black Cat Group Ltd. (formerly known as Akaroa Harbour Cruises) was the first operator in 1991 to be issued a permit. In 1992, DOC received a further four applications for both viewing and swimming with Hector's dolphins from companies that had been operating prior to lodging their application (Allum, 2009; Table, 1.3). These companies continued to operate until their permits were granted in 1998 (refer to Allum, 2009 for further details), subject to an existing Code of Conduct (COC) and the recommendations made at the time. It was considered that these activities were not likely to have any significant adverse effects on the behavioural patterns of Hector's dolphins. Most permittees were allowed to view dolphins for a maximum of 90 min per trip and up to 60 min when swimming (reduced to 45 min in 2007; Allum, pers. comm.). The maximum number of swimmers per trip has also been set at 10. DOC additionally placed an informal moratorium over issuing new permits until the potential effects (if any) of the existing level of dolphin-watching are known.

In 2005, there were four permits allocated to view and/or swim with Hector's dolphins within the harbour, comprising a maximum of 25 daily trips. These include up to 18 swimming, seven viewing and/or two kayak trips (Table 1.3). In 2007, three new operators applied for and were subsequently granted a viewing permit, increasing the maximum number of permitted daily trips from 25 to 32 (Allum, 2009). There are also discrepancies between operators in terms of the scale of their commercial operation. Some companies are permitted to operate more trips during the austral summer period (Table 1.3), with most trips occurring between 0600 and 1800 hr compared to 1100 to 1500 hr during the winter period.

Despite an increased demand for more permits, the companies that are already operational do not necessarily operate at full capacity, *i.e.* the maximum number of permitted daily trips is not always reached (Green, 2004; Allum, 2009; Appendix 1.1). This implies that there is potentially an opportunity for the current operators to legally increase their current effort. This is important to consider because the potential effects of the tourism industry on the South Island Hector's dolphins are likely influenced by the actual number of daily trips.

Table 1.3: Permitted trips allocated for viewing (DW), swimming (SW), and kayaking (KYK) with Hector's dolphins in Akaroa Harbour, New Zealand, by the Department of Conservation as of 2007. Note: summer corresponds to the period between October and April. In bold, companies that were operating prior to the implementation of the MMPR in 1992.

Company	Trips/day (summer)	Trips/day (winter)	Number of vessels	Maximum passengers
Akaroa Dolphins Ltd.[¤]	3 DW	3 DW	1	22
Akaroa Boat Hire[§‡]	1 KYK	1 KYK	8	8
Black Cat Group Ltd.	4 DW	2 DW	3	100
	8 SW	4 SW		14
Dolphin Experience Ltd.[*]	8 SW	8 SW	3	12 to 60
Fox II Sailing Adventures[‡]	3 DW[**]		1	30
Te Runanga o Ngai Tahu[‡∞]	3 DW	3 DW	n/a	n/a
Onuku Farm Hostel	2 SW		1	8
	or 2 KYK		12 KYK	12
TOTAL	*32*	*21*		

[¤] Formerly trading as Bluefin Charters;
[§] Bought by Akaroa Dolphins Ltd.; [‡] Permit granted in 2007;
[*]Bought by the Black Cat Group Ltd. in 2007 and fleet subsequently replaced in 2008;
[**] From January to May; [∞] Not operating as of 2009.

Green (2004) suggests some operators feel that the level of operation in Akaroa Harbour is possibly at maximum capacity, although it is unclear whether the underlying motive of their position is social, economic, or environmental. This is further illustrated by the number of tourists that participated in viewing or swimming activities in Akaroa between 2001 and 2007, which has remained around 50,000 per annum (Appendix 1.2). All operators also expressed concern for the welfare of the dolphins, with one noting that dolphins had the tendency to "get shyer" towards the end of the season, from about February (Green, 2004). Consequently, some operators were open to the possibility of changes to their permits in light of the perceived market saturation and potential effects of interactions on Hector's dolphin.

1.2. The South Island Hector's dolphin, an endemic and endangered species

1.2.1. Status and abundance

Hector's dolphin *(Cephalorhynchus hectori*, van Bénéden, 1881) is one of the four species in its genus, each of which inhabit cool, temperate, and nearshore waters in the Southern Hemisphere. Hector's dolphin, the smallest marine delphinid (Dawson, 2002), is endemic to New Zealand (Baker, 1978) and is easily identified conclusively by being the only delphinid in the country to have a black round dorsal fin (Dawson, 1985). In the past decade, the species has been further divided into two sub-species on the bases of morphological and genetic differences (Baker *et al.*, 2002): *C. h. hectori* around the South Island (41° S to 47° S) and *C. h. maui*, also known as Maui's dolphin, on the west coast of the North Island (36° S to 40° S).

The South Island Hector's dolphin (henceforth referred to as Hector's dolphin) is recognised by the International Union for the Conservation of Nature (IUCN) as *endangered* and the Maui's dolphin is listed as *critically endangered* (Reeves *et al.*, 2008). The latest abundance estimate of *C. h. hectori* is 7,268 dolphins (C.V. = 16.2%, 95% C.I. = 5,303 - 9,966; Dawson *et al.*, 2004; Slooten *et al.*, 2004) and *C. h. maui* 111 (C.V. = 44%, 95% C.I. = 48 - 252; Slooten *et al.*, 2006b; Fig. 1.4). These statuses are a consequence of anthropogenic impacts occurring throughout the range of the sub-species (Dawson and Slooten, 2005). Population modelling and loss of genetic diversity indicate population decline at both regional and national levels (*e.g.* Martien *et al.*, 1999; Pichler and Baker, 2000; Pichler, 2002; DuFresne, 2005; Burkhart and Slooten, 2003; Slooten, 2007). Many characteristics of this species appear to make it particularly susceptible to human-related activities, namely its habitat, distribution, and life history.

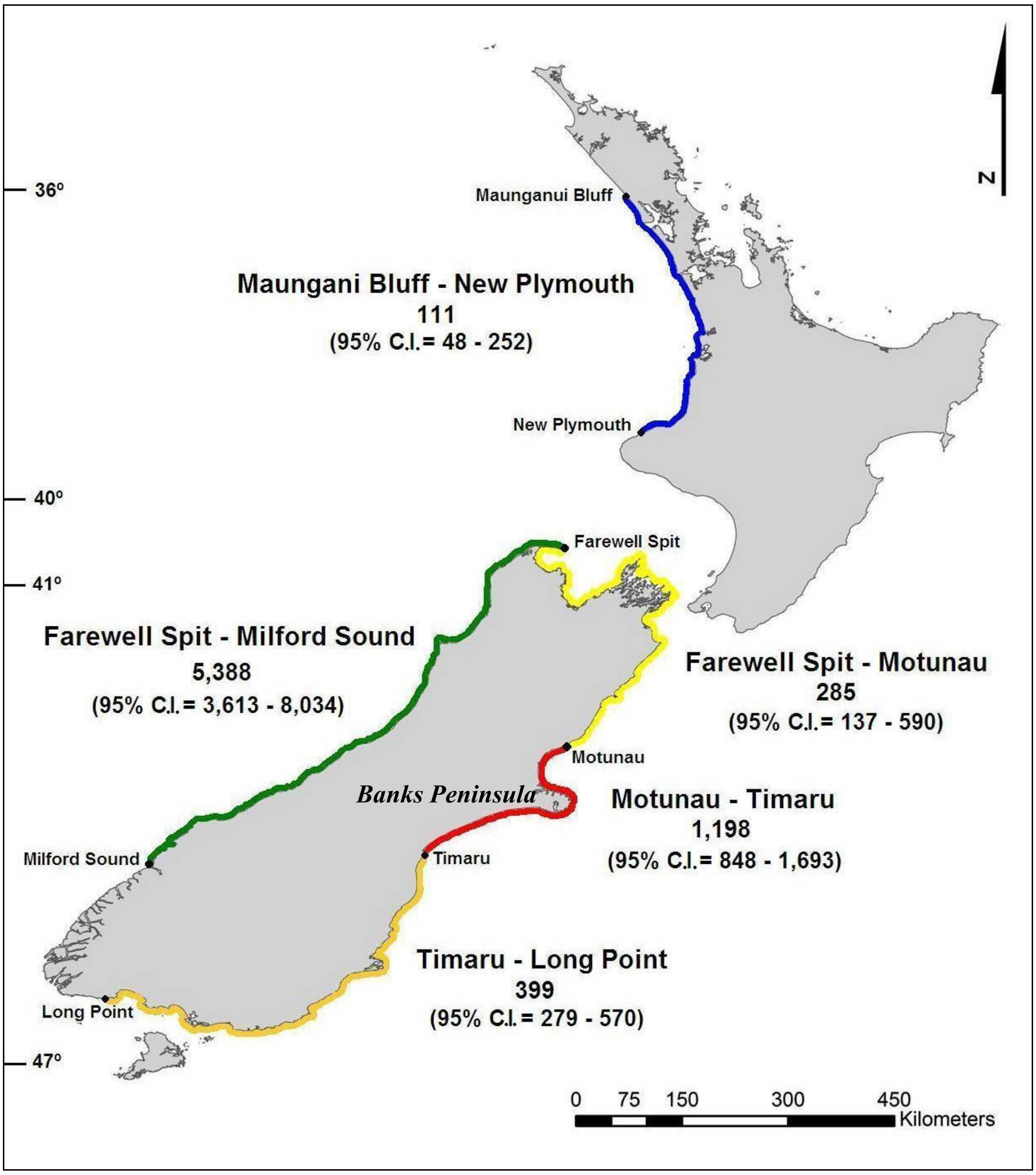


Fig. 1.4: Abundance of *Cephalorhynchus* around New Zealand. The five different colours represent the extent of the areas for which abundance was calculated separately (Clement *et al*., 2001; DuFresne *et al*., 2001; Slooten *et al*., 2004; 2006a). Note: 95% confidence intervals (C.I.) are in brackets.

1.2.2. Distribution

Hector's dolphin is typically found in shallow (less than 50 metres - m) and nearshore waters up to 20 nautical miles (nm) (*e.g.* Baker, 1978; Cawthorn, 1988; Dawson and Slooten, 1988; Dawson *et al*., 2000; Clement *et al*., 2001; DuFresne *et al*., 2001; Slooten *et al*., 2002; Ferreira and Roberts, 2003; Clement, 2005; Bräger *et al*., 2003; Slooten *et al*., 2006a; Rayment *et al*., 2006, 2010). The majority of sightings are within five nautical miles from the shore (Dawson *et al*., 2000; Clement *et al*., 2001;

DuFresne *et al.*, 2001; Rayment *et al.*, 2006). Its distribution is more likely to be limited by water depth than distance offshore (Rayment *et al.*, 2006). This is probably due to limited dive time due to its small length (up to 1.45 m long; Dawson, 2002) and capacity for oxygen storage (Noren and Williams, 2000), as well as a preference for feeding on demersal species (Slooten and Dawson, 1994). Hector's dolphin also exhibits a seasonal inshore-offshore movement, concentrated closer inshore during the austral summer months (*e.g.* Dawson and Slooten, 1988; Bräger and Schneider, 1998; Bräger *et al.*, 2002; Slooten *et al.*, 2006a; Rayment *et al.*, 2010). This movement pattern, however, tends to be less pronounced on the west coast of the South Island than at Banks Peninsula (Bräger *et al.*, 2003; Rayment *et al.*, 2006). A coastal habitat implies that Hector's dolphin is in closer proximity to human populations and activities than oceanic species. Potential risks caused by both commercial and recreational activities are also further increased due to the inshore movement pattern of this species over the austral summer.

Hector's dolphin distribution is limited to the North and South Islands of New Zealand (Fig. 1.4). Within their range, Hector's dolphins' distribution is very patchy (Baker, 1978; Cawthorn, 1988; Dawson and Slooten, 1988; Clement, 2005; Rayment *et al.*, 2009). Hector's dolphin is particularly abundant off the northern part of their range off the South Island, on both the east and west coasts (Baker, 1978; Dawson and Slooten, 1988; Dawson *et al.*, 2000; Clement *et al.*, 2001; DuFresne *et al.*, 2001). These two populations are, however, distributed over lengthy coastlines with high density hotspots intercepted by areas of very low abundance (Baker, 1978; Dawson and Slooten, 1988; Dawson *et al.*, 2000; Clement *et al.*, 2001; DuFresne *et al.*, 2001). On the east coast, the Banks Peninsula supports the highest densities of Hector's dolphins (Dawson *et al.*, 2000), with a population estimated at approximately 897 individuals using line-transect methods (C.V. = 28.2%, 95% C.I. = 522 - 1,543; Dawson *et al.*, 2000, 2004) and 1,119 using mark-recapture (C.V. = 21.0%, 95% C.I. = 744 - 1,682; Gormley *et al.*, 2005). Despite occurring all around Banks Peninsula, Hector's dolphin distribution is also patchy, with a few hot spots identified (Bräger *et al.*, 2002; Clement, 2005; Rayment *et al.*, 2009). Akaroa Harbour, one of the two main harbours around the peninsula, is one of the core habitats for Hector's dolphins, especially for dolphins sighted on the eastern and southern sides. Using line-transect surveys, the number of individuals in the harbour has been estimated at 62 (C.V. =

33.9, 95% C.I. = 40 - 97; DuFresne *et al.*, 2001; Dawson *et al.*, 2004). However, there is no true resident population within the harbour but, in fact, a high turnover of individuals (Bräger *et al.*, 2002; Webster and Rayment, 2006). This might explain why Hector's dolphins appear to exhibit diurnal movement, entering Akaroa Harbour in the morning and moving out of the harbour at night (Stone *et al.*, 1995; Stone *et al.*, 2005).

This species also has a limited alongshore home range and high site fidelity (*e.g.* Bräger *et al.*, 2002; Clement, 2005; Rayment *et al.*, 2009, 2010). As a result, semi-resident or resident groups can be found within relatively confined locations (Baker, 1983; Clement, 2005). The species alongshore home range is estimated to be, on average, between 31.0 and 49.7 kilometres (km) (Bräger *et al.*, 2002; Rayment *et al.*, 2009), which is similar to other *Cephalorhynchus* species (*e.g.* Elwen *et al.*, 2006; Heinrich, 2006). There is no evidence to suggest a different home range size between sexes (Bräger *et al.*, 2002).

Small home ranges and high philopatry have likely contributed to the observed levels of genetic divergence. Around the South Island, the species is divided into three distinct regional population units (West, East and South coasts) connected by little or no female dispersal (Pichler *et al.*, 1998; Pichler, 2002; Hamner *et al.*, 2009). Such genetic divergence levels over such small distances are unusual among cetaceans, especially considering the absence of geographical barriers (Pichler *et al.*, 1998).

Overall, the patchy distribution of Hector's dolphin, coupled with a strong natal fidelity and a limited alongshore movement, suggest limited opportunities for potential replenishment between healthy populations and those of adjacent areas affected by any human threat.

1.2.3. Life history

The Banks Peninsula population of Hector's dolphins is the most comprehensively studied, with research conducted on this population since the mid-1980s. Studies at this location have provided valuable information on the species life history, including survival rates (Slooten and Lad, 1991; Slooten *et al.*, 1992; Cameron *et al*., 1999; DuFresne, 2005), calving intervals (Slooten and Dawson, 1994), and intra-species associations (Slooten *et al.*, 1993; Bräger, 1999). As data have been collected over three decades, research now spans the life expectancy of this species, therefore, providing information that can be used for population modelling (*e.g.*, Martien *et al.*, 1999; Slooten, 2007; Slooten and Dawson, 2008).

Like many cetacean species, Hector's dolphin is sexually dimorphic, with females being longer (1.45 m *vs*. 1.32 m; Slooten, 1991; Duignan and Jones, 2005) and heavier (48 kilograms - kg- *vs*. 41.5 kg; Slooten, 1991). Hector's dolphin is also sexually dimorphic in colouration of the genital area, which may be important for sexual signalling and mate recognition (Dawson and Slooten, 1988). This sexual dimorphism allows determination of the sex of individuals in the field, as long as observation of the dolphin's ventral side is possible (*e.g.* during jumps or upside down swimming).

Hector's dolphin lives in a fission-fusion society, typical of many small cetaceans, with fluid association patterns and individuals mixing frequently (Slooten *et al.*, 1993; Bräger, 1999). Groups are typically small (usually two to eight individuals; *e.g.* Dawson and Slooten, 1988; Slooten and Dawson, 1994). Mean group size in the austral summer was estimated at 2.5 (C.V. = 64%) during aerial surveys at Banks Peninsula (Rayment, *et al.*, 2006). Within small groups (five or less individuals), there is a high degree of sex segregation; all of the adults associated with mothers and their young are female (Webster *et al*., 2009). Sex segregation and population fragmentation likely exacerbate problems associated with reproduction, due to the difficulty in finding a mate as local populations decline (Webster *et al*., 2009).

Hector's dolphin mating system has been described as "promiscuous" (Slooten *et al*., 2003). The authors also suggested that males do not monopolise females but instead move between groups to maximise the number of receptive females they encounter. A 1:1 sex ratio (Slooten and Dawson, 1988; Webster *et al*., 2009) further suggests that monopolisation is unlikely.

Hector's dolphin has a low potential for reproductive growth (1.8 - 4.9% per annum), with a more likely population growth rate of *ca*. 2% per annum (Slooten and Lad, 1991). The life expectancy of the species is between 20 and 25 years (Slooten, 1991; Webster, 2008). Males reach sexual maturity between six and nine years of age, and females have their first calf when between seven and nine years old (Slooten, 1991). Photo-identification studies around Banks Peninsula indicate that the calving interval is *ca*. two to three years and no more than half of mature females have a calf in any one year (Slooten, 1990; Slooten *et al*., 1992). The exact gestation period for Hector's dolphin is unknown but is thought to be approximately one year (Slooten and Dawson, 1994). Consequently, a female Hector's dolphin could produce a maximum of four to seven calves in her lifetime (Slooten, 1991). There is no evidence of reproductive senescence in female Hector's dolphin (Slooten, 1991). Overall, due to a late onset of sexual maturity, long calving interval and low reproductive rate, this species will be slow to recover from population decline (Slooten and Lad, 1991).

1.2.4. Threats to Hector's dolphin

Coastal species are particularly susceptible to human threats due to their inshore distribution, which overlaps with the primary areas for both recreational and commercial human activities. The endangered and endemic (Reeves *et al.*, 2008) Hector's dolphin is no exception. Indeed, the strong ecological preferences and philopatry aforementioned, make this species potentially vulnerable to stochastic events within its limited range. The scale of various anthropogenic threats to Hector's dolphin, in combination with their low population growth rate and patchy distribution, has resulted in drastic and continuing decline in their range and abundance (Dawson and Slooten, 2005; Slooten, 2007; Davies *et al.*, 2008).

The primary threat facing Hector's dolphin is fisheries by-catch (*e.g.* Dawson, 1991b; Slooten, 2007; Davies *et al.*, 2008). The vulnerability of this species to entanglement also depends upon the potential cumulative effects of other non-fishery-related threats. These include exposure to contaminants (Jones *et al.*, 1996, 1999; Stockin *et al.*, 2010b), vessel strike (Stone and Yoshinaga, 2000), and dolphin-based tourism (*e.g.* Bejder *et al.*, 1999; Nichols *et al.*, 2001; Martinez *et al.*, 2002; Green 2003). Other potential threats to Hector's dolphin, not yet quantified, but are a cause for concern, include coastal modification (Stone, 1999), aquaculture (*e.g.* Clement *et al.*, 1999; DuFresne *et al.*, 2000; Slooten *et al.*, 2001), prey depletion (Stone, 1999; Slooten and Dawson, 2005), and noise pollution (Stone, 1999; Martinez and Orams, 2009).

A genetically fragmented population structure (Pichler *et al.*, 1998; Hamner *et al.*, 2009) further implies that neighbouring populations would not buffer any impacts upon the localised populations. This highlights the need, therefore, to manage each population as a separate unit to provide maximum protection as a consequence of this genetic isolation and population fragmentation. With the development of human activities, including cetacean-watching, Hector’s dolphins have become a focal species in relation to management of human activities and conservation efforts (Suisted and Neale, 2004; Department of Conservation and Ministry of Fisheries, 2007). Moreover, the fact that this species is endemic, makes the management of all Hector’s dolphin populations the sole responsibility of New Zealand.

1.2.4.1. Fisheries by-catch and the Banks Peninsula Marine Mammal Sanctuary

Since the 1970s, the major threat facing Hector’s dolphin is entanglement in fishing gear, in particular monofilament gillnets set in the inshore coastal zone (*e.g.* Dawson, 1991b; Baird and Bradford, 2000; Duignan *et al.*, 2003; Dawson and Slooten, 2005; Secchi, 2006; Slooten, 2007; Davies *et al.*, 2008). This popular fishing method, both commercially and recreationally, is practised throughout the known range of this species (Slooten, 2007). New Zealand is also one of the few countries that permits recreational gillnet fishing. Hector’s dolphin is incidentally caught in inshore trawl fisheries, however, this method is thought to pose less risk to this species than gillnetting (*e.g.* Baird and Bradford, 2000; DOC and MFish, 2007). Overall, both sexes appear to be equally vulnerable to by-catch, although in some locations, males are much more prone to entanglement (Pichler, 2002). Juveniles (less than four years old) also appear to be more vulnerable (Slooten and Lad, 1991).

For both the east coasts of the North and South Island, significant loss in genetic diversity have occurred over the last 20-40 years (Pichler and Baker, 2000), probably as a result of precipitous population decline (Pichler *et al.*, 2003). The current total population is estimated at 27% of the population size in 1970 (Slooten, 2007). The author predicted that the population will continue to decline to 5,475 (C.V. = 20.0%) by 2050 under current management. Furthermore, in addition to the species habitat, fisheries-related mortality appears to have played a role in shaping the current distribution of Hector's dolphin. Since the 1970s, Hector's dolphin densities have decreased throughout its geographical range and populations have become more fragmented (Slooten, 2007).

Around the Banks peninsula region, Dawson (1991b) documented 230 deaths due to entanglement between 1984 and 1988. A by-catch rate that far exceeded sustainable levels was estimated, with a probability of population decline between 78 and 99% (Slooten and Lad, 1991). In response, a Marine Mammal Sanctuary (BPMMS) was established in 1988 (Dawson and Slooten, 1993) with strict regulations on recreational and commercial gillnet fishing. The sanctuary covers an area of 1,170 km^2 from Sumner Head to the Rakaia River, to four nautical miles offshore (Fig. 1.5). However, despite this protection, the Banks Peninsula population of Hector's dolphins is thought to be declining despite the BPMMS (Cameron *et al.*, 1999; DuFresne, 2005; Davies *et al.*, 2008; but see Gormley, 2009). By-catch continues outside the sanctuary's boundaries (Baird and Bradford, 2000; Dawson and Slooten, 2005) and in recreational nets set legally and illegally inside the boundaries (DOC Cetacean Stranding Database, 2006). Research has also shown that a substantial proportion of the local population occurs outside the BPMMS, particularly in winter (Slooten *et al.*, 2004; Clement, 2005; Slooten *et al.*, 2006a; Rayment, *et al.*, 2006) and, therefore, does not adequately protect this population (Slooten, 2007; Slooten and Dawson, 2008 ; Rayment *et al.*, 2010). To ensure the viability of this population, boundaries would need to be extended (Slooten *et al*., 2006a).

In 2008, a new amendment (Ministry of Conservation, 2008) has extended the northern and southern boundaries significantly while concurrently extending the seaward boundary to 12 nm (Fig. 1.5). The new regulations, however, do not prohibit gillnetting outside the previous four nm boundary (only mining and acoustic seismic surveys are restricted; Rayment *et al.*, 2010). Consequently, this amendment may not prevent the continuing decline of the population (Slooten *et al.*, 2006a; Slooten, 2007; Slooten and Dawson, 2008; Rayment *et al.*, 2010). High levels of movement would reduce the risk of depletion for populations adjacent to the sanctuary, but would increase the risk for the sanctuary area (Slooten, 2007). The author further argued that eliminating fisheries-related mortality throughout the species range is the best option to meet national and international guidelines for managing dolphin by-catch.

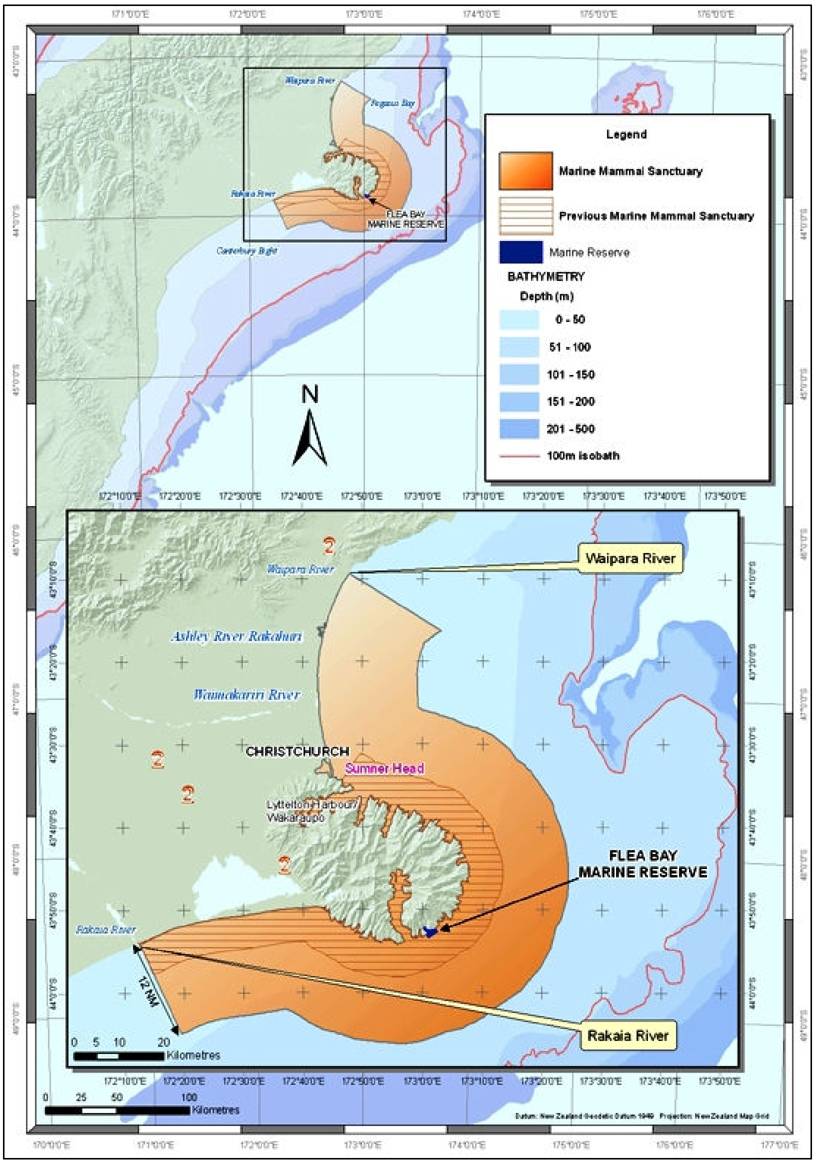


Figure 1.5: Location of Banks Peninsula and the Banks Peninsula Marine Mammal Sanctuary, New Zealand. The map includes the amendments of 2008 (Department of Conservation, 2008).

1.2.4.2. Pollution

Cetaceans, being apex predators and, therefore, at a high trophic level, are vulnerable to the bio-accumulation of toxic contaminants to potentially high levels of toxicity (Reijnders and Aguilar, 2002). Concentrations will vary with biological factors such as diet, body size, nutritive condition, gender, and reproductive biology (Aguilar *et* *al*., 1999). Contaminant levels are also correlated to cetacean habitat, with Northern Hemisphere and coastal species more likely to have higher concentrations than Southern Hemisphere and oceanic species (*e.g*. Jones *et al*., 1999). Hector's dolphin has the highest burdens of contaminants of New Zealand marine animals (*i.e*. polychlorinated biphenyls - PCBs- and organochlorine pesticides - OC) due to its high trophic level and its coastal habitat (Jones *et al*., 1996, 1999). From 1997 to 2009, higher concentrations of OC pesticide levels than previously reported were detected (Stockin *et al.*; 2010b). On the east coast of the South Island, Stockin *et al.* (2010b) found the highest concentration levels in this species, reflecting New Zealand legacy of DDTs usage (dichloro-diphenyl-trichloroethane) between the 1940s and 1970s, particularly in the Canterbury Plains (Stockin *et al.*; 2010b). However, PCBs concentrations were not found over the threshold levels considered to have immunological and reproductive effects. Considering that most of the persistent organic pollutants have not yet dispersed into the environment (Reijnders, 1996), concentration levels in Hector's dolphins and other marine wildlife is unlikely to decrease in the near future.

1.2.4.3. Vessel strike

The issue of vessel strike appears to be on the rise in New Zealand, with an increase in the number of cetaceans seen with propeller scars. Sometimes fatal damage to or close to vertebrae have been caused by collisions (*e.g*. Lusseau, 2002). However, there are a limited number of studies that have attempted to quantify the problem in New Zealand waters (Wiseman *et al*., 2003; Behrens, 2009; Stockin *et al.*, 2009b).

Hector's dolphin is not vessel-shy and often approaches to bow-ride, although this species tends to avoid fast vessels by diving (*e.g*. Baker, 1983; Slooten and Dawson, 1994). In addition, vessel traffic is increasing in many areas of Hector's dolphin geographical range, therefore, increasing the risk of vessel strike, especially in areas of high population density. Stone and Yoshinaga (2000) reported the death of two calves on consecutive days in Akaroa Harbour. The authors suggested that although mother-calf pairs generally avoid closely approaching vessels, they may be vulnerable to vessel strikes due to the reduced evasion ability and lack of experience of the calf (Stone and Yoshinaga, 2000). An increase in public awareness of appropriate behaviour when driving a vessel in areas occupied by cetacean species could help reduce this problem.

1.2.4.4. Cetacean-watching

To watch or not to watch? That is the question that has arisen over the past three decades as cetacean-watching around the world has grown exponentially. Although this industry is often portrayed as viable and benign, concerns about its sustainability have been raised (*e.g.* IFAW *et al.*, 1995; Lusseau and Bejder, 2007). Commercial cetacean-watching vessels hold usually a greater potential to disturb targeted species than general vessel traffic, including recreational vessels, due to the extended time periods spent with the species of interest. Despite the fact that research into the effects of tourism has tended to lag behind the growth of the industry, there is increasing evidence, both worldwide and within New Zealand, that cetaceans exhibit short-term reactions to the presence of vessels (refer to Parsons *et al.*, 2006a,b; Scarpaci *et al.*, 2008, 2009, 2010, for reviews; Table 1.4). The growing body of literature demonstrating impacts in different locations and with a range of species has led to some debate that whale-watching, if not carefully managed, is another form of harmful exploitation of cetaceans (Orams, 1999).

Short-term responses, such as the disruption of critical behaviours (*e.g.* resting and foraging), could potentially have long-term effects on the health and status of a population through displacement from important habitat(s) and/or a reduction in the biological fitness of a population. The long-term biological significance of such changes is difficult to establish and is a challenge facing tourism impact studies. A lack in baseline data usually renders this task even more challenging. A link between short- and long-term effects has, however, recently been ascertained (*e.g.* Bejder *et al.*, 2006a,b; Lusseau *et al.*, 2006a; Williams *et al.*, 2006), highlighting the need to manage cetacean-watching activities carefully.

Another issue associated with tourism impact studies is the fact that short-term responses vary with species, age class, gender, and individuals (*e.g.* Ritter, 1996; Constantine and Baker, 1997; Constantine, 2001; Lusseau, 2003b; Richter *et al.*, 2006). Factors such as type and number of vessel, type of approach, and length of interaction also elicit different responses (*e.g*. Kruse, 1991; Würsig *et al*., 1997; Ransom, 1998; Bejder *et al*., 1999; Constantine, 2001; Nowacek *et al*., 2001; Williams *et al*., 2002a,b; Neumann and Orams, 2006; Williams and Ashe, 2007; Markowitz *et al.*, 2009). These differences reinforce the need to assess the impacts of cetacean-watching tourism activities on a case by case basis. Management efforts are, however, further hindered by the lack of pre-disturbance data (Constantine, 1999) and lack of consistency in methodology between studies (IFAW *et al*., 1995), which prevents before and after impact as well as intra- and inter-species comparisons.

Table 1.4: Examples of short-term responses of cetaceans to the presence of vessels and/or swimmers.

Response	**References**
Behavioural activity	Würsig, 1996 ; Nowacek *et al.*, 2001; Lusseau, 2003a; Constantine *et al.*, 2004; Ribeiro *et al.*, 2005; Bain *et al.*, 2006; Williams *et al.*, 2006; Dans *et al.*, 2008; Stockin *et al.*, 2008a; Lusseau *et al.*, 2009; Markowitz *et al.*, 2009a ; Christiansen *et al.*, 2010 ; Visser *et al.*, 2010.
Group cohesion	Blane and Jaakson, 1994; Heimlich-Boran *et al.*, 1994; Barr and Slooten, 1999; Bejder *et al.*, 1999; Nowacek *et al.*, 2001; Green,2003; Ribeiro *et al*., 2005; Miller *et al*., 2008; Markowitz *et al*., 2009a.
Dive intervals	Baker and Herman, 1989; MacGibbon, 1991; Heimlich-Boran *et al.*, 1994; Corkeron, 1995; Janik and Thompson, 1996; Arnold and Birtles, 1998; Nowacek *et al.*, 2001; Lusseau, 2003b; Corbelli, 2006; Richter *et al.*, 2006; Miller *et al.*, 2008.
Whistle production rates/vocalisation	Scarpaci *et al*., 2000; Van Parijs and Corkeron, 2001; Erbe, 2002; Buckstaff, 2004; Lemon *et al.*, 2006; Sousa-Lima and Clark, 2008; Hawkins and Gartside, 2009.
Direction of travel/ Reorientation/ swimming speed	Kruse, 1991; Blane and Jaakson, 1994; Janik and Thompson, 1996; Arnold and Birtles, 1998; Williams *et al.*, 2002a,b; Goodwin and Cotton, 2004; Mattson *et al.*, 2005; Lusseau, 2006; Lemon *et al.*, 2006; Williams and Ashe, 2007; Markowitz *et al*., 2009a.

Hector's dolphin tourism

Hector's dolphins are one of the best-studied cetaceans in the world, particularly the Banks Peninsula population. While strong ecological preferences (*e.g.* high site fidelity and distribution closer inshore during austral summer months) make Hector's dolphins potentially vulnerable to human activities, they also make it an attractive target for tourism activities. Conservation challenges can, therefore, arise from such a "mixed blessing" (Williams *et al*., 2009b), *i.e*. when core habitats for a species overlap with high-use and/or high-risk (*e.g.* oil drills) human activities. This is particularly critical when the species in question is threatened or endangered (Williams *et al*., 2009b).

So far, six studies have specifically documented the responses of Hector's dolphins to different levels of vessel activity in Akaroa Harbour (Nichols *et al.*, 2001, 2002), Lyttelton Harbour and Timaru (Travis, 2008), Porpoise Bay (Bejder *et al.*, 1999; Green, 2003), and Motunau (Martinez, 2003). In contrast with both Akaroa and Lyttelton Harbours, other tourism locations are small-scaled (*i.e*. one operator) and not within close distance of one of New Zealand's major cities (*e.g*. Christchurch). Variables examined in these aforementioned studies include group dispersion, dolphin behavioural states in the presence and absence of vessels, as well as movement/orientation in relation to vessels and/or swimmers. A comparison of the dolphin orientation during an encounter between Motunau (where a commercial operator was not yet established) and Porpoise Bay (tours commenced in 1994) suggests that as Hector's dolphins get more exposure to vessels and/or swimmers over time, their tolerance levels towards vessel(s) increase (*i.e*. their movement is no longer random). Stone and Yoshinaga (2000) provide further anecdotal evidence of increased tolerance levels towards swimmers over a 15-year period in Akaroa Harbour. Most studies were conducted from land-based platforms, thereby removing the potential influence of a research vessel on the dolphin behaviour. Overall, there was no evidence that Hector's dolphins were being displaced or adversely affected by tourism activities even though short-term behavioural changes of Hector's dolphins to vessels and/or swimmers have been reported.

In Banks Peninsula, one of the strongholds of the species, commercial tour operators have a restricted area of operation. Dolphin-watching tours are only permitted in Lyttelton Harbour, Akaroa Harbours and at Le Bons Bay. Swim-with-dolphin trips are only permitted in Akaroa Harbour (Fig. 1.6). This implies that not all individuals within the Banks Peninsula population are exposed to tourism activities. To illustrate, Akaroa Harbour has the highest number of permitted trips (up to 32 per day). Akaroa Harbour is also one of the identified high-density hotspots (Clement, 2005). The harbour is, in fact, part of the home range of a large proportion of identified Hector's dolphins and a core habitat for half of these individuals (Bräger *et al.*, 2002; Rayment *et al.*, 2009). Those individuals are, therefore, potentially more susceptible to the aforementioned effects associated with tourism activities than individuals whose core use area is based around the southern bays.

Since the early 1990s, there has been a constant and dramatic increase in the number of vessels, whether commercial or recreational, in Akaroa Harbour (*e.g.* Stone, 1992; Stone *et al*., 1995, 1998; Nichols *et al*., 2001). The peak period in vessel activity is over the austral summer, coinciding with the calving season. As a result of increased tourism, concerns have been raised about the potential risk of vessel strike (Stone and Yoshinaga), habituation, and harassment (Stone, 1999). Finally, the absence of pre-tourism baseline data on the ecology and behaviour of Hector's dolphins at most locations (with the exception of Motunau; Martinez, 2003) renders the measurement of potential effects in the long-term more problematic and the management of tourism activities more challenging.

Fig. 1.6: Marine permit zones for commercial tour operators in Akaroa Harbour, Le Bons Bay, Lyttelton Harbour and Motunau, New Zealand (adapted from Allum, 2009).

1.3. Management of the cetacean-tourism industry in New Zealand

Concerns about the potential adverse effects on a targeted population both in the short- and long-term (refer to section 1.2.4.4.) have stimulated the development of regulations and guidelines to protect cetacean species (Garrod and Fennel, 2004; Gjerdalen and Williams, 2000). Globally, the development of the cetacean-watching industry has been so rapid that, as with research, planning and management agencies have lagged behind in terms of investigating and setting management priorities and policy directives to oversee the sustainability of the industry (Hoyt, 2001; Parsons *et al.*, 2003). The challenge to define the real cost of cetacean-watching on targeted populations has also made it difficult to translate the observed effects into management guidelines.

Cetacean-watching mainly occurs in coastal waters (Hoyt, 2001; O'Connor *et al.*, 2009). Consequently, the management of this industry is determined by domestic legislation. New Zealand is widely recognised as a world leader in managing cetacean-based tourism (Donoghue, 1996; Samuels *et al.*, 2000; Orams, 2004). New Zealand is one of the few countries to have legislation to regulate the industry, including swim-with-dolphin interactions (refer to Carlson, 2001, 2008 for reviews). The two key legal statutes that apply to cetacean-watching activities within New Zealand waters are the Marine Mammals Protection Act (MMPA, 1978; Appendix 1.3) and the Marine Mammals Protection Regulations (MMPR, 1992; Appendix 1.4). All marine mammals are fully protected under the MMPA. This Act was passed to consolidate diverse pieces of legislation into one statute, which primarily aimed "to make provision for the protection, conservation, and management of marine mammals within New Zealand and within New Zealand fisheries waters". In 1992, the MMPR were introduced, as an amendment of the MMPA, to provide for the control and management of all marine mammal tourism activities (both commercial and recreational).

In New Zealand, DOC is responsible for administering the MMPA and MMPR. It does so through issuing and monitoring marine mammal tourism permits, required for any commercial operation wanting to view and/or swim with any marine mammal species. As of 2004, there were an estimated 90 active cetacean-watching operators in the country out of approximately 110 marine mammal permit holders, which included seal viewing and swimming with wild dolphins (IFAW, 2005).

There are several criteria under which permits are issued. These can be summarised as a) permits should not be contrary to any conservation management strategies or plans under section 3 of the Act; b) they should be in the interests of conservation, management or protection of marine mammals; c) they should not have any significant adverse effects on the species targeted; d) operators and staff should have sufficient experience with marine mammals and the local area; and e) the commercial operation should have sufficient educational value. All permittees are required to comply with the MMPA and MMPR.

The MMPR were initially designed to regulate tourism activities targeting sperm whales and dusky dolphins in Kaikoura and did not distinguish between the requirements of different species at various locations (Baxter and Donoghue, 1995). It has since been used to regulate additional commercial operations focusing on a wide variety of other cetacean species. Each commercial permit granted by DOC can be supplemented with additional conditions or restrictions (via regulations and Codes of Conduct) pertaining specifically to the operation and behaviour around a targeted species. For example, permits can specify an area of operation, the number of daily trips allowed, the duration of encounters, whether or not swimming is permitted and under what conditions. The MMPR can also be adapted to incorporate new research findings into permit conditions in order to effectively minimise the effects of tourism on cetaceans. Other national management plans, whether or not statutory documents, also exist, such as the national Marine Mammal Action Plan 2005-2010 (Suisted and Neale, 2004). This plan provides a guide for the conservation management of New Zealand's marine mammals over the specified period and sets priorities for each species using key strategic documents and directive government policies.

The growing popularity and associated number of cetacean-watchers in New Zealand, implies that some of the conservancies around the country are now facing a new management challenge, *i.e.* limit the growth of the industry at a particular location or face a potential degradation of the resource, the environment, and the community that originally made it a successful tourism destination.

1.4. Rationale for this thesis

Recent research has linked the short-term effects of tourism with long-term biological consequences for the viability and fitness of targeted populations, including a decline in dolphin abundance, displacement from preferred habitats or a reduction in energy acquisition potentially causing a decrease in reproductive success (*e.g.* Lusseau, 2005a; Bejder *et al.*, 2006b; Lusseau *et al.*, 2006a; Williams *et al.*, 2006). It appears that even low-level tourism might not be as benign as previously considered (Bejder *et al.*, 2006b; Stockin *et al.*, 2008a). In light of these findings, assessing the potential effects of commercial and non-commercial vessel activities in Akaroa Harbour is both crucial and urgent given that: a) the endemic Hector’s dolphin is endangered; b) the Banks Peninsula population is likely still declining; c) the number of permitted daily trips in Akaroa Harbour is high; d) permits are due for renewal in 2012 and there is a demand for more permits; and e) there is a paucity of data on the effects of the local tourism industry (Constantine, 2004). This sense of conservation urgency is recognised in the Marine Mammal Action Plan for 2005-2010 (Suisted and Neale, 2004), where Hector’s dolphin is identified as *a priority species*. As a consequence, a key objective for DOC is to “effectively protect Hector’s dolphins against avoidable adverse effects of tourism”.

Stone (1999) drew attention to the fact that, while each anthropogenic threat considered in isolation may not raise concern, it is necessary to take into account the cumulative effects of other threats a species faces when assessing the vulnerability of a population to decline. Both Corkeron (2004) and Lusseau (2007) reemphasised this point by stating that while effects of tourism on cetaceans may be “trivial” compared to other human impacts (*i.e.* by-catch or pollution), their cumulative and potentially synergetic effects may be sufficient to tip a population towards decline or prevent it from recovering. Consequently, all potential human threats on a species or an area should be managed using an adaptive and integrated approach (Higham *et al.*, 2007).

An important aspect of maintaining adequate management policies is the knowledge of the species and ecosystems concerned (Mangel *et al.*, 1996). Contaminant levels and the effects of fisheries by-catch on the east coast Hector's dolphin population are now known (*e.g.* Dawson, 1991b; Slooten, 2007; Stockin *et al.*, 2010b). There is, however, a lack of information about the effects of vessels and tourism on this species at Banks Peninsula. Consequently, it is essential for the effective and sustainable management of the dolphin-watching tourism industry in Akaroa Harbour, and the species at large, to conduct a comprehensive study on the effects of interactions between vessels and Hector's dolphins.

1.5. Thesis structure and objectives

This thesis comprises six research chapters (Chapters II to VII) with an introductory (Chapter I) and concluding (Chapter VIII) chapter. Each research chapter has been part of a report to DOC, Canterbury conservancy (Martinez and Orams, 2009; Martinez *et al.*, 2009, 2010). In addition, chapter VI has been written in a publication format and represents a manuscript that is *submitted* (journal authorship and authors' contributions are detailed below). The format of this thesis resulted in some unavoidable repetition, particularly in relation to methods and materials. However, every effort has been made to limit duplication, where appropriate.

The aims of each chapter are as follows:

Chapter I provides an overview of: a) the cetacean-watching industry at a global, national, and local scale (Akaroa Harbour); b) the importance of dolphin-based tourism for the Akaroa community; c) the targeted species, the Hector's dolphin; d) research findings on the effects of the tourism industry; and e) the legal framework controlling cetacean-watching. The context of the present study is detailed and the absence of appropriate data and/or knowledge within the literature is further highlighted.

Chapter II examines the occurrence, demography, and behaviour of Hector's dolphins in Akaroa Harbour in the absence of vessels in an attempt to provide important baseline data. Behaviour was first compared with other locations around Banks

Peninsula, where tourism levels are lower or non-existent. It was then examined in relation to temporal and spatial scales in the harbour using a Geographic Information System (GIS). The potential presence of nursery areas within the harbour was also investigated using GIS. This chapter is a reformatted version of an unpublished report to DOC, co-authored with M.B. Orams and K.A. Stockin. Data for this chapter were collected by E. Martinez during fieldwork conducted around Banks Peninsula between 2005 and 2008. Data analyses were undertaken by E. Martinez. The report was written by E. Martinez and improved by edits and suggestions provided by M.B. Orams, D. Clement, and K.A. Stockin.

Chapter III details the vessel traffic levels observed within Akaroa Harbour in order to quantify the level of vessel activity Hector's dolphins are potentially exposed to during the austral summer months. Here the actual level of vessel traffic in the harbour is assessed, as well as the diel periods when commercial operators exert the greatest effort. The time operators spent engaged with dolphins (including cumulative time) is also determined. The location of both viewing and swimming encounters using ArcGIS is also provided. This chapter is a reformatted version of an unpublished report to DOC, co-authored with M.B. Orams and K.A. Stockin. Data for this chapter were collected by E. Martinez during fieldwork conducted in Akaroa Harbour between 2005 and 2008. Data analyses were undertaken by E. Martinez. The report was written by E. Martinez and improved by edits and suggestions provided by M.B. Orams, D. Clement, and K.A. Stockin.

Chapter IV examines the effects of tourism activities on Hector's dolphins in Akaroa Harbour. Focal group follows were conducted and three-minute scan-sample data were collected on vessel number and type as well as dolphin behavioural state. Markov chains were then used to describe transition probabilities and activity budget in the presence and absence of vessels. The effect of interactions between vessels and dolphins was quantified by comparing transition probabilities during *control*, *distant* (more than 300 m from a dolphin group), and *close* (less than 300 m) conditions. The influence of the number of vessels and vessel type was also investigated. This chapter is a reformatted version of an unpublished report to DOC, co-authored with M.B. Orams and K.A. Stockin. Data for this chapter were collected by E. Martinez during fieldwork conducted in Akaroa Harbour between 2005 and 2008. Data analyses were undertaken by E. Martinez. Assistance with Markov chains was kindly provided by D. Lusseau and D. Lundquist. The report was written by E. Martinez and improved by edits and suggestions provided by M.B. Orams, D. Clement, and K.A. Stockin.

Chapter V investigates the potential effects of swim-with-dolphin trips on Hector's dolphins. Details on trips statistics are provided (*e.g.* duration, number of swimmers involved). The orientation of dolphins towards and away from vessels and/or swimmers according to time into an encounter is assessed. The dolphin behavioural budget in relation to swimmer numbers and departure time (staggered *vs*. discrete) is also analysed. Finally, the influence of vessel approach and swimmer placement on dolphin behaviour is examined. This chapter is a reformatted version of an unpublished report to DOC, co-authored with M.B. Orams and K.A. Stockin. Part of that chapter is also *in press* in *Tourism Review International*. Data for this chapter were collected by E. Martinez during fieldwork conducted in Akaroa Harbour between 2005 and 2008. Data analyses were undertaken by E. Martinez. Assistance with GLM models and logistic regression was kindly provided by M.D.M. Pawley and J.A. Harraway. The report and manuscript were written by E. Martinez and improved by edits and suggestions provided by M.B. Orams, D. Clement, M.D.M. Pawley, and K.A. Stockin.

Chapter VI assesses the potential effects of the use of auditory stimulants during swim-with-dolphin interactions with Hector's dolphins. Here, the number of approaches, sustained, and close approaches were compared between the different techniques employed by swimmers when interacting with dolphins. Results are discussed in relation to the New Zealand legislation. This chapter is a reformatted version of a paper *in press* in *Marine Mammal Science*, co-authored with M.B. Orams, M.D.M. Pawley, and K.A. Stockin. Data for this chapter were collected by E. Martinez during fieldwork conducted in Akaroa Harbour in December 2008. Data analyses were undertaken by E. Martinez with the assistance of M.D.M. Pawley. The manuscript for this chapter was written by E. Martinez and improved by the edits and suggestions provided by M.B. Orams, D. Clement, M.D.M. Pawley, and K.A. Stockin.

Chapter VII provides insight into the potential exposure levels of Hector's dolphins using Akaroa Harbour as part of their home range. Photographic capture-recapture methods were used to determine the frequency of usage of the harbour by identifiable individuals. The 50 individuals identified were compared with the Banks Peninsula Hector's Dolphin Catalogue, which spans over 20 years, held by the University of Otago. This chapter is a reformatted version of an unpublished report to DOC, co-authored with M.B. Orams and K.A. Stockin. Data for this chapter were collected by E. Martinez during fieldwork conducted in Akaroa Harbour between 2005 and 2008. Data analyses were undertaken by E. Martinez. Assistance with the catalogue, photo-identification and the programme MARK was kindly provided by M. Merriman, M. Mariani, T. Webster, and G. Tezanos-Pinto, respectively. The report was written by E. Martinez and improved by edits and suggestions provided by M.B. Orams, D. Clement, G. Tezanos-Pinto, and K.A. Stockin.

Chapter VIII concludes by summarising the findings of each research chapter and considers their contribution to new knowledge. Population management implications are also identified to contribute to the sustainability of the tourism industry. Finally, future research priorities are provided.

CHAPTER II

Baseline fine-scale distribution, behaviour, and group dynamics of the South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) in Akaroa Harbour, Banks Peninsula

Photo: A.R.E.V.A. Project © 2007.

Chapter II draws on material that also appears in:
Martinez, E.; Orams, M.B.; Stockin, K.A. (2010). Responses of South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) to vessel activity in Akaroa Harbour, Banks Peninsula, New Zealand. Unpublished report to the Department of Conservation, Canterbury, New Zealand. 187p.

2.1. Introduction

Coastal marine environments are amongst the most highly impacted (Simmonds and Hutchinson, 1996) and difficult regions to manage due to conflicts between users with competing demands (*e.g.* commercial operations, fishermen, recreational vessel owners, and conservationists; Hughey, 2000). Not surprisingly, inshore cetacean populations are generally more at risk from increasing human related disturbance and degradation of the coastal marine environment (Klinowska, 1991; Moscrop, 1993; Reeves and Leatherwood, 1994).

In New Zealand, the rapid development and widening appeal of ecotourism has been associated with various confounding management challenges (*e.g.* symbiosis between tourism and conservation interests; Higham *et al*., 2001; Higham, 2007). When investigating the potential short-term responses of a particular species to cetacean-watching activities, it is essential to have baseline data, such as distribution, abundance, and behaviour budget (ideally prior to the establishment of a commercial tour operation) for comparative purposes (Constantine, 1999). If ecological and environmental factors are known to affect the behaviour of a species of interest, then these should be considered when assessing how much of the species behavioural change can be attributed to human activities and whether such change can be considered detrimental. Baseline data are, however, typically lacking when assessing the potential effects of watching and swimming with cetaceans (Constantine, 1999).

Primarily an inshore species, the South Island Hector's dolphin *Cephalorhynchus hectori hectori* (hereafter referred to as Hector's dolphin) is an attractive target for commercial tourism operations. The tourism industry targeting this species within Akaroa Harbour has expanded over the past 25 years. Although the movement and usage of the harbour by Hector's dolphins has been previously documented (*e.g.* Dawson, 1991b; Stone *et al*., 1995; Clement, 2005; Webster, 2008), it has neither been linked to behavioural activities nor assessed fine-scale. The behavioural activity budget of dolphins using Akaroa Harbour is currently unknown.

The endangered and endemic Hector's dolphin (Reeves *et al*., 2008) has become a focal species in relation to management of human activities and conservation efforts

(Suisted and Neale, 2004; Department of Conservation and Ministry of Fisheries, 2007). A relatively small range, a high-site fidelity, and a patchy distribution (e.g. Bräger *et al*., 2002; Clement, 2005; Rayment *et al*., 2009), emphasises the importance of understanding each population separately from both an ecological and conservation point of view. Determining density and activity patterns of Hector's dolphins using Akaroa Harbour when not interacting with vessels can, therefore, yield important information and assist in the provision of adequate management recommendations to ensure tourism sustainability (*e.g*. by protecting critical habitats).

2.2. Objectives

Central to any effective management of a species and or population, is a comprehensive knowledge of the biology and habitat use of the species being protected. Such insight ensures that management actions are made at a relevant and biologically meaningful scale. The main purpose of this chapter is to gather baseline/control data by:

1) Determining trends in occurrence and in group size of Hector's dolphin groups in relation to extrinsic and intrinsic factors.
2) Examining the activity patterns of dolphins within Akaroa Harbour and two other bays around Banks Peninsula, where vessel traffic is low.
3) Describing the Hector's dolphin density patterns in the harbour.
4) Identifying potential core areas for behavioural activities and calving/nursing within the harbour.

2.3. Materials and methods

2.3.1. Study site and observation platforms

2.3.1.1. Study site

Banks Peninsula, New Zealand, is a large volcanic peninsula protruding from the central-east coast of the South Island, at latitude 43º50' S (Fig. 2.1). The Peninsula spans an approximate area of 810 square kilometres (km^2), consisting of mainly steep, volcanic rock cliffs interspersed by deep valleys, long bays, and natural harbours that facilitate land-based observations (Herzer, 1981).

Fig. 2.1: Map of Banks Peninsula, showing the location of Akaroa Harbour, Le Bons Bay, and Te Oka Bay, New Zealand.

Akaroa Harbour, a crater formed by an eruption of a long extinct volcano (Lowndes, 2002), is a natural tidal inlet approximately 17 kilometres (km) in length with a predominantly north-south orientation (Heuff *et al.*, 2005). It is 5.5 km in width at its widest and 1.7 km at its narrowest point near the northern end. The maximum depth is 25 metres (m) at its south-facing entrance on the Canterbury Bight (Heuff *et al.*, 2005). The upper end of the Harbour (or *inner* harbour) opens into a series of shallow bays, which at low tide, are exposed. The harbour coastline primarily consists of rocky sides formed by steep cliffs and high surrounding hills, with more gradual beaches near the mid to upper reaches (Clement, 2005; Heuff *et al.*, 2005). The harbour has strong tidal flows (NIWA, 2010)[1] and productive waters (Clement, 2005).

2.3.1.2. Observation platforms

The primary mechanism for data collection in this study was land-based observations, which was especially suited here for several reasons. Firstly, shore-based observations offer a zero-disturbance method, *i.e.* no disturbance to the target species. Secondly, studies using a theodolite have proven to be a powerful tool with which to document small-scale movements, occupancy patterns, and behaviours of cetacean species since the 1970s (*e.g.* Würsig and Würsig, 1979). Since then, more than 20 species worldwide have been studied and tracked with a theodolite (refer to Samuels and Tyack, 2000; Bejder and Samuels, 2003 for reviews). In New Zealand, this method has been successfully applied to several species namely, sperm whales (*Physeter macrocephalus*; *e.g.* Richter *et al*., 2006), dusky dolphins (*Lagenorhynchus obscurus*; refer to Würsig *et al*., 2007 for summary; Lundquist and Markowitz, 2009), and Hector's dolphins (*e.g.* Bejder *et al*., 1999; Nichols *et al*., 2001; Green, 2003; Martinez, 2003; Travis, 2008). Finally, Hector's dolphins are strongly attracted to vessels (Dawson and Slooten, 1988; Stone *et al.*, 1995; Chapter III). This indicates that a land-based study is the most appropriate platform to gather data and investigate this species with regard to assessing the potential effects of vessel traffic on Hector's dolphins in Akaroa Harbour.

In this study, several stations were established within Akaroa Harbour (Figs. 2.2 and 2.3). Heights varied between 72.7 m above sea level for the lowest (*Lighthouse*) and 152.8 m for the highest (*9 Fathom*) (Fig. 2.2). The sites were strategically placed to limit the area obscured from the theodolite view and to ensure that most of the harbour could be surveyed. Hector's dolphin sightings within the upper end of the harbour (or *inner* harbour, Fig. 2.2) tend to mainly occur in January and are relatively infrequent compared with the rest of the harbour (Dawson, 1991b). As a result, most of that area was not taken into consideration.

[1] http://www.niwascience.co.nz/rc/prog/chaz/news/bpmov. Accessed 14/02/2010

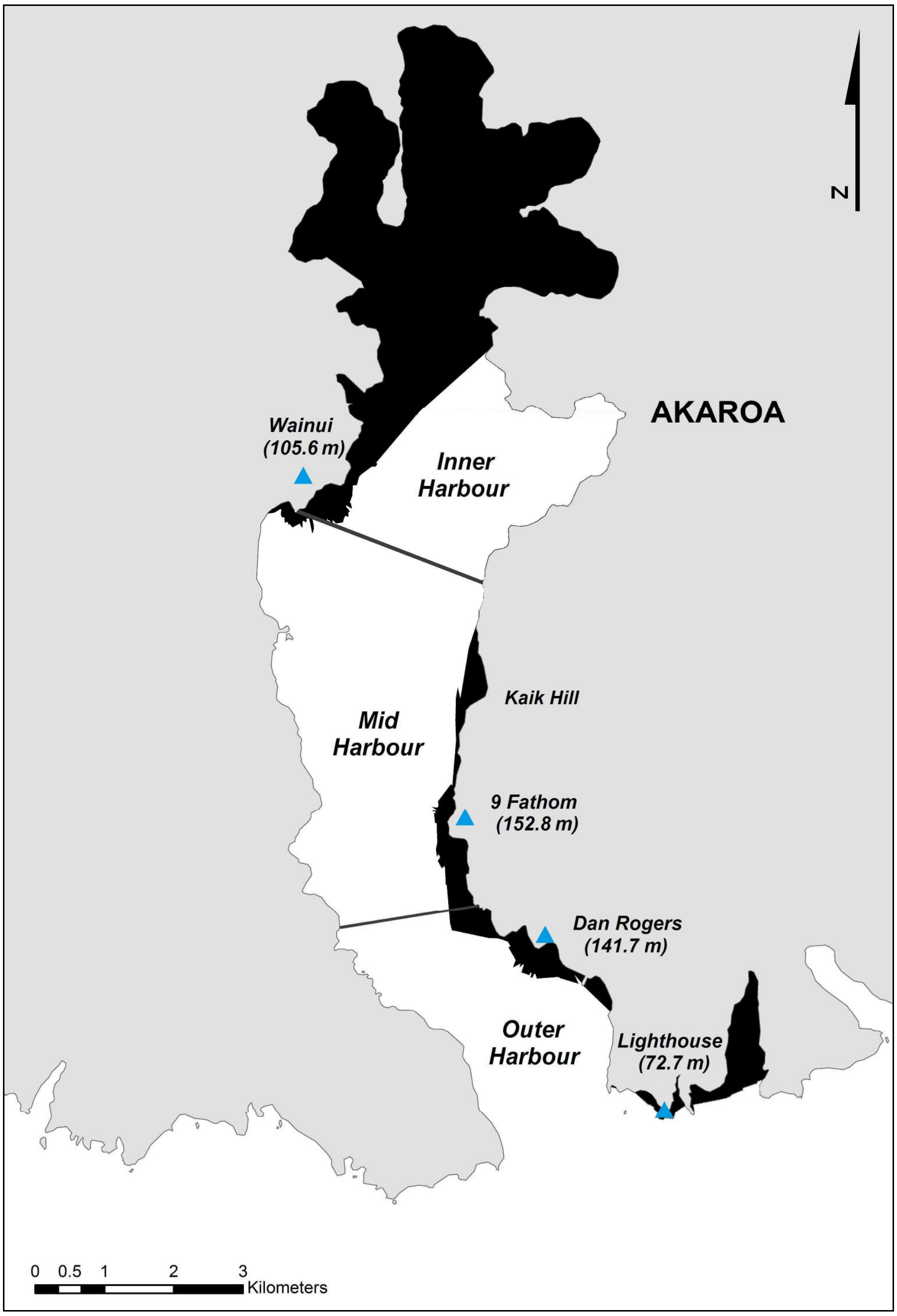


Fig. 2.2: Map showing the location of the four land-based stations (blue triangles) within Akaroa Harbour, Banks Peninsula, New Zealand. The shaded areas represent parts of the harbour that were out of sight from the stations. The shaded area of the inner harbour was not considered in this study due to Hector's dolphin low sighting rates (Dawson, 1991b).

Two additional land-based stations were established outside Akaroa Harbour in January 2006 and in November 2006, respectively. The former was positioned near Te Oka Bay (95.2 m above sea level, Fig. 2.1), on the south-eastern side of Banks Peninsula. The latter was situated in Le Bons Bay (113.3 m above sea level), on the most north-eastern point of the headland (Fig. 2.1). These particular locations were selected as *control* sites to collect further behavioural data in the absence of vessels.

In Le Bons Bay, only one local operator is legally permitted to offer one daily dolphin-watching trip (Allum, 2009). No commercial companies operate around the south-eastern bays, including Te Oka Bay.

All six sites were chosen based on site accessibility, view of the study area, orientation to the sun, and previous research. Clement (2005) indicated the presence of *hot spots* or high usage areas by Hector's dolphins around the Peninsula, including Akaroa Harbour, Te Oka Bay and Le Bons Bay.

Fig. 2.3: View from the four land-based study sites within Akaroa Harbour. A: *Wainui*. B: *9 Fathom*. C: *Dan Rogers*. D: *Lighthouse*. All stations face west except *Wainui*, which has a southern aspect. Photos: A.R.E.V.A. Project 2007.

2.3.2. Data collection

Between 2005 and 2008, shore-based observations were collected from November to March from the six fixed theodolite sites (Figs. 2.1 and 2.2). This five-month period was timed to coincide with optimal weather conditions and the more inshore distribution of Hector's dolphins over warmer summer months (*e.g.* Clement, 2005; Rayment *et al.*, 2010).

Data were collected between 0600 and 1800 hours (hr) in two, six hours blocks (*i.e.* 0600-1200 hr or 1200-1800 hr) to avoid observer fatigue and subsequent bias. To further prevent fatigue, a minimum of two observers rotated their position hourly (see section 2.3.2.1) and/or at the end of a focal group follow if observations were still being recorded at the hour mark. To further reduce bias, the principal investigator only (EM) operated the theodolite (see section 2.3.2.2 for sampling protocol). Observation effort varied and was limited to favourable environmental conditions, *i.e.* no rain and Beaufort Sea State (BSS) of two or less. If BSS increased above two or if weather conditions deteriorated, data collection was terminated to prevent sighting rates being negatively affected (Elwen *et al.*, 2009). Environmental variables such as BSS, wind speed and direction, temperature, percentage glare and cloud cover, were all recorded hourly and/or if noticeable change in conditions occurred. An index of overall sightability (from 1 to 4, 1 being very poor and 4 excellent), encompassing all the above conditions and was recorded at the same time. Only observations with a good or excellent sightability were included in the analyses.

2.3.2.1. Sampling protocol

At the start of each observation period, the study area was systematically scanned (Martin and Bateson, 1993). In addition to the theodolite operator (EM), a minimum of two trained observers scanned the study site to locate dolphin groups using Nikon or Tasco binoculars (7-10 x 50) and a tripod-mounted Acuter spotting field scope (60x magnification). Scans were standardised by searching in opposite directions (*e.g.* observer(s) scanned from east to west and the other(s) from west to east) to ensure equal time intervals between successive scans. This protocol was always completed to guarantee that all dolphin groups present had been recorded. In the absence of dolphin groups, observers continuously scanned the study area while assigned to a specific sector. The entire study site was under constant observation at any point in time.

While focal follows of individual dolphins offer clear advantages (Mann, 1999, 2000), this sampling technique was neither feasible nor appropriate for land-based surveys because Hector's dolphins have a low mark rate (Slooten *et al.*, 1992; Gormley *et al.*, 2005; Chapter VII). Consequently, group focal follows (Mann, 1999) were used to determine the behaviour and position of dolphin groups. This method is an accepted protocol used in other land-based studies (*e.g.* Bejder *et al.*, 1999; Lundquist and

Markowitz, 2009). A group was defined as individuals located in close proximity (less than five body lengths or approximately less than 10 m) from one another (Smolker *et al*., 1992).

Once a dolphin group was detected, the following variables were collected: group size, group composition, and behaviour. All variables were estimated independently by at least two observers and only recorded when all were in agreement. Group composition was categorised as *adult* groups or *mixed* groups, and *mother-calf* pair(s). *Mixed* groups were defined as any group including adults, and/or juveniles, and at least one *mother-calf* pair. Juveniles were described as individuals approximately two-thirds the size of an adult and frequently observed swimming in association with an adult animal but not in the infant position (Mann *et al*., 2000), suggesting that the individual was weaned. A *calf* was defined as an individual that was approximately 50% or less than the size of an adult and consistently observed in association with an adult, presumed to be the mother (Fertl, 1994). Within the *mother-calf* pair(s) category, two or more mother-calf pairs constituted a *nursery* group. *Adult* groups referred to any group of individuals not included in the prior classifications.

In the present study, the behavioural state of each focal group was recorded continuously at three-minute intervals. Behavioural states rather than events were chosen based on the biased ability to detect individual events from a distance (*i.e.* land-based stations). The predominant behavioural state of the focal group (Mann, 1999) was defined as the activity in which 50% or more of group members were simultaneously engaged. In this study, widely accepted categories of behavioural states were adopted, derived from Shane (1990a) to allow inter-species comparisons. Discrete behavioural events (*e.g.* aerial, sexual) previously described for Hector's dolphins (Slooten, 1994) were further incorporated in the behavioural state definitions used herein (Table 2.1). These states were defined to be mutually exclusive and cumulatively inclusive. Resting was not included in the analyses as it was only observed during five independent occasions. Hector's dolphins might engage in resting at night, however, the nocturnal behaviour of this species is unknown.

Table 2.1: Definitions of the behavioural state categories used in the present study in Akaroa Harbour, New Zealand (derived from Shane, 1990a; Slooten, 1994). Mother-calf pair behaviour was based on the behavioural state of the mother.

State (abbreviation)	Definition
Milling (MIL)	Dolphins exhibited non-directional movement, with frequent changes in heading. No net movement. Group spacing and dive interval vary but are less than 1 min for the latter.
Diving (DIV)	Dolphins' direction of movement varies. Groups dive for prolonged intervals (> 1 min) often arching their backs at the surface to increase speed of descent. Group spacing varies. The presence of birds diving close to a group is also indicative of diving behaviour. Note - this represents the "feeding/foraging" category defined in other studies.
Socialising (SOC)	Dolphins observed chasing and/or engaged in any other physical contact with other individuals in the group. Aerial, sexual, and aggressive behaviours are frequently observed. Group is often split into small subgroups dispersed over a large area. Dive intervals vary. No obvious forward movement.
Travelling (TRA)	Dolphins engaged in persistent, directional movement, swimming with short, relatively constant dive intervals. Group spacing varies.
Resting (RES)	Dolphins engaged in slow movements (*i.e.* less than 1.5 km/hr) in a constant direction, with little evidence of forward propulsion. Dolphins were occasionally stationary. Dive intervals were short, relatively constant, and synchronous. Group spacing is tight (*i.e.* less than one body length between individuals). Resting lacked the active components of the other behaviours described.

Sightings were classified into three different categories: *control*, *distant*, and *close* (refer to Table 2.2 for definition). In this chapter, the primary interest was the collection of data in potentially non-impact situations. Consequently, data collected under a *close* condition were excluded from analyses. A distance of 300 m was chosen to define that category in order to be consistent with the Marine Mammals Protection Regulations (MMPR, 1992).

Table 2.2: Definitions of the different categories used to classify sightings of Hector's dolphins in relation to the presence and absence of vessels in Akaroa Harbour, New Zealand.

Category	Definition
Control	Absence of vessel(s) in visible range within the study area.
Distant	Presence of vessel(s) in the study area but further than 300 m from the focal group.
*Close**	Presence of vessel(s) within 300 m of the focal group.

**Close* corresponds to *impact* in other studies (*e.g.* Lusseau, 2003a; Stockin *et al.*, 2008a).

2.3.2.2. Theodolite protocol

A Sokkia Set 5 digital total station or theodolite (x30 telescope) was used to record dolphin positions in Akaroa Harbour. A theodolite is a surveying instrument capable of measuring simultaneously horizontal and vertical angles of a target object with great accuracy. If the height of the instrument above sea level is known, simple trigonometrical equations allow calculations of the position of a dolphin group. The precision and accuracy of position acquired via a theodolite are proportional to the instrument's elevation above sea level and inversely proportional to the distance of the target (Würsig *et al.*, 1991). This means that the further an animal is from the shore, the higher the theodolite station must be for reasonable precision and accuracy. Most stations elevations in this study were 100 m or more above sea level, reducing substantially position errors (Würsig *et al.*, 1991).

The theodolite was placed in the same position and at the same height at each station via a landmark placed on the ground for the duration of the study to further reduce errors in the accuracy of a position mentioned above. Once in place, the horizontal circle of the theodolite was orientated at the start of each survey and checked at hourly intervals (unless disturbed, *e.g.* bumped) by setting the true bearing to a reference target. Surveying landmarks of known altitude and location (*e.g.* a trig station) were used for calibration purposes. A secondary reference point (usually at a much lower altitude) was also established to calibrate observations when the primary reference point was not visible (*e.g.* due to cloud cover).

The theodolite was connected to a laptop computer operating *Cyclopes* 2004 version 3.121 software (© 2004, University of Newcastle, Australia; Fig. 2.4). This tracking software allows the real time recording of the angles (horizontal and vertical) to the target, measured from the reference point. Readings are then converted into rectangular (X, Y), easting and northing coordinates (UTM zone 59S) for the target (or fix), taking into account the instrument's position and height above sea level (including tidal fluctuations).

A designated target at sea level was fixed and checked in real time on the computer screen prior to observations commencing. This protocol ensured that every succeeding position would be recorded in the correct position. Theodolite fixes of a dolphin group were always taken at the group's estimated centre.

Certain zones of the study area were obscured from the theodolite view (Fig. 2.5). The extent of these zones was estimated by taking fixes of the edge of the land, which represented geographical positions on the water surface, delineating the unobservable area. Considering only the area within the field of view, 45.9 km^2 were effectively searched within Akaroa Harbour and its entrance.

Fig. 2.4: Theodolite connected to a laptop computer running *Cyclopes* (© 2004, University of Newcastle, Australia). Photo: A.R.E.V.A. Project 2007.

2.3.3. Data analysis

In this study, inferences about data analyses were restricted to a finite population (*i.e.* Hector's dolphins frequenting Akaroa Harbour, Le Bons Bay, or Te Oka Bay waters) with a definite sample frame (*i.e.* November to March). Within those conditions, it has been argued that sampling inference is unaffected by auto-correlation and that "classical sampling theory will perform "as advertised" (Pawley, 2006), in line with De Gruijter and ter Braak (1990). The selection of which time period as well as which station to sample was highly dependent on weather conditions are was, therefore, considered random. In an effort to ensure maximum independence of each observation, Hector's dolphin sightings with a similar group size and composition recorded within a 30 min-period and a 500 m-radius were excluded from analysis (distance was calculated using the *Cyclopes* software).

Statistical tests were performed using statistical package *Minitab* version 15 (Minitab Inc., 2007), unless otherwise stated. The distribution of continuous response variables were initially tested for normality and homoscedasticity using Anderson-Darling and Bartlett's and Levene's tests, respectively (Zar, 1996). A series of *post-hoc* (Bonferroni or Dunn's multiple comparison tests) were run when applicable. Significance was accepted at the alpha (0.05).

2.3.3.1. Sighting Per Unit Effort (SPUE)

In order to standardise unequal effort in both time and space across the different stations, the Sighting Per Unit Effort (SPUE) algorithm was used to assess Hector's dolphin presence in Akaroa Harbour. In this study, SPUE was defined as the number of Hector's dolphin sightings (whether groups or solitary individuals) per hour of active search effort. Active search effort excluded time conducting behavioural follows (Chapters IV, V). SPUE allowed comparisons between discrete spatial (*i.e.* location: stations) and temporal units (*i.e.* diel, month, and season) within the study area.

For analysis, some grouping was necessary. The harbour was divided into two sections (*middle* and *outer*; defined previously in Dawson, 1991b). The middle harbour comprised both the *inner* and *mid* sections due to a small sampling size within the *inner* harbour (mainly out of sight; Fig. 2.2). Diel patterns in SPUE were investigated by assigning each observation to a two-hour time period within the sequence 0600-0759, 0800-0959, through to 1600-1759 hr. Because the distributions of SPUE were non-normal and data transformation did not improve normality or homoscedasticity, Kruskal-Wallis tests (Zar, 1996) were used to test for differences in SPUE for the different variables.

2.3.3.2. Distribution and density patterns

Hector's dolphins exhibit a seasonal shift in distribution (*e.g.* Rayment *et al*., 2010). As a result, the monthly distribution of sightings (standardised per hour of effort) was calculated for Akaroa Harbour and plotted in relation to the areas defined as *inner*, *mid*, and *outer* sectors of the harbour (Fig. 2.2). For analysis purposes, an arbitrary line, levelled with the town of Akaroa (Fig. 2.5), was created using ArcGIS version 9.1 (© ESRI Inc.). The distance of each sighting to that line was then determined in ArcGIS, taking into consideration the station where a sighting was recorded. Non-parametric Kruskal-Wallis tests were performed to assess monthly differences in the distribution of dolphin sightings within Akaroa Harbour given that the assumptions of normality and homoscedasticity were not satisfied.

Finally, thematic maps for Akaroa Harbour were constructed in ArcGIS taking into consideration the following variables: month, behaviour, and group composition (groups containing calves only). To investigate whether the distribution of dolphin groups showed a consistent pattern in relation to these variables, sightings were overlayed with a polygon-gridded base layer, also created in ArcGIS. Each polygon measured 300 m x 300 m (or 0.09 km^2; Fig. 2.5), an area chosen to be consistent with the MMPR (1992, refer to section 2.3.2.1). The number of dolphins and/or sightings within each polygon was subsequently calculated using a function under Hawth's Analysis Tools, an extension for ArcGIS (Copyright © 2001-2010, Hawthorne L. Beyer, Spatial Ecology LLC). As search effort differed between stations, the density of dolphin sighted within each polygon was calculated as the number of sightings per hour of search effort. To determine whether or not Hector's dolphins used the study area uniformly, density maps were visually examined to identify potential core areas in dolphin distribution with respect to month, behaviour, and group composition. Pearson's χ^2 tests were applied to assess whether the proportion of sightings varied between the sectors of the harbour.

2.3.3.3. Behaviour

A series of binomial *Z*-tests for proportions (Fleiss, 1981) was run on the initial sighting dataset and 95% confidence intervals (C.I.) calculated to compare the activity patterns of Hector's dolphins between the different sites under a *control* condition as well as between *distant* and c*ontrol* conditions within Akaroa Harbour. When sampling size was too small, breaking one of the Z-test for proportions assumptions, a Fisher's Exact test was performed instead. The non-detection of a significant difference would allow pooling data together in order to increase sample size under a *control* condition.

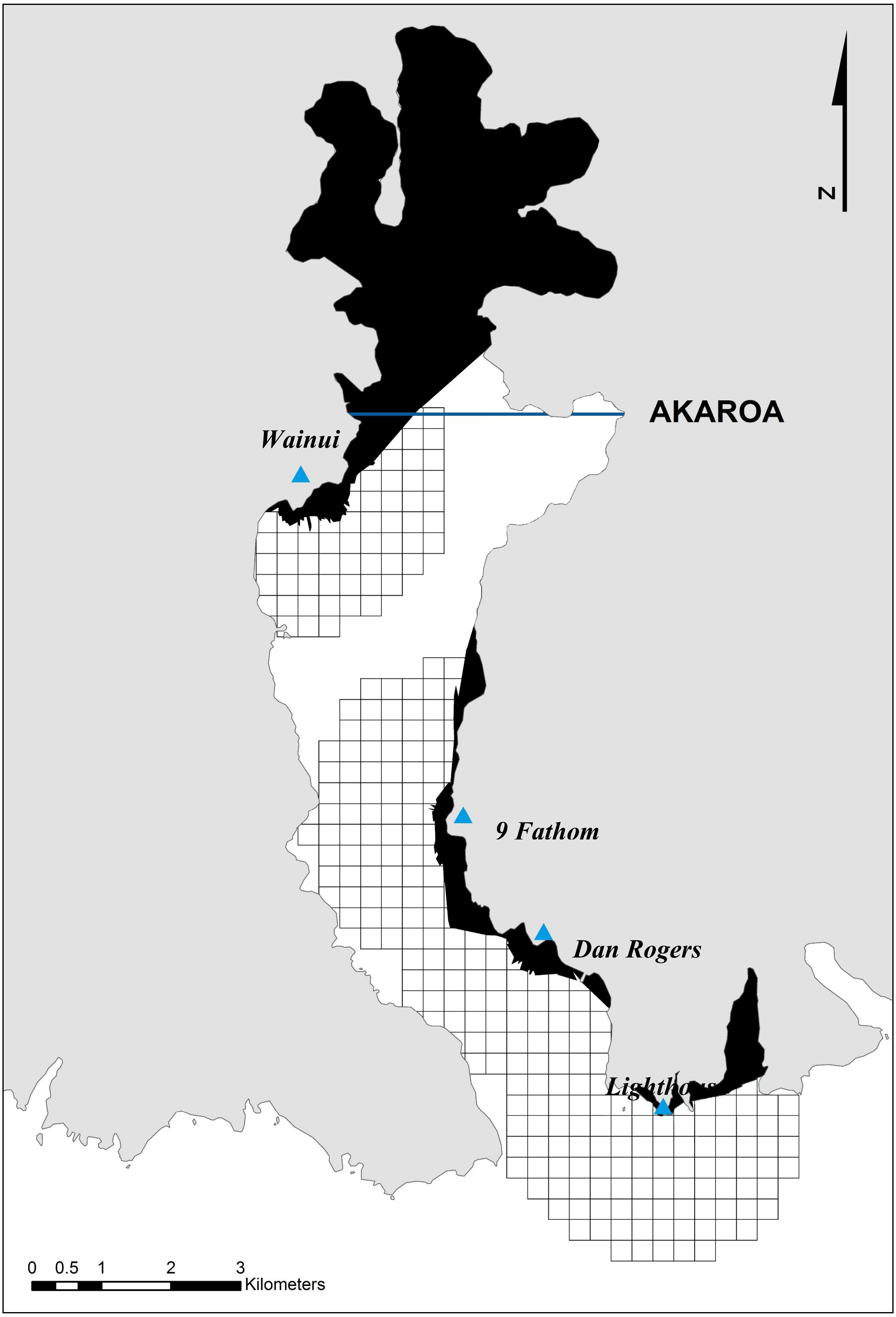


Fig. 2.5: Map of Akaroa Harbour, New Zealand, showing the grid system (within a maximum distance of 2km from each station) used to define Hector's dolphin density patterns. Each grid covers an area of $0.09 km^2$ (300m x 300m). The different land-based stations are indicated by blue triangles and the area out of view from each station is shaded in black. The blue line represents the arbitrary reference line created with ArcGIS (© ESRI) used for analyses.

2.3.3.4. Group size and composition

Data satisfied both the assumption of normality and homoscedasticity. As a result, a series of one-way ANOVAs was run to evaluate a relationship between group size and the following variables: location (Akaroa Harbour, Te Oka Bay, and Le Bons Bay), behaviour, and group composition (*adults*, *mixed*, *nursery* groups). *Post-hoc* testing was performed using Tukey's HSD test.

Group size was also categorised into four different classes of 1, 2-5, 6-10 and > 10 individuals (*i.e.* solitary individuals, small, medium, and large groups, respectively). To assess whether differences existed across the three different locations, Z-test of proportions were used (Fleiss, 1981).

When investigating group composition across the different locations, differences in the proportion of *adults*, *mixed*, and groups containing *mother-calf* pair(s), were tested using Z-test for proportions. Particular attention was given to single *mother-calf* pairs, *nursery*, and *mixed* groups within Akaroa Harbour to detect monthly trends, which were tested using a Pearson's χ^2 tests. Finally, the percentage of multiple *mother-calf* pairs within a *nursery* groups was also determined.

2.4. Results

2.4.1. Effort

Land-based surveys were conducted over a total of 225 days from 0600 to 1800 hr. Uncontrollable circumstances, primarily weather conditions, resulted in unequal effort between seasons and the different land-based platforms (Table 2.3). Between the three locations, a total of 3,950 independent groups were observed and 3,133 positions recorded. Dolphins were sighted within Akaroa Harbour, Le Bons Bay, and Te Oka Bay over 37.8%, 59.6%, and 50.1% of field effort, respectively. Hector's dolphins were always present at both Le Bons Bay and Te Oka Bay, while absence of sightings from the different Akaroa Harbour stations accounted for 13.3% of the total field observations (Table 2.3). During 95.5% of these cases, dolphin groups were not observed from *Wainui* or *9 Fathom* stations (Fig. 2.2), mainly during the months of November or March.

Table 2.3: Summary of effort and data collected across all field seasons at three different locations around Banks Peninsula, New Zealand, between November 2005 and March 2008.

	2005/2006	2006/2007	2007/2008	Total
Akaroa Harbour				
Number of days in the field	56	52	58	*166*
Number of hours of observation	244.9	182.7	204.1	*631.7*
% of time dolphins observed	30.1	44.5	38.9	*37.8*
Number of days dolphins absent	11	8	3	*22*
Total number of group sighted	772	953	910	*2635*
Total number of positions taken	503	736	813	*2052*
*Le Bons Bay***				
Number of days in the field	n/a	16	5	*21*
Number of hours of observation	n/a	51.4	27.0	*78.4*
% of time dolphins observed	n/a	59.5	59.6	*59.6*
Number of days dolphins absent	n/a	0	0	*0*
Total number of group sighted	n/a	321	213	*534*
Total number of positions taken	n/a	238	212	*450*
*Te Oka Bay**				
Number of days in the field	6	15	17	*38*
Number of hours of observation	34.0	64.4	62.0	*160.4*
% of time dolphins observed	33.0	61.2	56.0	*50.1*
Number of days dolphins absent	0	0	0	*0*
Total number of group sighted	103	278	400	*781*
Total number of positions taken	103	205	323	*631*

Observations were started in November 2006 (*) and in January 2006 (**)

2.4.2. SPUE

The sighting rate of Hector's dolphins groups per unit effort or SPUE in Akaroa Harbour varied significantly with location (Table 2.4). Sightings were significantly lower in the middle (*inner* and *mid* sections together) than the *outer* sector of the harbour (Mann-Whitney *U*: W = 28,369.0, $p < 0.0001$). When considering each station independently (Fig. 2.2), SPUE increased significantly as land observations were made closer to the harbour entrance (Table 2.7; Kruskal-Wallis: $H_3 = 134.69$, $p < 0.0001$). *Post-hoc* analysis revealed sighting rates at *Wainui* to be significantly lower than all other stations (Dunn's multiple comparison test: $p < 0.001$). SPUE at *9 Fathom* was also significantly lower than at both *Dan Rogers* ($p < 0.05$) and *Lighthouse* ($p < 0.001$).

Significant diel ($H_5 = 15.394$, $p = 0.009$; Table 2.4) and monthly ($H_4 = 54.141$, $p < 0.0001$) variations in SPUE were also detected. *Post-hoc* analysis indicated that sighting rates were significantly lower in November than in both December and January ($p < 0.001$), while in January SPUE was significantly higher than in November, February, and March ($p < 0.001$). Sightings in late afternoon (1600-

1759 hr) were also significantly lower ($p < 0.05$) than in late morning (1000-1159 hr). SPUE varied significantly between field seasons, with less dolphins observed within the harbour in 2005/2006 ($H_3 = 14.885$, $p = 0.0006$). *Post-hoc* analysis indicated that SPUE in that season was significantly lower than in other field seasons ($p < 0.01$). Overall, Hector's dolphin groups were more likely to be observed in the last two years of the field study, within the *outer* harbour region, especially in January and prior to midday.

Table 2.4: Summary of sighting rates (SPUE) for Hector's dolphins from the four stations in Akaroa Harbour, New Zealand. Note: S.E. = standard error of the mean.

Variable	Mean	Median	S.E.	Range	n
Stations					
Wainui	1.642	0.000	0.289	0 - 26.7	192
9 Fathom	5.002	1.800	0.632	0 - 46.7	159
Dan Rogers	5.355	3.450	0.581	0 - 55.0	130
Lighthouse	7.353	4.550	0.675	0 - 55.4	162
Harbour					
Middle	3.164	0.000	0.337	0 - 46.7	351
Outer	6.463	4.000	0.458	0 - 55.4	292
Time of day					
0600-0759	5.127	2.000	0.818	0 - 46.7	105
0800-0959	5.110	3.000	0.576	0 - 26.7	126
1000-1159	5.771	3.000	0.701	0 - 55.0	127
1200-1359	5.171	1.500	0.820	0 - 55.4	117
1400-1559	3.122	1.400	0.520	0 - 36.0	97
1600-1759	2.469	1.000	0.410	0 - 14.0	71
Month					
November	2.494	0.000	0.394	0 - 25.7	122
December	4.670	3.000	0.502	0 - 30.0	133
January	7.622	4.500	0.797	0 - 55.4	133
February	3.698	2.000	0.609	0 - 55.0	126
March	4.595	1.000	0.700	0 - 36.9	129
Season					
2005-2006	3.281	1.300	0.356	0 - 46.7	247
2006-2007	5.252	2.400	0.560	0 - 55.4	186
2007-2008	5.764	3.000	0.573	0 - 55.0	210

2.4.3. Distribution and density patterns in Akaroa Harbour

2.4.3.1. Potential bias associated with land-based observations

There is a potential bias associated with land-based observations. Sightings are more likely to be made when dolphin groups are closer to a theodolite station. Consequently, prior to plotting and mapping Hector's dolphin's sightings using ArcGIS version 9.1 (© ESRI Inc.), the distribution of dolphin group positions (or fixes) within 500 m distance intervals relative to the actual theodolite location was calculated (Fig. 2.6).

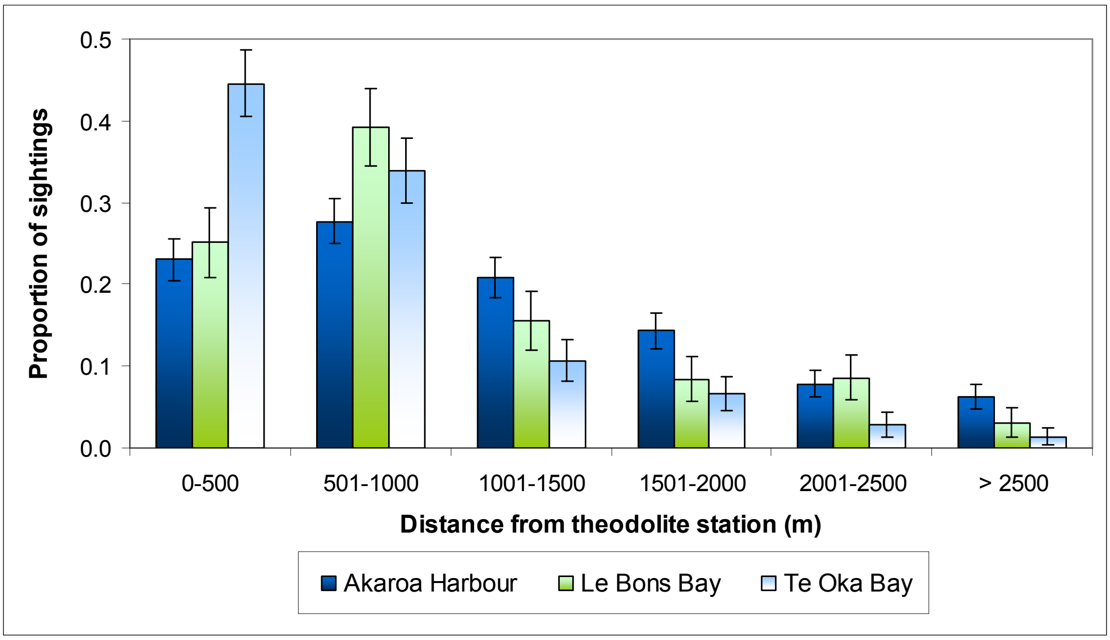


Fig. 2.6: Proportion of Hector's dolphin sightings according to distance (m) from theodolite land-based stations for three locations around Banks Peninsula, New Zealand. Bars represent the 95% confidence intervals.

The frequency distribution of these fixes was not uniformly distributed across distances (Pearson's χ^2 test: $\chi^2_5 = 242.3$, $p < 0.0001$). Most of the association was due to dolphin groups being sighted more than expected from short distances (zero to 1,000 m) and less than expected at distances beyond 2,000 m, as indicated by the Freeman-Tukey deviates. As a consequence, only sightings recorded within 2,000 m of a station were taken into account for analysis purposes. This reduced the area effectively searched by *ca.* 50%, down to 26.3 km^2.

2.4.3.2. Distribution of sightings

Hector's dolphins were present in the harbour during the entire study period, *i.e.* between November and March. The number of sightings standardised per effort (here hours) in the *outer* harbour were high for the duration of the study with an average of more than five sightings per hour, except in November (Fig. 2.7). The inshore movement exhibited by Hector's dolphins during the austral summer months was most apparent in the *inner* harbour, and less so in the middle harbour, where dolphins were only primarily sighted in January but less frequently than the rest of the harbour (Fig. 2.7).

2.4.3.3. Mean distance of sightings

The monthly mean distance of sightings to an arbitrary line levelled with Akaroa township (Fig. 2.5) revealed that, for most stations, sightings occurred further inside the harbour between January and February (Fig. 2.8). No difference was evident from the *Lighthouse* station (Kruskal-Wallis: $H_4 = 5.787$, $p = 0.216$). Trends observed at *9 Fathom* were marginally insignificant ($H_4 = 9.124$, $p = 0.058$). However, the distance to dolphin groups recorded from the other two stations situated within the harbour varied significantly between months at *Dan Rogers* ($H_4 = 13.441$, $p = 0.009$; Fig. 2.8) and *Wainui* ($H_4 = 9.589$, $p = 0.022$). *Post-hoc* tests indicated that on average most dolphin groups from *Dan Rogers* sighted over January were significantly closer to Akaroa (*i.e.* located further within the harbour), than in November (Dunn's multiple comparison test: $p < 0.01$). No significant differences among months were detected at *Wainui* ($p > 0.05$).

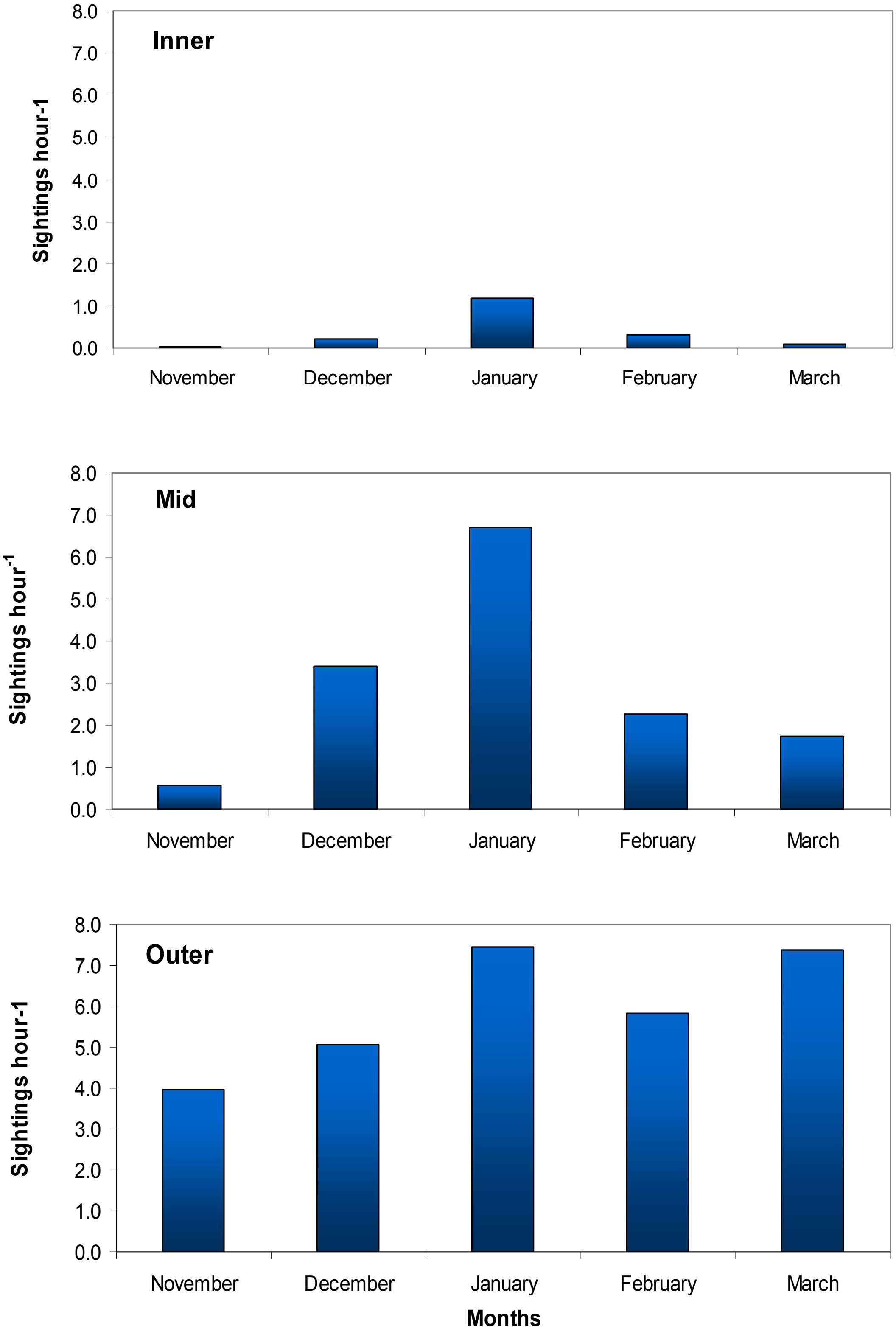


Fig. 2.7: Changes in the distribution of Hector's dolphin sightings within three defined areas in Akaroa Harbour, New Zealand (*inner*, *mid*, and *outer* harbour). Histograms give the monthly frequency of the number of sightings hour^{-1}.

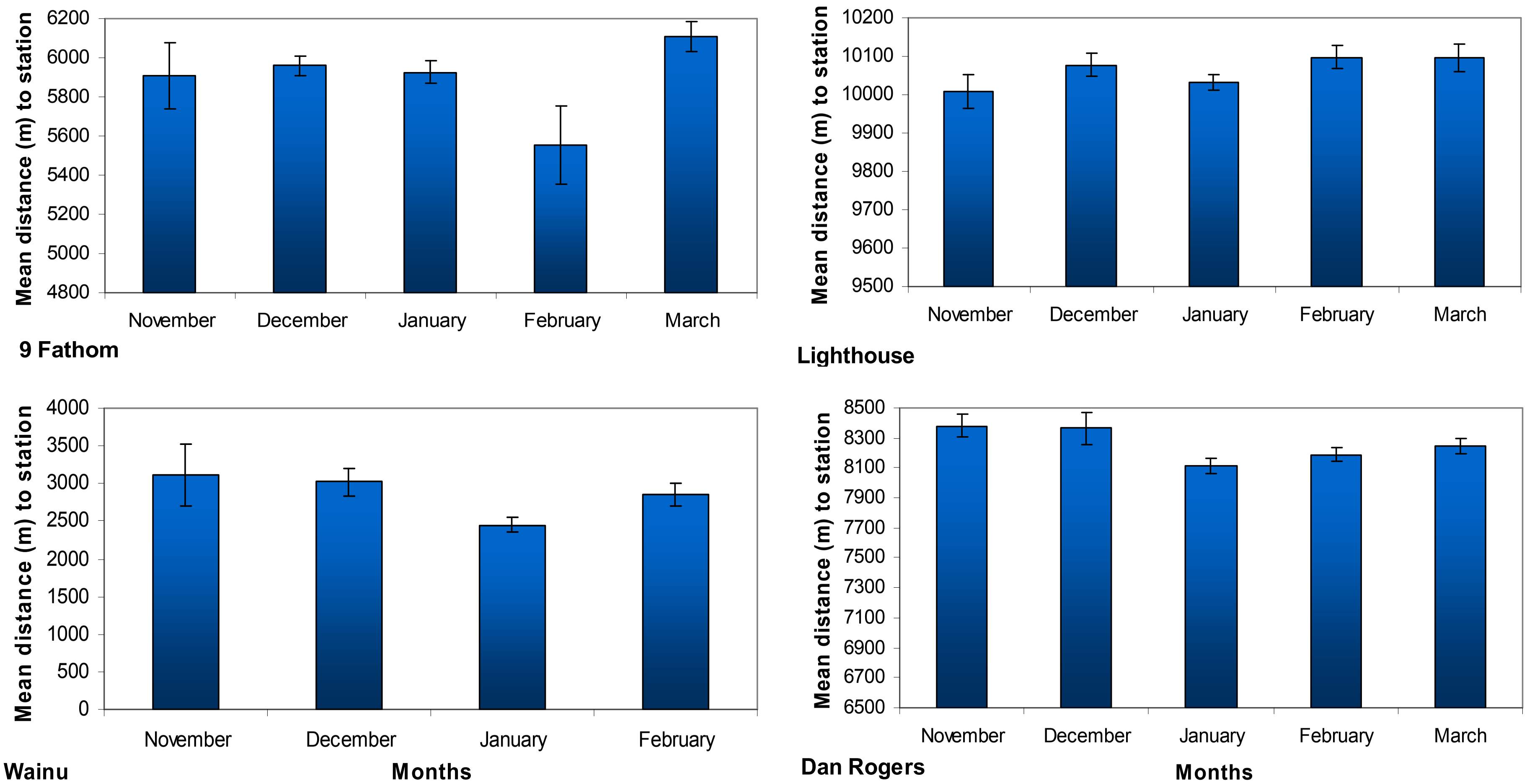


Fig. 2.8: Mean distance of Hector’s dolphin sightings recorded each month from the four different stations in Akaroa Harbour, New Zealand. Bars represent standard error. Note: only three sightings were recorded in *Wainui* in March and were, therefore, not included due to small sample size. For clarity purposes, the y axis was scaled according to the distance observable at each of the four stations from Akaroa township.

2.4.3.4. Density patterns

Monthly density patterns

The monthly use of Akaroa Harbour by Hector's dolphins was not visually uniform. Density patterns clearly indicated an inshore movement of dolphins, peaking in January (Fig. 2.9). In November and March, most sightings were recorded in the *outer* sector of the harbour, while between December and February, dolphin groups were found further inside (Fig. 2.9). Hector's dolphins used most of the harbour in January, being observed within 42.5% of the total study area. This was confirmed by the monthly distribution of sightings within the three sectors of the harbour, which differed significantly (Pearson's χ^2 test: $\chi^2_{15} = 62.298$, $p < 0.0001$). In November and March, sightings occurred less in the *inner* harbour (Freeman-Tukey deviates < -1), but more than expected in the *inner* harbour during January, *mid* harbour in December, and *outer* sector during February (Freeman-Tukey deviates > 1). Sectors of the harbour close to *Dan Rogers* and *Lighthouse* stations indicated high dolphin density areas across all five months (Fig. 2.9). Other high density zones included sections of the harbour close to *9 Fathom* station, principally in December, as well as around *Wainui* station in January (Fig. 2.9).

Behavioural density patterns

Regardless of behaviour, Hector's dolphin groups did not use the harbour uniformly. Travelling was the most widespread (50.3% of the total study area) behavioural state. Diving and milling were observed in 38.4% and 33.2% of the total study area, respectively. In contrast, the distribution of socialising groups was the patchiest (Fig. 2.10), recorded in all three sectors of the harbour, but observed in only 13.4% of the study area. In addition, the distribution of dolphin groups within the *inner*, *mid*, and *outer* harbour varied significantly (Pearson's χ^2 test: $\chi^2_{12} = 50.182$, $p < 0.0001$), with socialising occurring more than expected within the *inner* harbour (Freeman-Tukey deviates > 1). Both socialising and milling groups were also recorded more in the *mid* and less in the *outer* harbour (Freeman-Tukey deviates > 1 and < -1, respectively), while the opposite trend applied to travelling. Finally, except for socialising, all other behaviours exhibited many high density areas around the four stations (Fig. 2.10). However, none were specific to a particular behaviour.

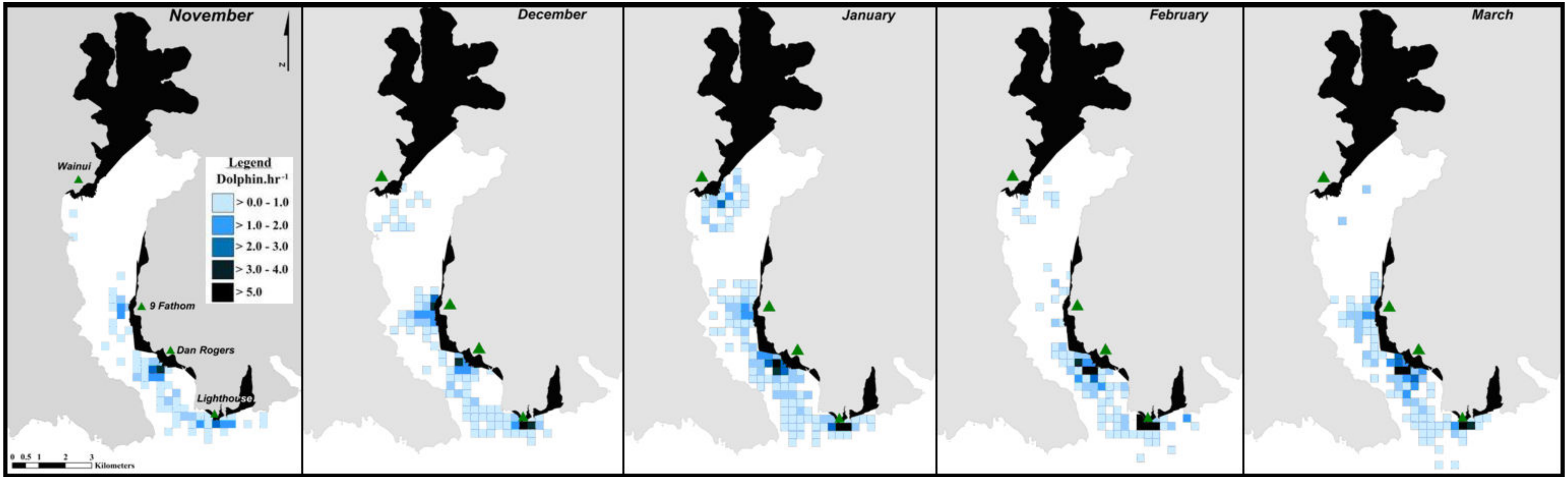


Fig. 2.9: Monthly density patterns of Hector's dolphin sightings in Akaroa Harbour, New Zealand. The colour of each quadrat varied according to the number of dolphins standardised for effort. The four land-based stations are symbolised by green triangles.

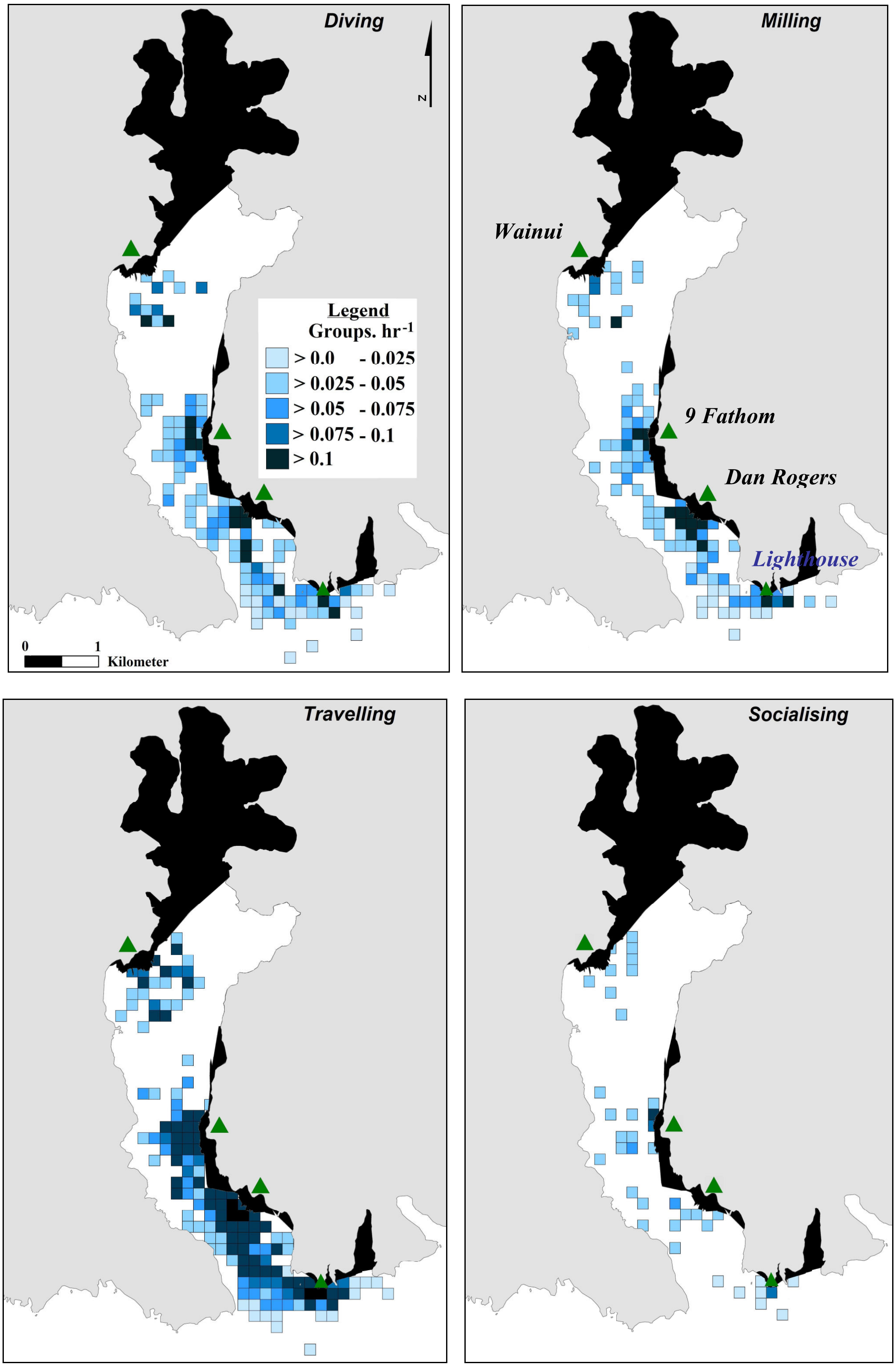


Fig. 2.10: Density patterns of Hector's dolphin sightings for each behavioural activity in Akaroa Harbour, New Zealand. The colour of each quadrat varied according to the number of groups sighted, standardised for effort. The four land-based stations are symbolised by green triangles.

Mother and calves

Mother and calves represented 12.1% of the total number of sightings recorded. They did not use Akaroa Harbour uniformly (Fig. 2.11), whether in *nursery* or *mixed* groups. They were observed in only 13.7% and 14.0% of the study area, respectively. Density patterns (Fig. 2.11) indicated a possible tendency of pairs to favour the *outer* sector of Akaroa Harbour, where 83.2% of mother and calves pairs were sighted. This preference was confirmed when compared to the distribution of *adult* only groups (Pearson's χ^2 test: χ^2_6 = 6.654, p = 0.036). Groups containing calves occurred less than expected in the *mid* harbour but more in the *outer* section in relation to adult only distribution, as indicated by Freeman-Tukey deviates. The number of groups containing calves was also very low north of *9 Fathom* station. It is worth noting that part of the *mid* harbour was not covered because of the 2,000 m cut off for analysis. Finally, density patterns indicated that the distribution of *nursery* (whether single or multiple mother-calf pairs) and *mixed* groups was analogous within the harbour (Fig. 2.11). No difference was detected in the number of pairs sighted between group types in the *mid* and *outer* harbour (χ^2_6 = 2.571, p = 0.277).

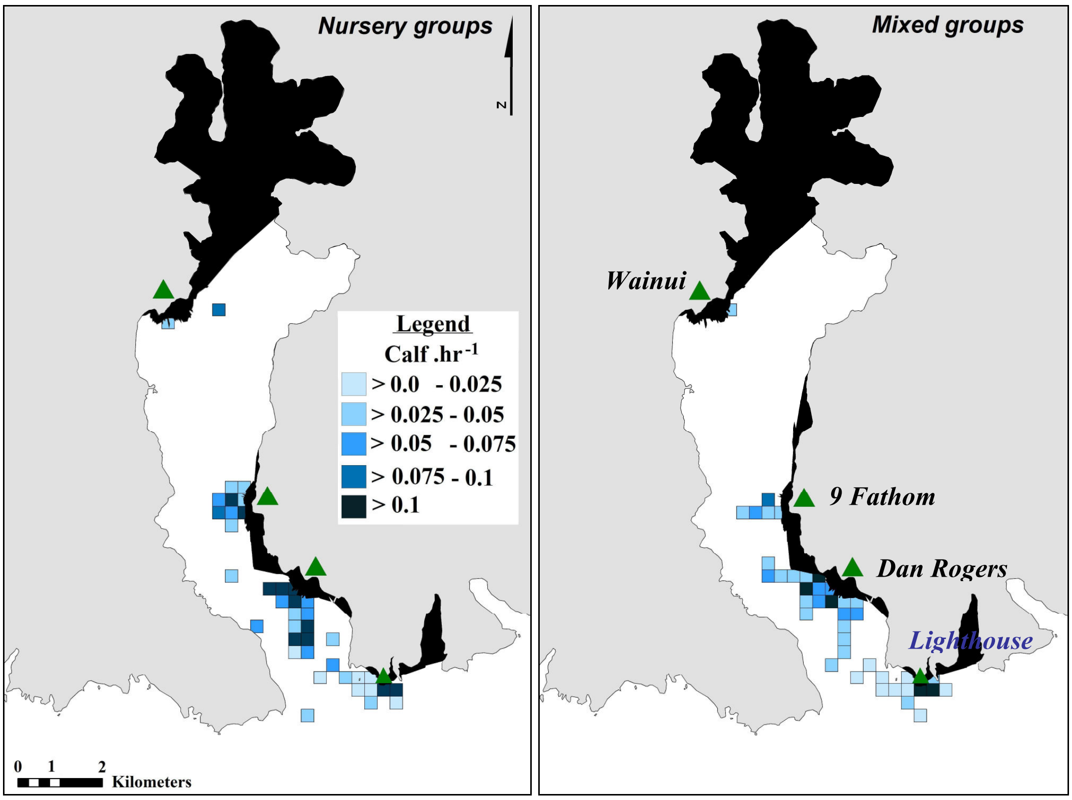


Fig. 2.11: Density patterns for *nursery* (here single pairs and multiple mother-calf pairs) and *mixed* groups of Hector's dolphins in Akaroa Harbour, New Zealand. The colour of each quadrat varied according to the number of mother-calf pair(s) sighted, standardised per effort. The four land-based stations are symbolised by green triangles.

2.4.4. Behaviour

2.4.4.1. Activity budget at Te Oka Bay, Le Bons Bay, and Akaroa Harbour

When comparing the activity budget of Hector's dolphins between locations, no significant difference was detected (*Z*-tests of proportions: $p > 0.05$), with the exception of socialising (Fig. 2.12). While no significant difference was detected between Le Bons Bay and Te Oka Bay ($z = 1.04$, $p = 0.300$, 95% C.I.: 1.3 - 4.3%), dolphins were observed socialising significantly less in Akaroa Harbour than at both Le Bons Bay (Fisher's Exact test: $\chi^2 = 13.33$, $p < 0.0001$, 95% C.I.: 2.2% - 38.9%) and Te Oka Bay (Fisher's Exact test: $\chi^2 = 18.25$, $p < 0.0001$, 95% C.I.: 2.8 % - 46.8%). Consequently, behavioural data could not be pooled for *control* data across sites to increase sampling size.

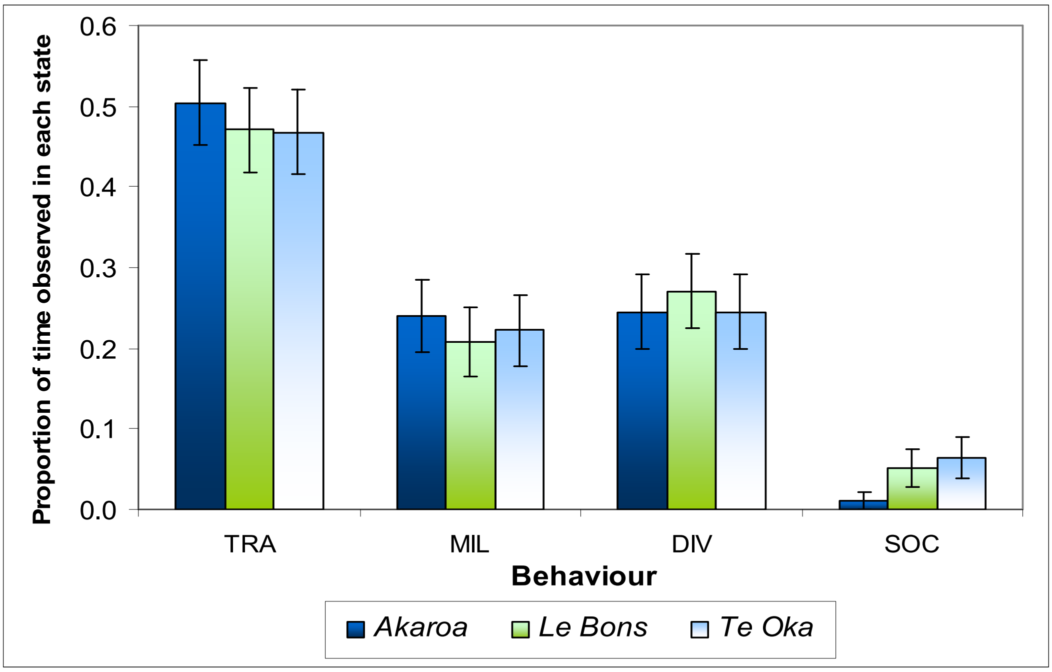


Fig. 2.12: A comparison of activity budget for Hector's dolphin groups at three different locations around Banks Peninsula, New Zealand, in the absence of vessels (*Control*). Behaviour assessed as the state observed at each initial sighting. Bars represent 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising.

2.4.4.2. Activity budget at Akaroa Harbour

Hector's dolphins in Akaroa Harbour were observed 13.8% and 51% under *control* and *distant* conditions, respectively. Under *distant* conditions, dolphins spent more time socialising than travelling and diving than compared to in *control* observations (Fig. 2.13). However, these differences were not significant (Z-tests of proportions: $p > 0.05$), except for socialising, which was observed significantly more often under a *distant* condition (Fisher's Exact test: $\chi^2 = 9.18$, $p < 0.004$, 95% C.I.: 1.6 % - 16.3%).

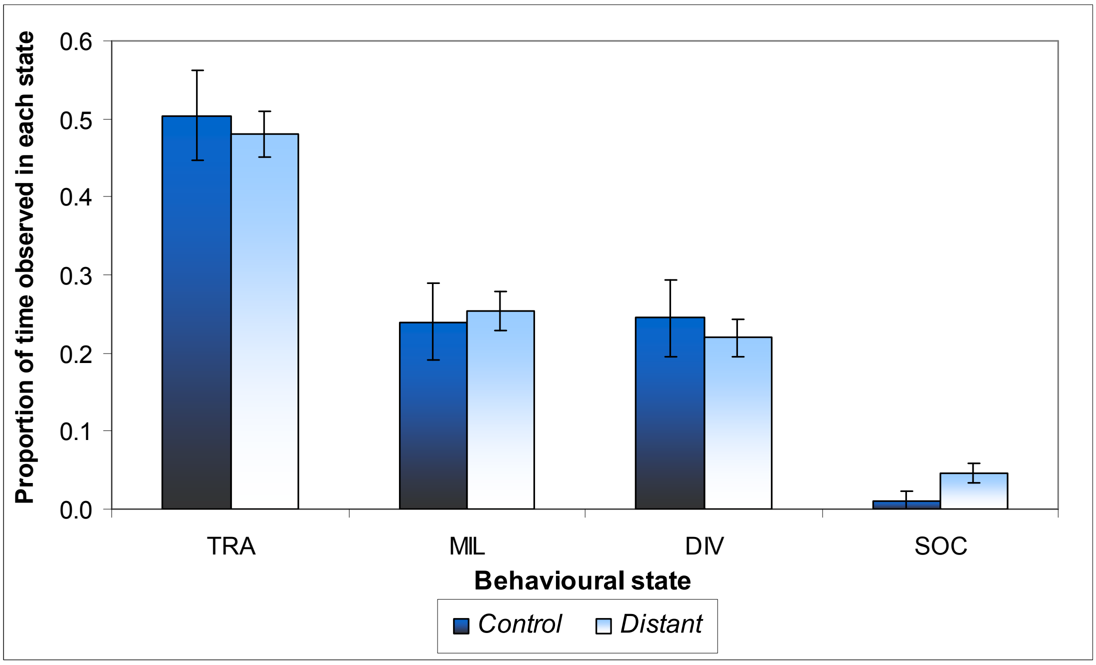


Fig. 2.13: A comparison of activity budget for Hector's dolphin groups in the absence (*control*) and non-interacting presence of vessels (*distant*) in Akaroa Harbour, New Zealand. Behaviour was assessed as the state observed at each initial sighting. Bars represent 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising.

2.4.5. Group size and composition

2.4.5.1. Group size

Group size varied significantly between locations (ANOVA: $F_2 = 61.802$, $p < 0.0001$), with the largest groups recorded in Akaroa Harbour (Table 2.5). Disparity in group size classes were also detected between Akaroa Harbour, Le Bons Bay, and Te Oka Bay. In all three locations, Hector's dolphins were predominantly observed in groups of two to five individuals (Table 2.5). However, larger groups (six or more dolphins) were significantly less frequent in both Le Bons Bay (*Z*-test for proportions: $z = -3.89$, $p = 0.001$) and Te Oka Bay ($z = -8.68$, $p < 0.0001$) than in Akaroa Harbour. Furthermore, singletons represented a significantly larger proportion in Te Oka Bay than in Akaroa Harbour ($z = 7.56$, $p < 0.0001$). Consequently, data could not be pooled and group size was only analysed for Akaroa Harbour.

Table 2.5: Summary of mean group size and group classes for Hector's dolphins at three different locations around Banks Peninsula, New Zealand. Note: S.E. = standard error of the mean.

		Group	*Size*			*Group*	*Classes (%)*
Location	**Mean**	**S.E.**	**Range**	**n**	**Singletons**	**2-5 individuals**	**≥ 6 individuals**
Akaroa Harbour	3.2	0.038	01 - 21	2,403	7.3	83.2	9.5
Le Bons Bay	2.8	0.057	01 - 09	529	8.7	86.2	5.1
Te Oka Bay	2.5	0.044	01 - 11	722	19.0	78.7	2.3

Group size varied significantly according to behaviour (ANOVA: $F_3 = 11.01$, $p < 0.0001$). *Post-hoc* Tukey's HSD tests indicated that socialising groups were significantly larger than groups engaged in diving ($p = 0.0004$), travelling ($p < 0.0001$), and milling ($p = 0.026$). Both diving and travelling groups were also significantly smaller than milling groups ($p = 0.0004$ and $p = 0.027$, respectively).

Group composition also significantly affected group size (ANOVA: $F_2 = 114.47$, $p < 0.0001$; Table 2.6), with *mixed* groups significantly larger than groups comprised of either *adults* only or *nursery* groups/single *mother-calf* pairs (Tukey's HSD tests: $p < 0.0001$).

Table 2.6: Variance in Hector's dolphin group sizes observed within Akaroa Harbour, New Zealand. Note: S.E. = standard error of the mean.

Variable	**Mean**	**Median**	**S.E.**	**Range**	**n**
Behaviour					
Diving	2.9	3	0.075	1 - 11	408
Milling	3.5	3	0.093	1 - 20	453
Socialising	4.1	4	0.209	1 - 11	93
Travelling	3.2	3	0.052	1 - 21	1,323
Group composition					
Adults	3.1	3	0.036	1 - 20	2,214
Mixed	5.9	5	0.315	3 - 21	101
Mother-calf/nursery	3.3	2	0.196	2 - 10	88
All groups with calves	4.7	4	0.212	2 - 21	189

2.4.5.2. Group composition

No differences across years were detected ($p > 0.05$) allowing datasets to be pooled at each location. The large majority of groups observed (92.1%) were composed of *adults* only (n = 2,214). *Mixed* groups represented a further 4.2% (n = 101) of the sightings and single *mother-calf* pairs as well as *nursery* groups the remaining 3.7% (n = 88). The proportion of groups with mother and calves was similar between Akaroa Harbour and

Le Bons Bay (4.5%, n = 24, z = -0.89, p = 0.373). However, in Te Oka Bay, this proportion was twice as high (7.3%), differing significantly between sites (n = 53, z = -3.53, p < 0.0001). Due to these differences, group composition data were not pooled across the three locations.

Mother and calves in Akaroa Harbour

The first calf was observed in November (19/11/05, 05/11/06, and 28/11/07) in all three sampling seasons. The proportion of groups comprising of at least one calf increased with time, peaking in January (Fig. 2.14).

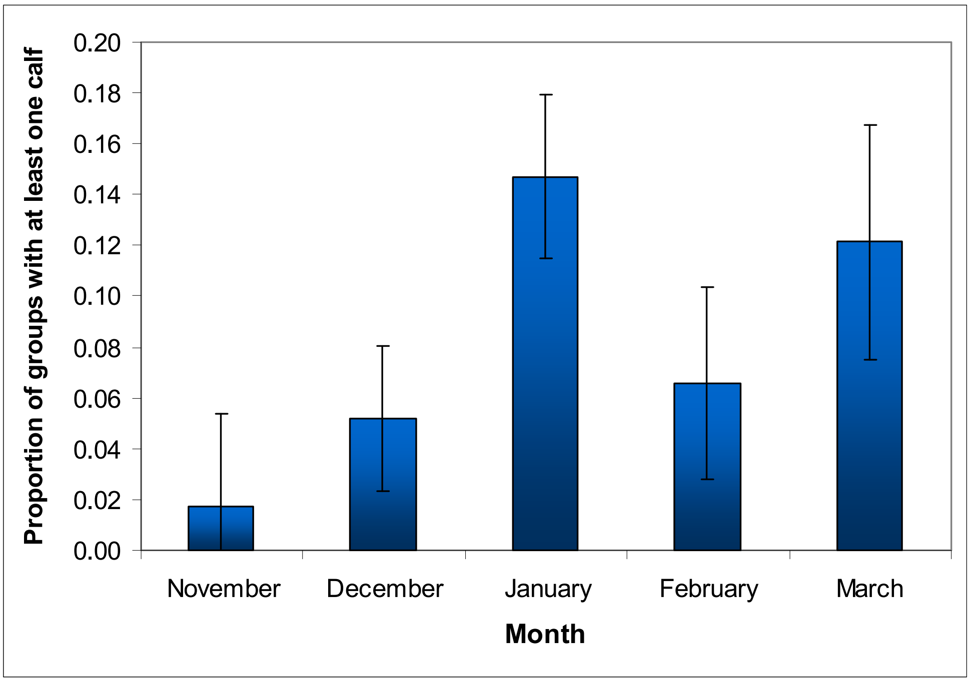


Fig. 2.14: Proportions of Hector's dolphin groups with at least one calf present in Akaroa Harbour, New Zealand. Bars represent the 95% confidence intervals.

With the exception of November, the ratio of single *mother-calf* pairs, *nursery*, and *mixed* groups was very similar (Fig. 2.15). From December to March, approximately 50% of calves were sighted within *mixed* groups and a lower proportion as single *mother-calf* pairs (*ca.* 20%) (Fig. 2.15). The lower proportion of *nursery* groups observed in December was not significant (Pearson's χ^2 test: χ^2_{12} = 2.563, p = 0.861). *Nursery* groups contained between two and five pairs, with two pairs forming the large majority (66%, n = 24; Fig. 2.16). *Nursery* groups of four mother-calf pairs were not observed in this study.

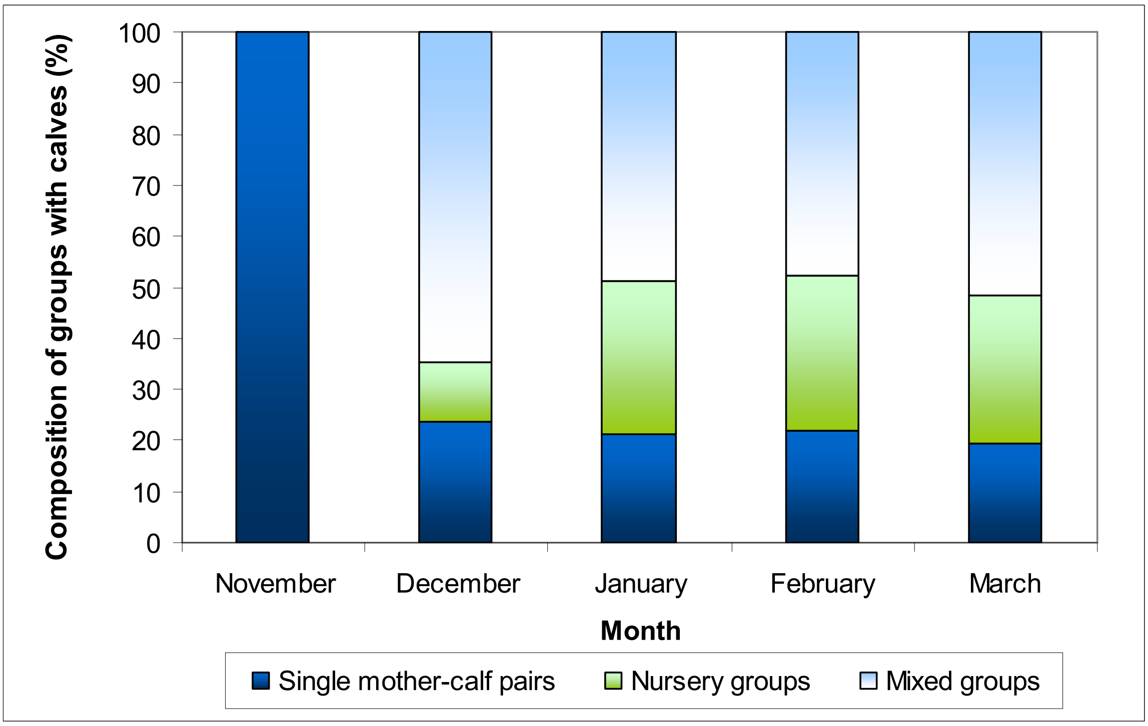


Fig. 2.15: Composition of Hector's dolphin groups encountered in Akaroa Harbour, New Zealand, by month showing the percentage of the different group types containing mothers and calves.

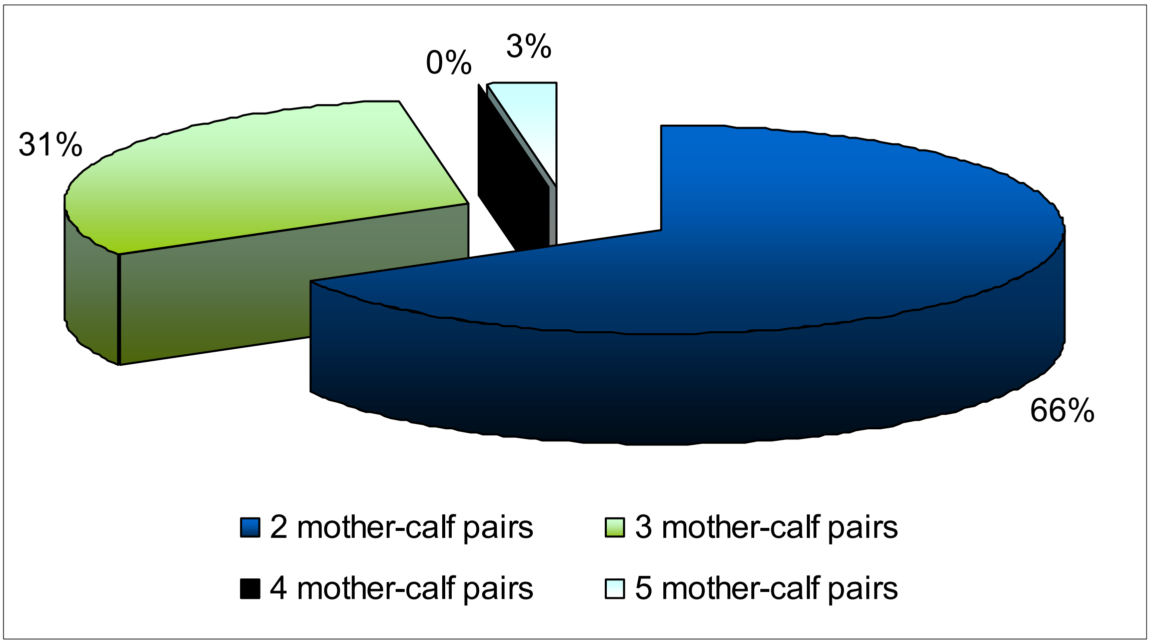


Fig. 2.16: Percentage of multiple Hector's dolphin mother-calf pairs within *nursery* groups in Akaroa Harbour, New Zealand. Note: Groups consisting of four mother-calf pairs as well as groups of more than five mother-calf pairs were not observed in Akaroa Harbour.

2.5. Discussion

This study presents baseline (*control*) data describing Hector's dolphin sightings, activity budget, and fine-scale density patterns within Akaroa Harbour. Although no baseline data were collected prior to the establishment of a local tourism industry, *control* data (collected in the absence of vessels) will facilitate the detection of any short-term effects of human activities from dolphin-watching and/or swimming trips (Chapters IV and V).

Density patterns

Despite the known distance bias associated with shore-based observations, density patterns determined in this study were consistent with Clement (2005). Several hotspots were identified in Akaroa Harbour, including the area between the Kaik Hill and the Akaroa Harbour entrance along the eastern side. It appears Hector's dolphins exhibit a non homogenous fine-scale distribution pattern.

Most studies on coastal delphinid species suggest that patterns in habitat selections occur primarily as a function of distribution, movement, and abundance of their prey species and secondly, to refuges from predators (Stevick *et al*., 2002). A patchy distribution was detected for all behaviours, although no specific area associated with a particular behaviour was apparent. Travelling, the most frequently observed behaviour (60%), occurred over a larger area within the harbour. A similar pattern was described by Ribeiro *et al*. (2007) for the Chilean dolphin (*Cephalorhynchus eutropia*). These authors suggest that travelling could represent a route between food patches. This could also be the case in Akaroa Harbour because the majority of high density patches overlapped between diving, travelling, and milling. In cetaceans, an association between travelling and foraging has been also widely reported, with animal groups moving rapidly over areas poor in resources and staying longer in rich feeding grounds (Karczmarski *et al*., 2000). Stevick *et al*. (2002) further argued that the greater the level of food predictability, the more evident will be the movement pattern.

On a temporal scale, Hector's dolphins exhibit an inshore movement over the austral summer (Baker, 1978; Cawthorn, 1988; Dawson and Slooten, 1988; Bräger and Schneider, 1998; Bejder and Dawson, 2001; Green, 2003; Martinez, 2003; Clement, 2005; Slooten *et al*., 2006a; Rayment *et al*., 2010), a pattern also confirmed by fine-scale density patterns in this study. In January, Hector's dolphins were found to be the furthest inside the harbour (*i.e.* the *inner* and upper *mid* sectors), which is consistent with Dawson (1991b).

Monthly density patterns further corroborated the preference of Hector's dolphins for a zone between the Kaik Hill and the harbour entrance along the eastern side (Clement, 2005). The low usage within the vicinity of *9 Fathom* station in February could be an artefact of sampling. A high number of dolphin groups were sighted while interacting with vessels and were not taken into consideration in the present analysis, *i.e. close* condition (Chapter III). The reason as to why Hector's dolphins might prefer certain areas was however, beyond the scope of this study.

SPUE

Trends in SPUE were consistent with fine-scale density patterns. The inshore movement of Hector's dolphins coincided with a peak in SPUE in January. This pattern also explains a higher SPUE for the *outer* harbour between November and March, particularly from the *Lighthouse* station located at the harbour entrance.

According to previous research, Hector's dolphins do not move randomly within Akaroa Harbour, but instead exhibit a diurnal movement (Stone *et al*., 1995). This pattern was also observed using satellite-tagged individuals around Banks Peninsula (Stone *et al*., 2005). If dolphins tend to move inshore in the morning and offshore after midday, this could also explain why SPUE was high within the harbour until 1200 hr and decreased throughout the afternoon. Heaviside's dolphins (*C. heavisidii*) in South Africa also display diurnal use of inshore waters, with the number of individuals observed greatly reduced after noon (Elwen *et al*., 2009).

Behaviour

The understanding of spatial and temporal fluctuations in behaviour is necessary to appreciate how a population uses its environment and, moreover, how to effectively manage that population (Stockin *et al*., 2009a). The proportion of time Hector's dolphins spent diving (foraging in other studies) in Akaroa Harbour was similar to both Le Bons Bay and Te Oka Bay, *i.e.* between 20% and 25%. This suggests that around Banks Peninsula a quarter of the dolphin daily activity needs to be allocated to diving to obtain the necessary energy requirements. Any diversion of time and energy away from resource acquisition such as foraging opportunities could, therefore, potentially result in a substantial decrease in energy intake, which may have significant biological consequences (*e.g.* Boggs, 1992; Williams *et al*., 2006; Lusseau and Bejder, 2007).

When considering the other behaviours, the baseline activity budget of Hector's dolphins in the harbour was remarkably analogous to the other two sites. The only exception was socialising, which was significantly lower in Akaroa Harbour. Generally, the activity budgets of Hector's dolphins in Akaroa Harbour and Porpoise Bay, Southland (Green, 2003), do not concur with each other nor with other species in the *Cephalorhynchus* genus. In Porpoise Bay, dolphins spent the majority of their time diving (70%), following by milling (15%), socialising (10%), and travelling (5%). Chilean dolphins in Yalda Bay, Chile, were most frequently observed (53.4%) in food-related behavioural activities (foraging and feeding), followed by travelling (34.1%), resting (6.7%), and socialising (5.8%) (Ribeiro *et al*., 2007). While Commerson's dolphins (*C. commersonii*) in Bahía Engaño, Argentina (an open-water area near Golfo Nuevo), spent 37% of their time travelling, 30% resting, and approximately 23% feeding (Coscarella *et al*., 2010). These differences are likely related to the habitat characteristics and prey availability at each location, although may also be an artefact of differences in data collection between the studies. These inter- and intra-species differences emphasise the importance of gathering baseline data at a population level to avoid making inappropriate generalisation within and across species.

Group size and group class

Group size is a major component of social organisation and probably the most often examined. Several studies suggest that the size and composition of a group in small delphinids may be related to strong ecological factors such as the physical characteristics of the habitat, predation, prey availability, and social-environmental aspects of the populations (*e.g.* Norris and Dohl, 1980; Würsig and Würsig, 1980; Shane *et al.*, 1986; Baird and Dill, 1996; Connor *et al*., 2000a; Gygax, 2002; Gowans *et al*., 2007). Coastal species generally form groups of fifty or fewer individuals (Wells *et al.*, 1980). In contrast, species living offshore and in open waters typically form much larger aggregations because prey distribution and availability are more scattered and less predictable (Connor *et al*., 2000a).

Hector's dolphin groups are usually small (Dawson and Slooten, 1988). In Akaroa Harbour, the mean group size was 3.2 (S.E. = 0.004) individuals, which is in line with previous research in the same location (Stone *et al*., 1995; Dawson *et al*., 2000). Despite subtle variations between the three sites around Banks Peninsula, group size, range, and group class were consistent with other locations in New Zealand (*e.g.* Baker, 1978; Bejder and Dawson, 2001; Green, 2003; Martinez, 2003) as well as other coastal species within the *Cephalorhynchus* genus (*e.g.* Mermoz, 1980; Leatherwood *et al*., 1988; Ribeiro *et al*., 2005). This is to be expected given that all four species have similar morphology, diet, and habitat preferences (Dawson, 2002).

Activity patterns are one of the prime factors directly influencing group size and, indirectly, the social organisation of delphinids (Shane *et al*., 1986). Groups frequenting Akaroa Harbour were significantly larger when socialising. Slooten (1994) recorded higher rates of sexual behaviours in groups comprising 11 to 15 individuals. In this species, fusion between different groups is critical for stimulating social and sexual behaviours (Slooten, 1994).

Larger groups engaging in socialising activities have also been recorded in other delphinid species (*e.g.* Bottlenose dolphins: *Tursiops* sp.: Bearzi *et al*., 1999; Shane, 2004; Atlantic white-sided dolphins: *Lagenorhynchus acutus*: Weinrich *et al*., 2001; and *Sotalia* sp.: Azevedo *et al*., 2005; Flach *et al*., 2008). In contrast, when engaged in diving behaviour, Hector's dolphin groups were significantly smaller than milling or socialising aggregations, confirming previous findings by Slooten and Dawson (1994). This dispersion into smaller groups may be related to foraging efficiency, which is often linked to the prey distribution (*e.g.* Gygax, 2002).

Group composition

The group composition of Hector's dolphins in Akaroa Harbour observed during the course of this study was in agreement with that previously reported for this species (Webster, 2008). The *adults* only category represented the large majority (> 90%) of groups observed. This trend was also apparent in both Le Bons Bay and Te Oka Bay. An explanation for such a high proportion of adult only groups is unknown but could be reflective of the low breeding rate of this endangered species (Slooten and Lad, 1991).

Mother and calves

Calf sighting rate peaked in January, which corresponds with the late austral spring and summer calving period of this species (Slooten, 1991), which is typical of high latitude populations of dolphins (Börjesson and Read, 2003). Groups containing at least one calf consisted of either single *mother-calf* pairs, *nursery* groups (up to five pairs) or *mixed* groups. The occurrence of these three group types in this study is consistent with Wesbter (2008). The author reported that *nursery* groups occurred only between December and May, while single *mother-calf* pairs represented the majority of sightings between March and August. Webster (2008) also further suggested that there is some evidence of sex segregation in Hector's dolphin *nursery* groups, with only females observed closely associating with mother and calves (Webster, 2008).

In bottlenose dolphins, larger *nursery* groups form when calves are smaller and more vulnerable (Mann and Smuts, 1999). Large groups are likely to provide increased protection from predators and/or conspecifics as well as social opportunities for calves (Gibson and Mann, 2008). Typically, groups with calves in this study were significantly larger than groups without, similar to Webster's (2008) findings. This pattern is commonly observed in other delphinid species; such as common dolphins (*Delphinus* sp., Stockin *et al*., 2008c), Indo-Pacific humpback dolphins (*Sousa chinensis*, Karczmarski, 1999), bottlenose dolphins (Hubard *et al*., 2004), Atlantic white-sided dolphins (Weinrich *et al*., 2001), dusky dolphins (Degrati *et al*., 2008), and Tucuxi dolphins (*Sotalia fluviatilis*, Azevedo *et al*., 2005).

It has been recommended that specific areas used for calving, nursing, and raising calves are identified as critical habitats for cetacean species (Hoyt, 2005). The designation of important areas for a species can assist managers when proposing mitigation measures for anthropogenic disturbances. Akaroa Harbour appears to be an area used regularly by mothers and calves. However, no evidence of exclusive nursery areas or areas used more often by groups with calves was found. The presence of twice as many groups with calves in Te Oka Bay compared to Akaroa Harbour suggests that the former may be a more important calving area around Banks Peninsula, concurring with Webster (2008). However, the proportion of groups with calves was lower in the present study, probably owing to the fact that the entire harbour/bays were not surveyed from shore-based stations.

In concurrence with Webster (2008), this study indicated that Hector's dolphin groups containing calves were more likely to be found in the *outer* than in the *inner* harbour. Such preference could be attributable to the fact that the *outer* harbour is the mixing zone of the harbour with open bay waters, and likely a productive zone (Clement, 2005). The growth of a calf has usually high energy cost for the mother, increasing her energy requirement during the nursing period (*e.g.* Kastelein *et al.*, 2002, 2003). Other factors affecting lactating female energetic demands could also be at play, including human pressure.

2.6. Conclusion

There is growing support within the international community for special consideration to be given for areas that are deemed key areas and habitats for a species or population (Agardy, 1994). The identification of such areas inherently relies on a sound understanding of the species behaviour and habitat use. The influence of oceanographic features and other parameters such as bathymetry on the distribution of Hector's dolphins has already been studied (*e.g.* Bräger *et al.*, 2003; Clement, 2005; Slooten *et al.*, 2006a; Rayment *et al.*, 2010) and was, therefore, beyond the scope of this study. Although Hector's dolphins did not appear to use certain sectors of the harbour for specific behavioural activities or as nursery areas, a preference for a zone previously described by Clement (2005) was evident (*i.e.* between Kaik Hill and the harbour entrance).

The activity budget generated here provides the first baseline data for the detection of possible behavioural differences associated with vessel traffic, including tourism activities in Akaroa Harbour (Chapters IV and V). Overall, no differences in the behavioural budgets of Hector's dolphins were detected between the three sites around Banks Peninsula under *control* conditions, with the exception of socialising. Nichols *et al.* (2001) suggested that vessel traffic in Akaroa Harbour did not displace Hector's dolphins. Therefore, it can be hypothesised that dolphins may adjust their behavioural budget in relation to vessel traffic levels and tourism activities while within the Harbour (Chapter IV).

CHAPTER III

Vessel traffic levels and encounters with the South Island Hector's dolphins (*Cephalorhynchus hectori hectori)* in Akaroa Harbour, Banks Peninsula

Photo: A.R.E.V.A. Project © 2006.

Chapter III draws on material that also appears in:
Martinez, E.; Orams, M.B.; Stockin, K.A. (2010). Responses of South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) to vessel activity in Akaroa Harbour, Banks Peninsula, New Zealand. Unpublished report to the Department of Conservation, Canterbury, New Zealand. 187p.

3.1. Introduction

Threats to cetacean populations from anthropogenic activities can be particularly high in coastal areas, due to the increase in human density and intensity of activities. Coastal cetacean populations depend on habitats frequently used for activities such as fishing, shipping, coastal development, tourism, and recreation to name a few. Motorised vessels, in particular, may constitute an important source of disturbance, as well as cause physical injuries and mortality (*e.g.* Stone and Yoshinaga, 2000; Nowacek *et al.*, 2001; Stockin *et al.*, 2008b; Behrens, 2009; Stockin *et al.*, 2010a).

Cetacean-watching vessels constitute a particular type of vessel traffic that deserves special attention given that these vessels actively engage cetaceans as part of their operation. On a global scale, the cetacean-based tourism industry has experienced an exponential growth over the past two decades (Hoyt, 2001; O'Connor *et al.*, 2009). Given the growing number of vessels within important cetacean habitats (McCarthy, 2004), there is a pressing need to assess and measure the effects of vessel activity on targeted populations (National Research Council, 2005).

The long-term sustainability and assumed conservation contribution of the cetacean-based tourism industry have recently been challenged by the International Whaling Commission (IWC). In 2006(b), the IWC stated that "[t]here is compelling evidence that the fitness of individual odontocetes repeatedly exposed to whale-watching vessel traffic can be compromised and that this can lead to population level effects". Since the release of the IWC statement, an increasing amount of scientific literature has also indicated that cetacean-based tourism may not be as benign as previously assumed. Vessel activities have been linked to various short-term responses in cetaceans, including changes in behavioural budget, dive intervals, direction of travel, vocalisation, group cohesion, and habitat use (refer to Parsons *et al.*, 2006a,b; Scarpaci *et al.*, 2008, 2009, 2010 for reviews). The issue of noise pollution from cetacean-watching and small vessels has also been raised (Au and Green, 2000; Erbe, 2002; Williams *et al.*, 2002a; Buckstaff, 2004; Jensen *et al.*, 2009; Martinez and Orams, in press), given that cetaceans rely on sound to navigate, communicate, and forage (Richardson *et al.*, 1995).

Interpretations of interactions between cetacean populations and tourism activities are, however, quite complex due to several factors, including a lack of baseline data, complex behavioural patterns, and prior displacement of the most sensitive individuals once exposed to a stress factor such as tourism activities and/or high vessel traffic levels (*e.g*. Constantine, 1999; Williams *et al.*, 2002a; Bejder and Samuels, 2003; Bejder *et al.*, 2006a; Jensen *et al.*, 2009). In addition, a recent long-term study (Bejder *et al.*, 2006b) of dolphin abundance in Western Australia demonstrated that assessments based on short-term studies may lead to erroneous conclusions about the actual effects of tourism on cetaceans. The authors emphasised that the moderated responses detected did not necessarily indicate that the local population of bottlenose dolphins (*Tursiops* sp.) had become habituated to vessel presence over time. Rather, individuals most sensitive to vessel disturbance had left the area prior to the commencement of their study. Furthermore, Miller *et al.* (2008) suggested that understanding the effects on individuals that relocate *versus* individuals that remain in areas of high vessel traffic could be critical for impact mediating effects of vessel traffic on other cetacean populations that are limited to specific habitats.

The cetacean-watching tourism industry within Akaroa Harbour, Banks Peninsula, focuses on the endemic and endangered Hector's dolphin, *Cephalorhynchus hectori hectori* (hereafter referred to as Hector's dolphin), throughout the year. The harbour is also the only location in New Zealand where commercial swim-with-dolphin trips with this species are permitted (Allum, 2009). As of 2010, there were 32 daily permitted commercial trips targeting the species (refer to Chapter I, section 1.1.3.2., for further details). The potentially high number of encounters and the increasing number of studies in New Zealand demonstrating the significant effect of tourism on various delphinid species are cause for concern (*e.g*. bottlenose dolphins *Tursiops truncatus*: Lusseau, 2003a,b; Constantine *et al.*, 2004; common dolphins *Delphinus* sp.: Neumann and Orams, 2006; Stockin *et al.*, 2008a; dusky dolphins *Lagenorhynchus obscurus*: Würsig *et al.*, 1997; Barr and Slooten, 1999; Markowitz *et al.*, 2009a; and Hector's dolphins: Bejder *et al.*, 1999; Nichols *et al.*, 2001; Green, 2003). Prior to establishing whether the current level of vessel traffic and tourism activities are affecting Hector's dolphins in Akaroa Harbour (Chapters IV to VII), it is imperative to gather baseline data on the ecology of individuals using Akaroa Harbour

(Chapter II) and determine what level of tourism exposure Hector's dolphins could experience.

3.2. Objectives

Stone *et al.* (1998), followed by Nichols *et al.* (2001, 2002) gave the first descriptions of vessel traffic levels in Akaroa Harbour. Their research, however, did not include the entire harbour and was temporally constrained to the months of January and February. While the studies covered the peak in tourism activities and vessel traffic over the austral summer, it did not encompass the known period when Hector's dolphins can be regularly encountered within the harbour (*e.g*. Dawson, 1991b; Bräger *et al.*, 2003; Dawson *et al.*, 2004; Clement, 2005). This study attempts to close this knowledge gap by describing and quantifying the overall level of vessel activity in Akaroa Harbour between November and March. The objectives, in particular, aimed to determine, the:

1) Current level of traffic in the harbour.
2) Different types of vessels using the harbour.
3) Diurnal period(s) when permitted operators exert the greatest effort.
4) Average time permitted operators spend with dolphins.
5) Amount of time permitted operators cumulatively spend with dolphins.
6) Location of encounters within the harbour.

3.3. Materials and methods

3.3.1. Study area

This study encompasses Akaroa Harbour, within the permitted swimming and viewing area of operation for the commercial tour operators based in the Akaroa township (Fig. 3.1). The harbour, situated on the southern side of Banks Peninsula, is approximately 17 kilometres (km) long, with a predominantly north-south orientation (Heuff *et al.*, 2005). Further details of the study area are provided in Chapter II (section 2.3.1). Akaroa Harbour is also part of the Banks Peninsula Marine Mammal Sanctuary, where fishing activities are regulated in order to protect Hector's dolphins

(Fig. 1.5; Dawson and Slooten, 1993; Chapter I, section 1.2.4.1). There are no specific restrictions on vessel traffic *per se* within its boundaries.

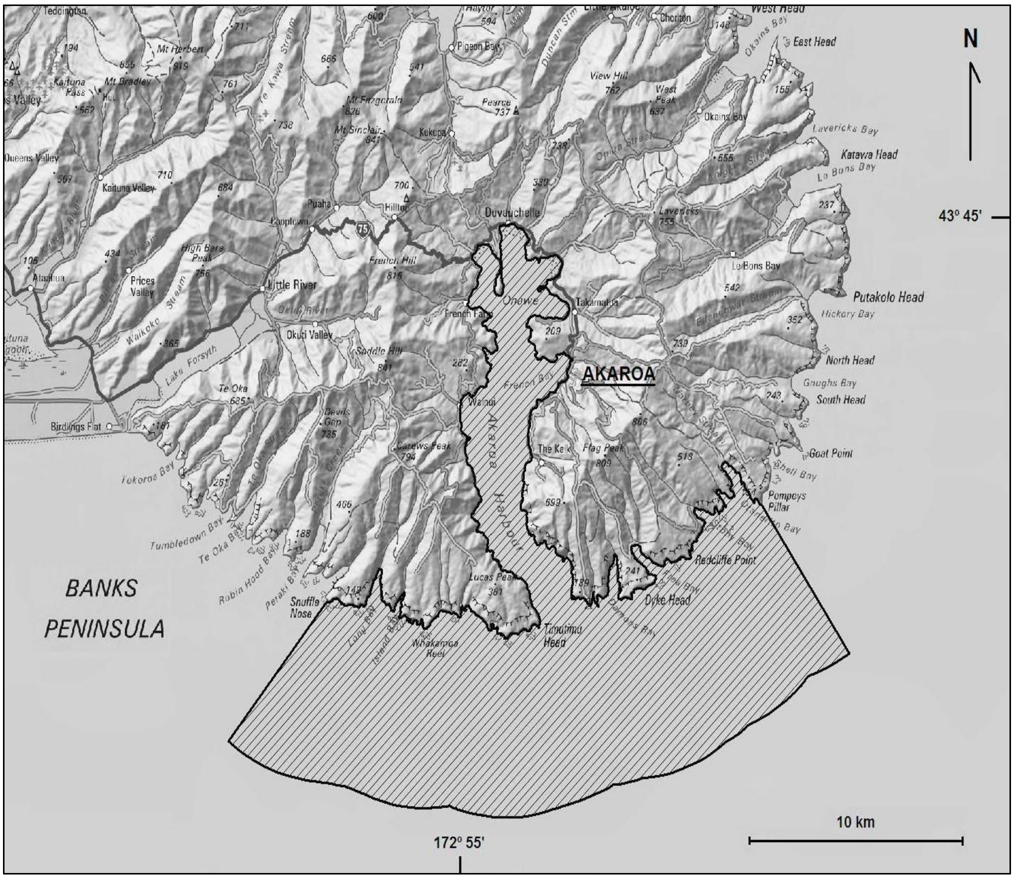


Fig. 3.1: Permitted area of operation for commercial tour operators based in Akaroa, New Zealand (Source: Department of Conservation, Canterbury).

3.3.2. Survey platforms, effort, and survey protocol

3.3.2.1. Survey platforms

Land-based platforms

Land-based, theodolite tracking stations were the primary platform for data collection. This technique is a non-invasive method of recording vessel and cetacean movement, as well as dolphin behaviour from elevated shore-based stations (Würsig *et al.*, 1991). Four different stations were used (Fig. 3.2), with height varying between 72.7 metres (m) above sea level for the lowest (*Lighthouse*) and 152.8 m for the highest (*9 Fathom*). Stations were strategically placed to limit the area obscured from the theodolite view and to ensure that the greatest proportion of the harbour could be surveyed (refer to Chapter II, section 2.3.1.2, for further details).

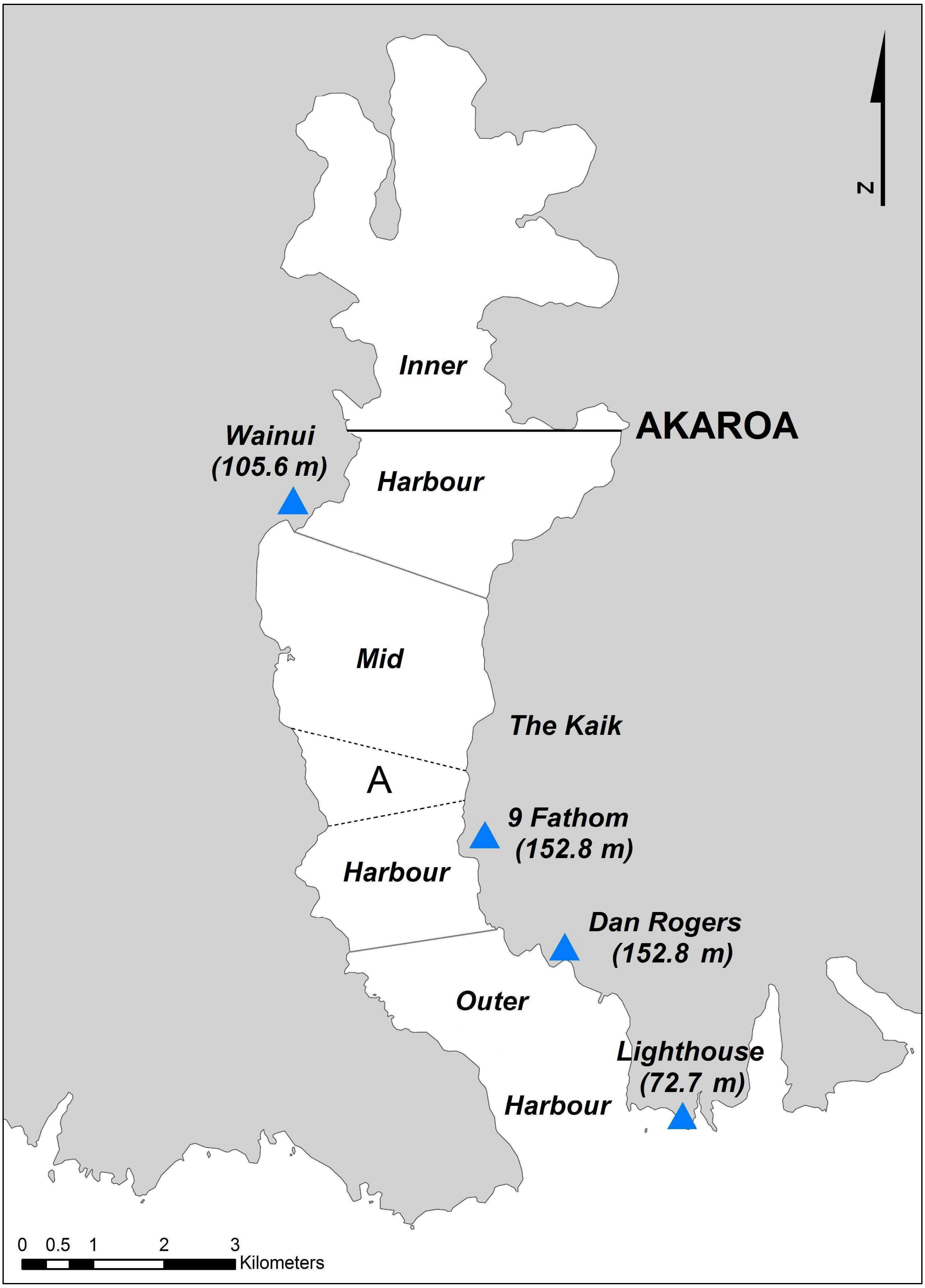


Fig. 3.2: Map of Akaroa Harbour showing the *inner*, *mid*, and *outer* harbour survey regions separated by a grey line (Dawson, 1991b). The location of the four land-based stations is shown by blue triangles. The black line levelled with Akaroa represents the arbitrary reference line created with ArcGIS (© ESRI) and used for analysis. Dotted lines delimit the study site used by Nichols *et al.* (2001), represented by the letter A.

Vessel-based platforms

Commercial vessels to view and swim with dolphins were also used as platforms to record the location of encounters as well as conduct behavioural (Chapters IV to VI) and photo-ID surveys (Chapter VII). These surveys were opportunistic due to onboard space availability. At the time of this study, five tour operators were permitted to operate within and around Akaroa Harbour (Table 3.1): the Black Cat Group Ltd. (BC), Dolphin Experience Ltd. (DE), Akaroa Dolphin Ltd. (AD), Onuku Farm Hostel (OFH), and Fox II Sailing Adventures (Fox II).

Table 3.1: Summary of permitted commercial vessels that operated in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Note: DW = Dolphin-watching; SW = Swimming-with-dolphin. In bold are the vessels used as survey platforms in this study.

Operator	Number of vessels	Vessel Name	Activity	Length (m)	Maximum Passengers
Black Cat Group Ltd.	3	Black Cat	DW	17.3	100
		Cat II	SW/DW	12.0	30
		Canterbury Clipper	SW/DW	8.2	14
Dolphin Experience Ltd.	3	**Dolphin Experience**	SW/DW	12.6	60
		Dolphin Adventurer	SW/DW	9.0	20
		Dolphin Watcher	SW/DW	7.0	12
Akaroa Dolphin Ltd.	1	**Akaroa Dolphin**	DW	11.6	22
Fox II Sail Adventures	1	Fox II	DW	15.2	30
*Onuku Farm Hostel**	1	Unknown	SW/DW	5.8	8

* Kayaks not included

Only BC, DE, and AD vessels were deemed suitable platforms (Table 3.1), primarily due to size and likelihood of available research space on board. Except for AD, which only offered dolphin-watching trips, the other five vessels provided swim trips (Fig. 3.3). In 2007, BC acquired DE and by the end of 2008 had replaced all the DE fleet. All vessels were easy to distinguish due to their shape, size, and company name displayed on the hull. This prevented any confusion between vessels and type of tour provided.

Fig. 3.3: Commercial tour vessels used as opportunistic research platforms in Akaroa Harbour, New Zealand. From Dolphin Experience Ltd.: A) Dolphin Experience; B) Dolphin Adventurer; C) Dolphin Watcher. From the Black Cat Group Ltd.: D) Cat II; E) Canterbury Clipper, and from Akaroa Dolphin Ltd.: F) Akaroa Dolphin.

3.3.2.2. Survey effort

Between 2005 and 2008, observations were conducted between November and March from the four fixed vantage points (Fig. 3.2) and various vessel platforms (Fig. 3.3). This time period coincided with the peak in tourism activities and the known austral summer distribution of Hector's dolphins, when they are more likely to be encountered within Akaroa Harbour and within one nautical mile from shore (*e.g.* Dawson, 1991b; Clement, 2005; Rayment *et al.*, 2010).

Data were collected from land between 0600 and 1800 hours (hr), in 6hr blocks (*i.e.* 0600-1200 hr or 1200-1800 hr), to avoid observer fatigue and subsequent bias. To further prevent fatigue, observers (a minimum of two) rotated their position hourly or at the end of a group focal follow if observations were still being recorded at the hour mark. To further reduce bias, only the principal investigator (EM) operated the theodolite (refer to Chapter II, section 2.3.2. for further details).

Data were collected from commercial swim-with-dolphin trips that departed at approximately 0600 hr, 0900 hr, 1200 hr, 1400 hr, and 1600 hr. Swim trips at 0600 hr and 1600 hr were only offered if there was sufficient demand and/or daylight. In addition, AD (the only dolphin-watching opportunistic platform used) left Akaroa at 1045 hr, 1215 hr, and 1515 hr. An attempt was made to undertake equal sampling effort across the different departure times in order to cover as much of the commercial daily activities as possible.

Observations were limited to favourable environmental conditions, *i.e.* no rain and Beaufort Sea State (BSS) of two or less. If BSS increased above two or if weather conditions deteriorated, data collection was terminated to prevent sighting rates being negatively affected (Elwen *et al.*, 2009). Environmental variables such as BSS, wind speed and direction, temperature, percentage glare and cloud cover, were all recorded hourly or if noticeable change in conditions occurred. An index of overall sightability (from 1 to 4, 1 being very poor and 4 excellent), encompassing all the above conditions, was recorded at the same time. Only observations with a good or excellent sightability were included in the analysis.

3.3.2.3. Survey protocol

Land-based survey protocol

Following methods detailed in Chapter II (section 2.3.2.1.), the study area was systematically scanned using Nikon or Tasco binoculars (7-10 x 50), a tripod-mounted Acuter spotting field scope (60x magnification), and a Sokkia Set 5 digital total station or theodolite (30x telescope).

Hector's dolphin sightings

Once Hector's dolphins were detected, a group focal follow (Mann, 1999) was used to determine the focal group's position, size, and behaviour (refer to Chapter II, section 2.3.2.1, for further details). A group was defined as individuals located in close proximity (less than five-six body lengths or approximately less than 10 m) from one another (Smolker *et al.*, 1992). The presence of a calf within a group was also recorded. *A calf* was described as an individual that was approximately 50% or less than the size of an adult and consistently observed in association with an adult, presumed to be the mother (Fertl, 1994).

Sightings were subsequently classified into three categories: *control*, *distant*, and *close* (Table 3.2). A distance of 300 m was chosen to distinguish the *distant* and *close* categories, which is consistent with the Marine Mammals Protection Regulations (MMPR, 1992; Appendix 1.4).

Table 3.2: Definitions of the different categories used to classify sightings of Hector's dolphins in relation to the presence and absence of vessels in Akaroa Harbour.

Category	Definition
Control	Absence of vessel(s) in visible range within the study area.
Distant	Presence of vessel(s) in the study area but further than 300m from the focal group.
*Close**	Presence of vessel(s) within 300m of the focal group.

**Close* corresponds to *impact* in other studies (*e.g.* Lusseau, 2003a).

Vessel traffic

Every hour, in addition to previously described environmental variables, the number and type of vessels visible within the study area were recorded. If the same vessel was present at the next hour mark, it was counted again to give an accurate estimate of vessel traffic. Vessel type was classified into four main categories (Table 3.3).

Table 3.3: Definitions of vessel types using Akaroa Harbour, New Zealand.

Vessel type	Definition
Commercial	Any vessel providing wildlife cruises, swim-with-dolphin tours, or any other tours from a commercial operator.
Fishing	Any commercial fishing vessel.
Research	Any vessel involved with research or governmental activity.
Recreational	Any vessel not included in the other categories. When possible, this category was further divided into different vessel types: sail, kayaks, motor (except jetskis), and jetskis.

When possible, vessels were tracked via theodolite (see Chapter II, section 2.3.2.2. for further details) to determine the travel path taken within the study area in addition to speed. Each position was recorded every minute (min) in the middle of a vessel hull and at water level. When tracking both vessel(s) and a focal dolphin group, positions were taken alternatively. Tracking vessels is very accurate, given that they are large and easy to place within the theodolite view. A laptop was connected to the theodolite running *Cyclopes* 2004 version 3.121 (© 2004, University of Newcastle, Australia), which calculated vessel speed in real time, between each fix taken and for the duration of a track (see Chapter II, section 2.3.2.2. for further details).

Encounters between vessels and Hector's dolphins

Under a *close* condition, an encounter was considered to be initiated whenever a vessel of any type came within 300 m of a focal group, with the intention of viewing or swimming with dolphins by reducing their speed. The time the vessel arrived and departed was recorded (hh:mm), allowing for encounter length to be calculated.

An interaction was defined as when at least one dolphin swam within 10 m (or five-six dolphin body lengths) of a vessel and/or swimmer and remained within its proximity for at least five seconds. A typical viewing or swimming encounter consisted of several interactions unevenly distributed and of varying duration. There was no minimum or maximum time period defining an encounter. In the case of swim-with-dolphin events, an encounter was judged to have commenced when the first swimmer entered the water and ended when the last swimmer got back on-board the vessel.

Upon the initial interaction, Hector's dolphin responses were defined relative to the movement direction of the group in relation to vessel and/or swimmer and were coded as *attraction*, *avoidance*, or *neutral* (see Table 3.4 for definitions adapted from Neumann and Orams, 2005). This method ensured that movement direction could be recorded from both land- and vessel-platforms.

Table 3.4: Definitions of sampling protocol terms (adapted from Neumann and Orams, 2005).

Term	Definition
Approach	One or several dolphins swimming past a swimmer and within less than one dolphin body length of a swimmer. Underwater approaches were not taken into account due to low visibility.
Attraction	At least 50% of a group changed its direction of travel and actively moved towards a vessel or swimmer(s) reducing the distance between them to less than four dolphin body lengths).
Avoidance	More than 50% of a group changed direction/path and actively swam away from vessel/swimmer(s) more than three times in succession, increasing the distance between them. Also, dolphins dove and surfaced away from the swimmers.
Neutral	No apparent change in behaviour, despite an initial approach within 5m of vessel or swimmer(s), continued swimming and did not appear to be attracted towards them in any way. Also when dolphins were present within more than 5m of a vessel or swimmer(s) but not actively swimming away from them (*i.e.* swimming away no more than 3 times in succession).

During the entire duration of an encounter, vessel(s) were continuously tracked via theodolite, recording a position every minute. A position was also taken at the first interaction and when the vessel departed, as well as at the start and end of a swim encounter, if applicable. The number and type of vessels involved in an encounter were also noted.

Vessel-based survey protocol

When on-board a commercial vessel, survey route was not predetermined. Instead, orientation was largely based on the skipper’s discretion and, therefore, influenced by prevailing weather and/or sea conditions, and any previous sightings. Vessels typically travelled at speeds of 10-20 knots (kts) within the harbour until a dolphin group was encountered. Skippers of swim-with-dolphin vessels would only venture outside Akaroa Harbour (Fig. 3.1) if dolphin groups found inside the harbour were deemed inappropriate for swimming or if no dolphin had been sighted. Operators of swimming trips did not engage with groups containing mother-calf pair(s), in line with the MMPR (1992) and their permit conditions.

Once a group was sighted, the same protocol used for land-based observations was followed to determine encounter duration. Positions at the start and end of each interaction, whether viewing or swimming with Hector’s dolphins, were recorded using a handheld Global Positioning System unit (Garmin GPS 60). A position of the vessel was also taken every minute for the whole duration of the trip using the same GPS unit.

3.3.3. Data analysis

In an effort to ensure maximum independence of each observation, successive view or swim attempts with a same dolphin group were not considered independent and were, therefore, excluded from analyses.

Statistical tests were performed using statistical package *Minitab* version 15 (Minitab Inc., 2007) for the majority of analyses, unless otherwise stated. The distribution of response variables were initially tested for normality and homoscedasticity using Anderson-Darling and Bartlett’s and Levene’s tests, respectively (Zar, 1996). A series of *post-hoc* (Bonferroni or Dunn's multiple comparison tests) were run when applicable. Significance was accepted at the alpha (0.05) level.

3.3.3.1. Proportion of time Hector's dolphins observed in the absence (*control*) and presence of vessels (*distant* and *close*)

The proportion of time Hector's dolphins were observed under a *control*, *distant*, and *close* condition was calculated, including 95% confidence intervals. A Pearson's χ^2 test was applied to examine monthly and seasonal variation. The proportion of time dolphin groups spent in the absence of vessels (*control*) was also compared with other locations around New Zealand.

3.3.3.2. Description of vessel traffic in Akaroa Harbour

Following Dawson's arbitrary boundaries within Akaroa Harbour (1991b; Fig. 3.2), the harbour was further divided into two zones, *i.e.* middle and *outer* sectors. The middle harbour comprised both the *inner* and *mid* sectors described in Dawson (1991b), because most of the *inner* harbour was obscured from vision from most stations and resulted in a small sampling size. Assumptions of normality and homoscedasticity were not satisfied. As a result, a Mann-Whitney U test was then performed to examine whether the difference in vessel traffic existed between these two areas.

Kruskal-Wallis tests were also used to examine diel and monthly variations in vessel traffic in each sector of the harbour because parametric test assumptions were not satisfied. The proportion of each vessel type making up the overall traffic was determined for all seasons. Vessel type was then taken into consideration to assess whether any differences existed in the middle (*inner* and *mid*) and *outer* harbour, according to time of day and month. In order to increase sampling size for each vessel type, days of the week were categorised as follows: weekdays, Fridays or weekends/statutory holidays. The relationship between day and vessel type was evaluated with a series of Kruskal-Wallis tests. Fridays could potentially be an outlier with higher traffic levels than other weekdays. Consequently, data on vessel traffic collected on that day were considered as a separate category in the analysis. Except for the diel dataset, the independent sampling unit is taken to be the daily number of vessels standardised per hour of observation to reduce auto-correlation.

Comparison with Nichols et al. (2001)

Nichols *et al.* (2001) conducted the first research in Akaroa Harbour describing vessel traffic according to vessel type. The proportion of each vessel type corresponding to those used in this study (*i.e.* commercial, recreational, research, and fishing) was calculated for the 1999/2000 study period from the authors published data. The study area between the two studies differed. As a result, only data collected in January from *9 Fathom* station (Fig. 3.2) were considered for the purpose of this analysis to limit bias. Differences in relation to vessel type between the two studies were tested with a binomial Z-test for proportions (Fleiss, 1981), with 95% confidence intervals (C.I.) calculated.

3.3.3.3. Correlation between SPUE and vessel traffic levels

In an effort to ensure maximum independence between observations, the total number of vessels and dolphins was averaged for each day spent in the field or per hour time period and considered as a sample unit. Assumptions about normality and homoscedasticity were not satisfied. As a result, Spearman's rank correlation tests were subsequently conducted to assess the strength of association between the mean number of Hector's dolphin sightings per time of active search effort or SPUE and the mean number of vessels for each corresponding field season. To determine whether an association also existed between the presence of dolphins and vessels in relation to time of day, a Kendall's tau correlation test was performed, rather than a Spearman's rank correlation test due to a small sampling size.

3.3.3.4. Encounters between Hector's dolphins and vessels

From land-based data, the duration of encounters observed according to vessel type was calculated. The independent sampling unit was taken to be individual encounters. Successive swim attempts with a same dolphin group (n = 22) were not considered independent and were, therefore, excluded from analysis. The normality and homoscedasticity assumptions were not met. As a result, Kruskal-Wallis tests were used to examine if there was a difference in encounter length in relation to: a) vessel type as well as among commercial and non-commercial vessel categories; and b) month among dolphin-watching and swimming trips. Encounters of less than a minute were excluded from analysis.

Cumulative time

A *cumulative encounter* was defined as the total time successive vessels spent in the presence of a focal dolphin group. The average time length and proportion of this type of encounter continuing past the permitted maximum time of 90 min were calculated. Field view from the various shore-based stations could occasionally be obstructed. Consequently, only cumulative encounters that could be observed from start to finish were included in the analysis.

3.3.3.5. Reaction of Hector's dolphins to vessel speed

Each vessel tracked during the study period under a *distant* or *close* condition was considered as an independent sampling unit when calculating the average speed of the different vessel types. If a vessel encountered a focal dolphin group (*i.e. close* condition) and attempted to approach and interact more than once with that same group, the second attempt was excluded from analysis to ensure independence across encounters.

Data did not meet the normality and homoscedasticity assumptions. A series of Kruskal-Wallis tests was, therefore, performed to: a) assess if vessel speed varied with vessel type; b) examine the differences in vessel speed before, during, and after an encounter; and c) investigate whether Hector's dolphin response towards vessels was influenced by vessel speed. This variable was also taken into consideration when vessels left the vicinity of a dolphin group, as under the MMPR regulation 18(m), vessels should not exceed wake speed until the vessel is at least 300 m away from the nearest individual.

3.3.3.6. Occurrence of encounters

To examine whether monthly variation existed in the location of encounters between Hector's dolphins and recreational as well as commercial vessels, the distance of each encounter from Akaroa township was calculated using the same arbitrary reference line described in Chapter II (refer to section 2.3.3.2. for further details; Fig. 3.2) and created using ArcGIS version 9.1 (© ESRI Inc.). A relationship between time (*i.e.* month) and the location of encounters (*i.e.* distance to Akaroa) for different vessel types (recreational, commercial dolphin-watching and swimming trips) was evaluated using a Kruskal-Wallis test given that the assumptions for a parametric test were not satisfied (Zar, 1996). The independent sampling unit is taken to be the first encounter with Hector's dolphins for each trip.

Maps of encounters were also constructed in ArcGIS, according to vessel type using land-based data, as well as months and calf presence using data recorded from vessel platforms. To investigate whether the distribution of encounters showed a consistent pattern in relation to these variables, positions were overlayed with the same 300 x 300 m (or 0.09 km^2) polygon-gridded base layer detailed in Chapter II. All coordinates were converted using the UTM zone 59S projection. Following methods described in Chapter II (section 2.3.3.2.), the number of encounters within each polygon was subsequently calculated using a function under Hawths Analysis Tools, an extension for ArcGIS (Copyright © 2001-2010, Hawthorne L. Beyer, Spatial Ecology LLC). The proportion of encounters within each quadrat was then calculated to create density maps. These maps were examined visually to identify potential areas of high encounter rate with respect to vessel type, month, and presence of calves. To assess whether a relationship existed between the aforementioned three variables and the location of encounters within Akaroa Harbour (*i.e. inner*, *mid*, and *outer* harbour), Pearson's χ^2 tests were performed (Zar, 1996). The *inner* and *mid* sectors of the harbour were pooled (or middle harbour), when necessary, due to small sampling size, in order to satisfy the conditions of the test.

3.4. Results

Over three consecutive austral summers, commencing in 2005, data were collected between November and March. Land-based surveys were conducted over a total of 166 days between 0600 and 1800 hr, resulting in a total of 631.7 hr of observations. In addition, a total of 581 commercial tours were surveyed during the same period, comprising 420 swim-with-dolphin tours and 161 wildlife cruises (Table 3.5).

Table 3.5: Summary of opportunistic vessel observations onboard commercial tours between November 2005 and March 2008 in Akaroa Harbour, New Zealand.

	Swim-	***With-***	***dolphin***	***trips***		***Dolphin***	***watching***	***tours***	
Departure	**0600hr**	**0900hr**	**1200hr**	**1400hr**	**1600hr**	**1015hr**	**1245hr**	**1515hr**	**Total**
November	0	32	21	25	1	10	11	18	*118*
December	7	34	22	28	5	19	13	15	*143*
January	13	36	27	22	7	12	7	4	*128*
February	0	30	22	19	9	14	6	4	*104*
March	0	26	15	17	2	16	6	6	*88*
Total	*20*	*158*	*107*	*111*	*24*	*71*	*43*	*47*	***581***

3.4.1. Proportion of time Hector's dolphins observed in the absence (*control*) and presence of vessels (*distant* and *close*)

From a total of 631.7 hr spent conducting observations in Akaroa Harbour, Hector's dolphins were present 37.8% of the time (Chapter II). Across all three field seasons, dolphin groups were observed 13.8% of time with no vessels visible (*control*) and 35.2% with vessels within a distance of 300 m (*close*). The remaining 51% corresponded to the presence of vessels in the harbour that exceeded 300 m (*distant*). In comparison with other sites around New Zealand (Table 3.6), the amount of time Hector's dolphins spent under *control* conditions in Akaroa Harbour was approximately five and seven times lower than in Porpoise Bay (Green, 2003) and Te Oka Bay, Banks Peninsula, respectively.

Table 3.6: Percentage of time Hector's dolphin groups were observed in the absence of vessels (*control*) at various locations around New Zealand.

Location	**Control (%)**	**Number of operators**
Akaroa Harbour (this study)	13.8	5 (25 trips/day)
Porpoise Bay (Green, 2003)	67.0	1 (3 trips/day)
Motunau (Martinez, 2003)	72.6	1 (1 trip/day)
Le Bons Bay (this study)	76.9	1 (1 trip/day)
Te Oka Bay (this study)	95.1	None

In Akaroa Harbour, the level of vessel activity in which dolphin groups were subjected to varied significantly between seasons (Pearson's χ^2 test: $\chi^2_4 = 186.90$, $p < 0.0001$; Fig. 3.4). In 2006/2007, dolphin groups were observed more than expected under a *close* condition (Freeman-Tukey deviates > 1) and less under both *control* and *distant* conditions (Freeman-Tukey deviates < -1). The converse trend was apparent in 2007/2008.

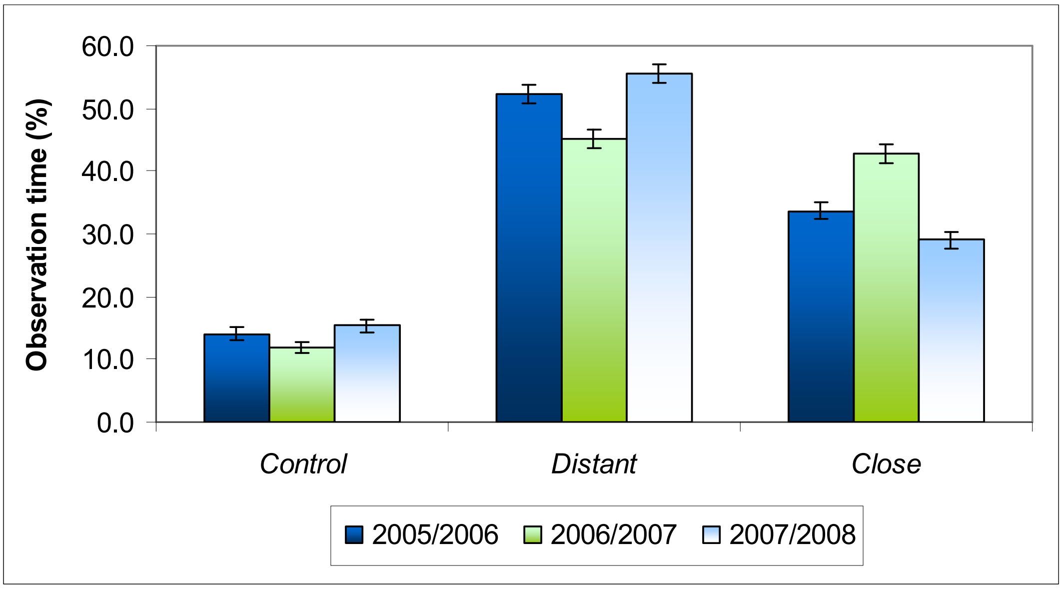


Fig. 3.4: Total observation time (percentage) of Hector's dolphin groups within Akaroa Harbour, New Zealand, according to vessel absence (*control*) or presence (*distant* and *close*) between November 2005 and March 2008. Bars represent the 95% confidence intervals.

The amount of time Hector's dolphins were observed in relation to various levels of vessel activity also exhibited significant monthly variation (χ^2_8: 267.763, $p < 0.0001$; Fig. 3.5). Freeman-Tukey deviates revealed dolphin groups were sighted under *control* conditions more during November and less so in both January and March. In December and February, fewer observations were made than expected under *distant* and more so under *close* conditions, with the opposite trend evident in March.

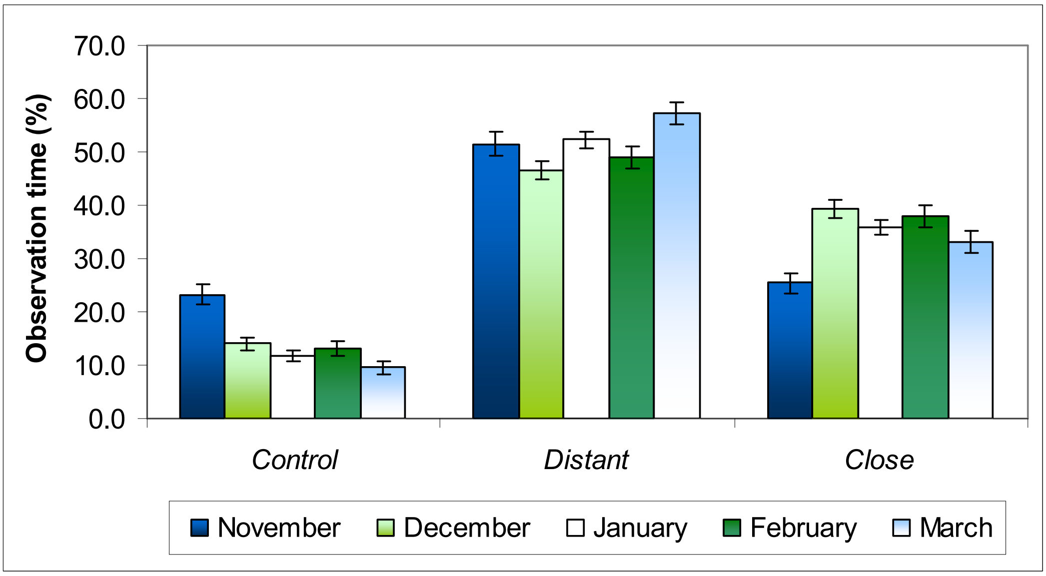


Fig. 3.5: Total observation time (percentage) per month of Hector's dolphin groups within Akaroa Harbour, New Zealand, according to vessel absence (*control*) or presence (*distant* and *close*) between November 2005 and March 2008. Bars represent the 95% confidence intervals.

3.4.2. Description of vessel traffic in Akaroa Harbour

Vessel traffic in Akaroa Harbour, including commercial and recreational vessels, is not homogeneous. The median hourly number of vessels varied significantly between the two main sectors of Akaroa Harbour (Mann-Whitney *U*: W = 34,693, $p < 0.0001$), being higher within the middle (*inner* and *mid*; median = 0.5, n = 370) than in the *outer* harbour (median = 0.2, n = 260).

In both sectors, vessel traffic increased from November to peak in January before subsequently decreasing (Fig. 3.6). While the monthly median number of vessels also varied significantly in the middle harbour (Kruskal-Wallis: $H_4 = 25.928$, $p < 0.0001$), it did not differ in the *outer* harbour ($H_4 = 4.900$, $p = 0.298$). In the middle harbour, the median number of vessels was significantly lower (Dunn's multiple comparison test: $p < 0.0001$) in both November and March than in January.

The large majority of vessel traffic (n = 4,628) was comprised of recreational vessels (72.9%), followed by commercial (21.6%), commercial fishing (4.0%), and research vessels (1.5%). In the middle harbour, the presence of both commercial fishing (H_4 = 5.082, $p = 0.279$) and research vessels ($H_4 = 5.912$, $p = 0.206$) did not vary significantly throughout the austral summer months (Fig. 3.7).

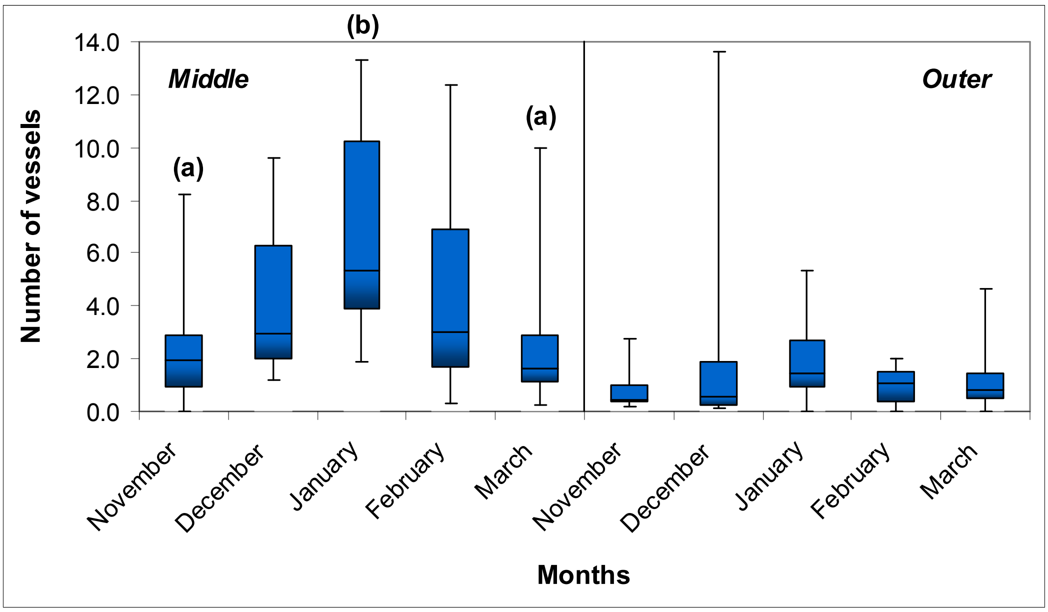


Fig. 3.6: Monthly number of vessels in the middle and *outer* sector of Akaroa Harbour, New Zealand, between November 2005 and March 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate months that were significantly different to other groups.

In contrast, both commercial and recreational vessel traffic exhibited significant monthly variation (Fig. 3.7). The number of commercial tour vessels was highest between December and February, peaking in January ($H_4 = 13.215$, $p = 0.011$), where rates differed significantly from lower November rates (Dunn's multiple comparison test: $p < 0.05$). Recreational vessels followed a very similar pattern ($H_4 = 25.512$, $p < 0.0001$), with the majority of traffic occurring between December and February. Significantly more vessels were observed in January compared to both November and March ($p < 0.001$).

Vessel traffic within the *outer* harbour did not always follow the same trend (Fig. 3.8). There were less commercial vessels present in the *outer* sector in January than in both November and March. However, no significant monthly difference was detected for any of the vessel categories (Commercial: $H_4 = 6.085$, $p = 0.193$; Fishing: $H_4 = 2.627$, $p = 0.622$; Recreational: $H_4 = 6.855$, $p = 0.144$; Research: $H_4 = 2.062$, $p = 0.724$).

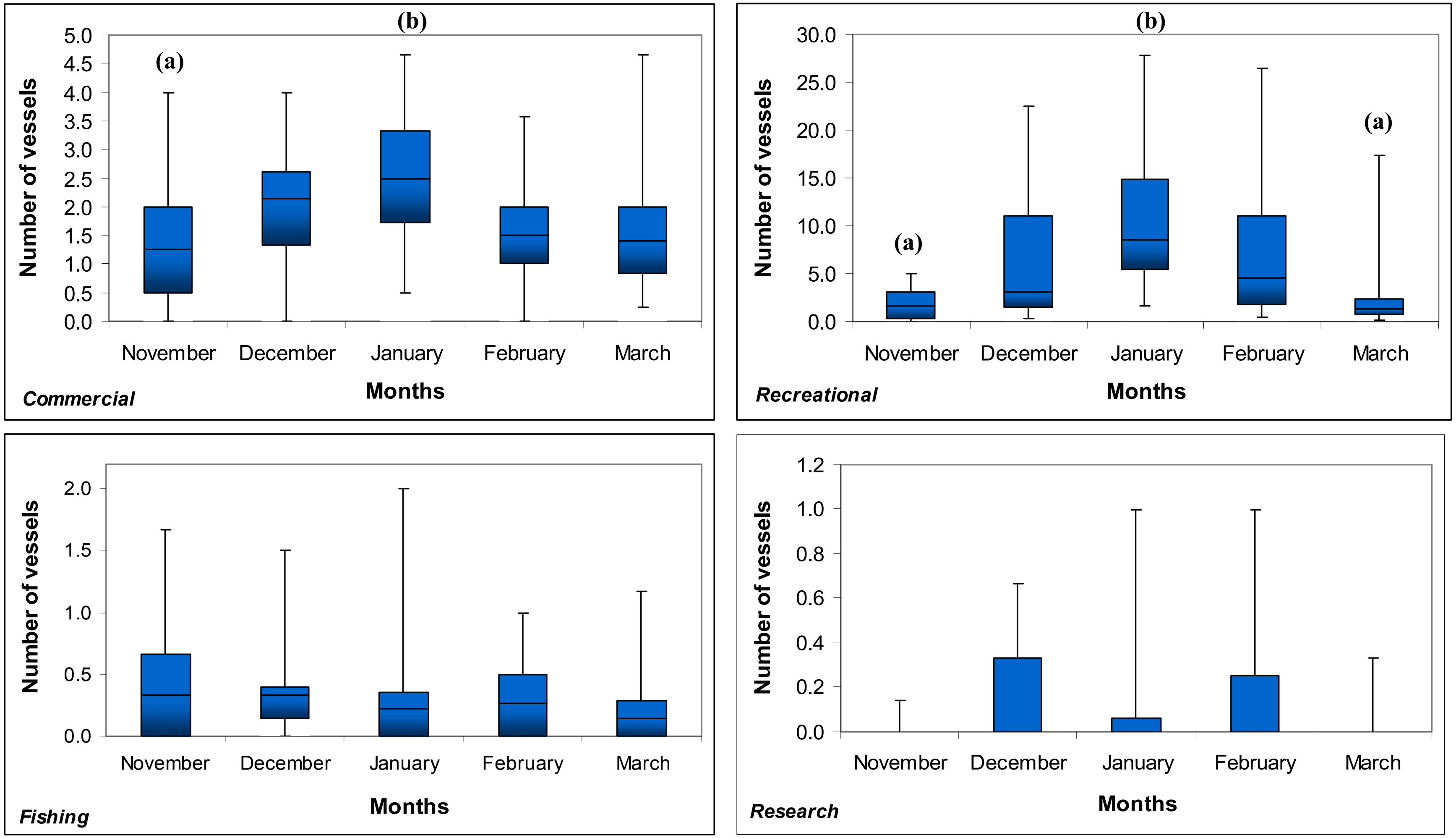


Fig. 3.7: Hourly number of vessels per month according to vessel type in middle sector of Akaroa Harbour, New Zealand, between 2005 and 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate months that were significantly different to other groups.

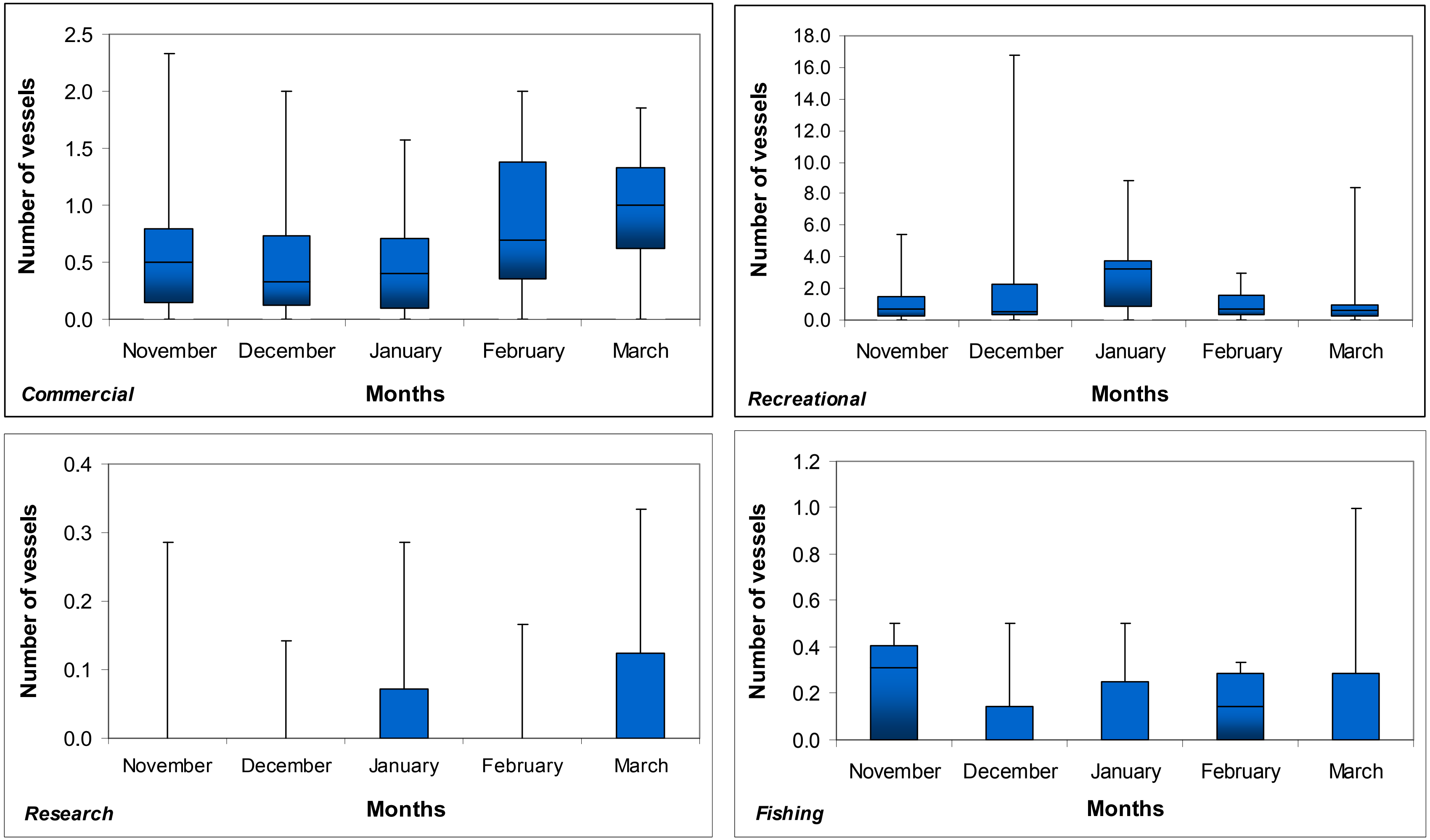


Fig. 3.8: Hourly number of vessels per month according to vessel type in *outer* sector of Akaroa Harbour, New Zealand, between 2005 and 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values.

Within the middle harbour, diel differences were detected ($H_{12} = 320.88$, $p < 0.0001$). Traffic was significantly lower (Dunn's multiple comparison test: $p < 0.05$ or less) early in the morning and late in the afternoon than the rest of the day ($p < 0.05$ or less, refer to Fig. 3.9). A similar trend was found in the *outer* harbour ($H_{12} = 242.27$, $p < 0.0001$), although not to the same extent (Fig. 3.9). At 0600 hr, traffic was significantly lower than most other time intervals ($p < 0.05$ or less, refer to Fig. 3.9).

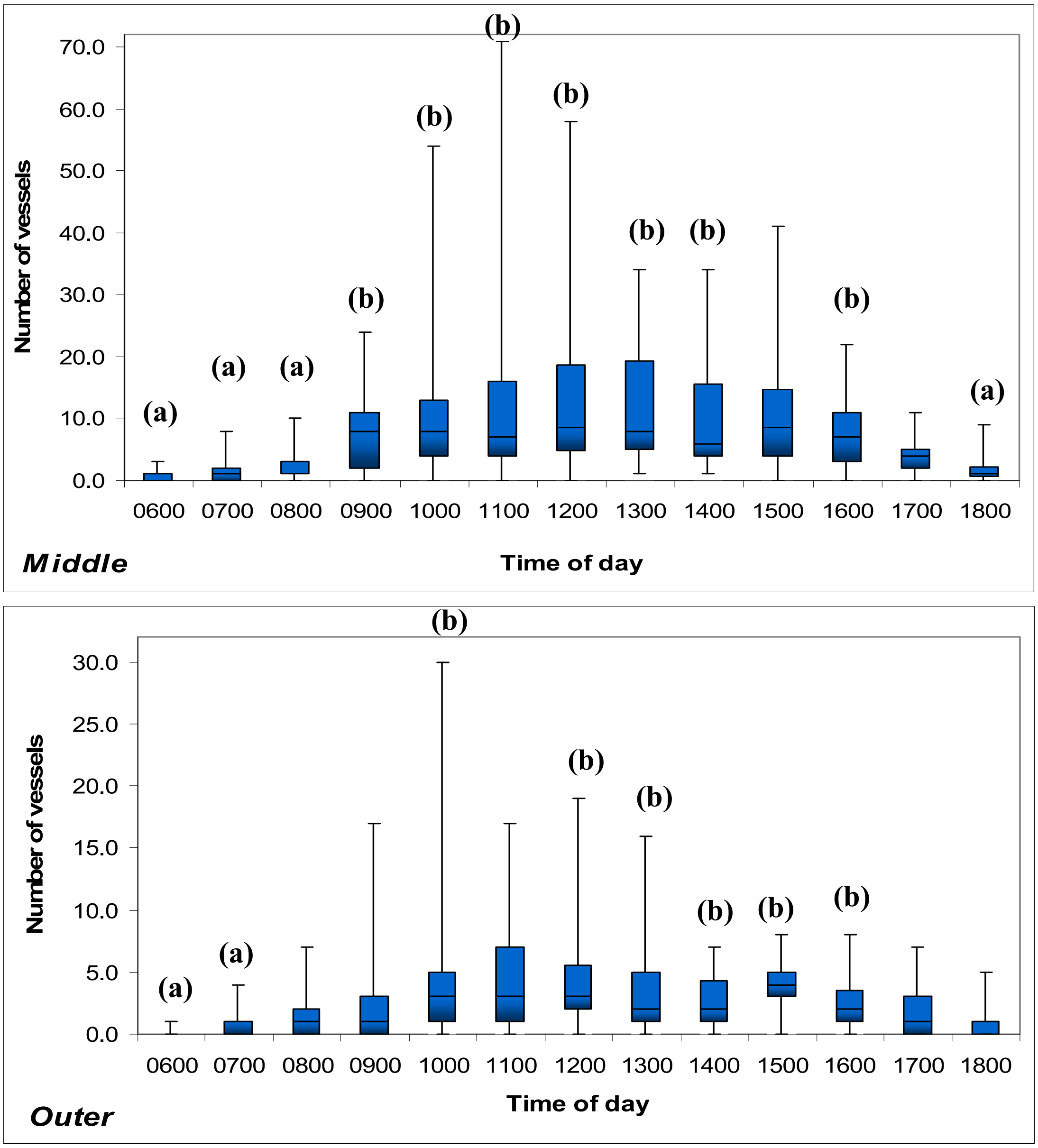


Fig. 3.9: Number of vessels according to time of day in the middle and *outer* sector of Akaroa Harbour, New Zealand, between November 2005 and March 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate time intervals that were significantly different to other groups.

The different vessel types observed across the different daytime hours also varied significantly, although they did not follow the same overall trend (Fig. 3.10). Commercial fishing activity within the harbour peaked between 0700 and 0900 hr (H_{12} = 31.102, $p = 0.002$). Research vessels (H_{12} = 39.168, $p < 0.0001$) were predominantly recorded before 1200 hr. Commercial tourism vessels (H_{12} = 275.46, $p < 0.0001$) were mainly present in the harbour between 0900 and 1700 hr (when most tours occurred), peaking between 1200 and 1500 hr (refer to Fig. 3.10). Recreational traffic increased until it peaked at 1200 hr before decreasing (H_{12} = 174.56, $p < 0.0001$). Recreational traffic was highest between 1000 and 1500 hr (refer to Fig. 3.10).

Finally, when investigating the weekly vessel traffic, differences between vessel types were detected (Fig. 3.11), with the exception of commercial vessels (H_3 = 4.781, $p = 0.092$). The other vessel types used the harbour differently across the week. While the number of fishing vessels was higher on weekdays (H_3 = 6.397, $p = 0.041$), more recreational vessels were present in the harbour during weekends (H_3 = 35.563, $p < 0.0001$). On weekends, there were five times as many recreational than commercial vessels recorded. Research vessels were observed more often on Fridays and over the weekend than during the rest of the week (H_3 =9.478, $p = 0.009$).

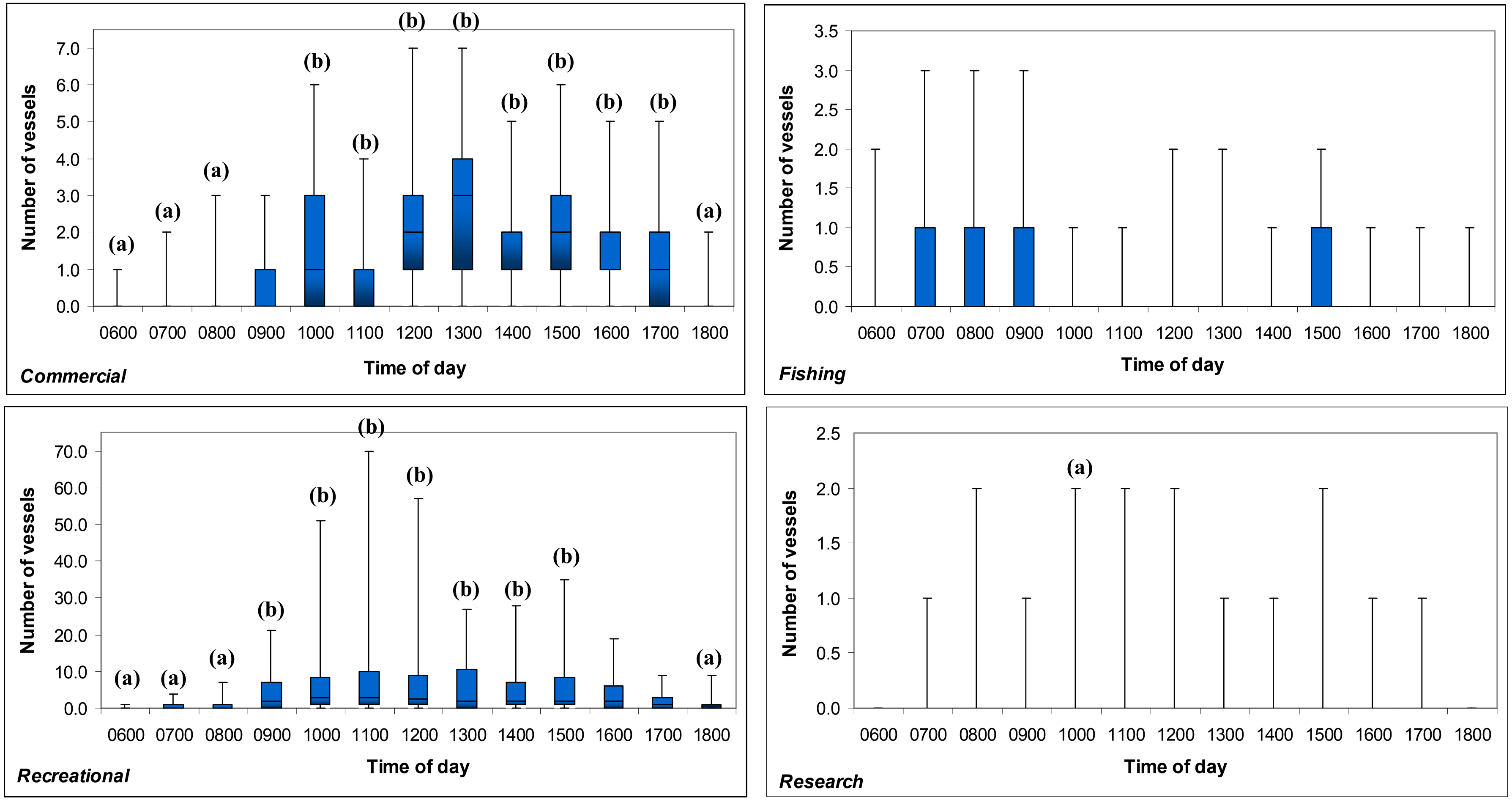
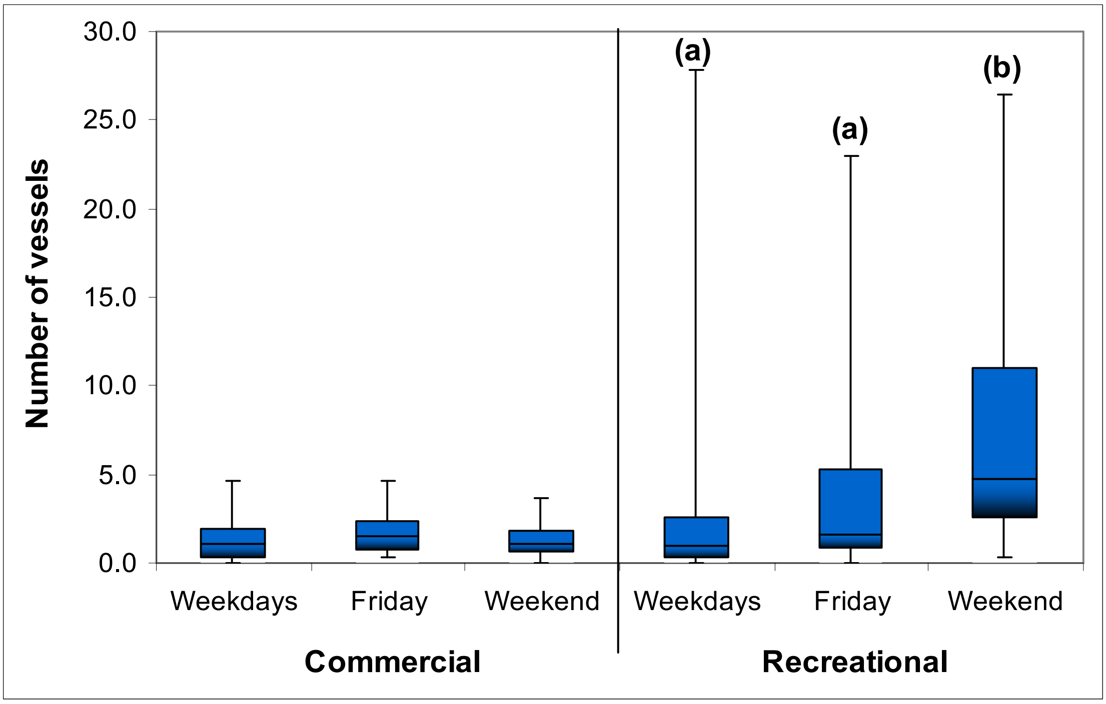


Fig. 3.10: Number of vessel according to time of day for the different vessel types in Akaroa Harbour, New Zealand, between 2005 and 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate time intervals that were significantly different to other groups.



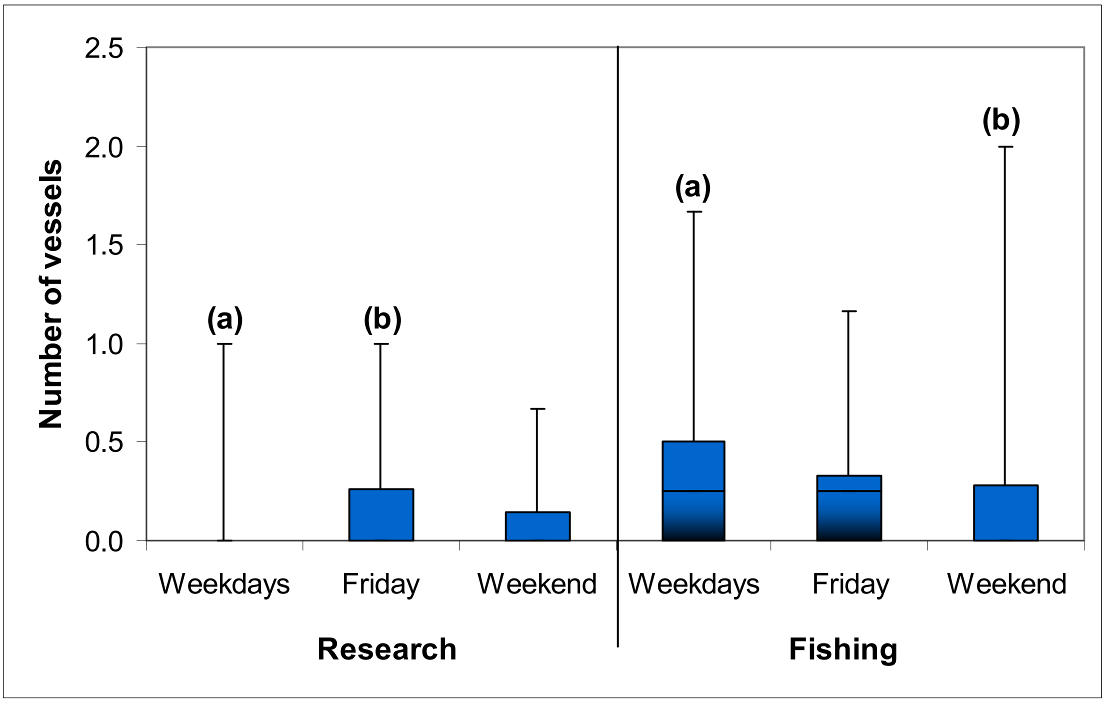


Fig. 3.11: Number of vessels according to day and vessel type in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate days that were significantly different to other groups.

Comparison with Nichols et al. (2001)

A comparison between the two studies using only data collected from *9 Fathom* station revealed a very similar trend (Fig. 3.12) with recreational vessels forming the large majority of the vessel traffic within the harbour (more than 70%). Except for commercial vessels ($p > 0.05$), vessel traffic according to vessel type did change significantly between the two studies (*Z*-test of proportion: $z = -0.92$, $p = 0.359$). Since 1999-2000, the number of recreational vessels has significantly increased ($z = -4.47$, $p < 0.0001$) compared to a decrease in the number of both fishing ($z = 3.49$, $p < 0.0001$) and research vessels ($z = 8.05$, $p < 0.0001$).

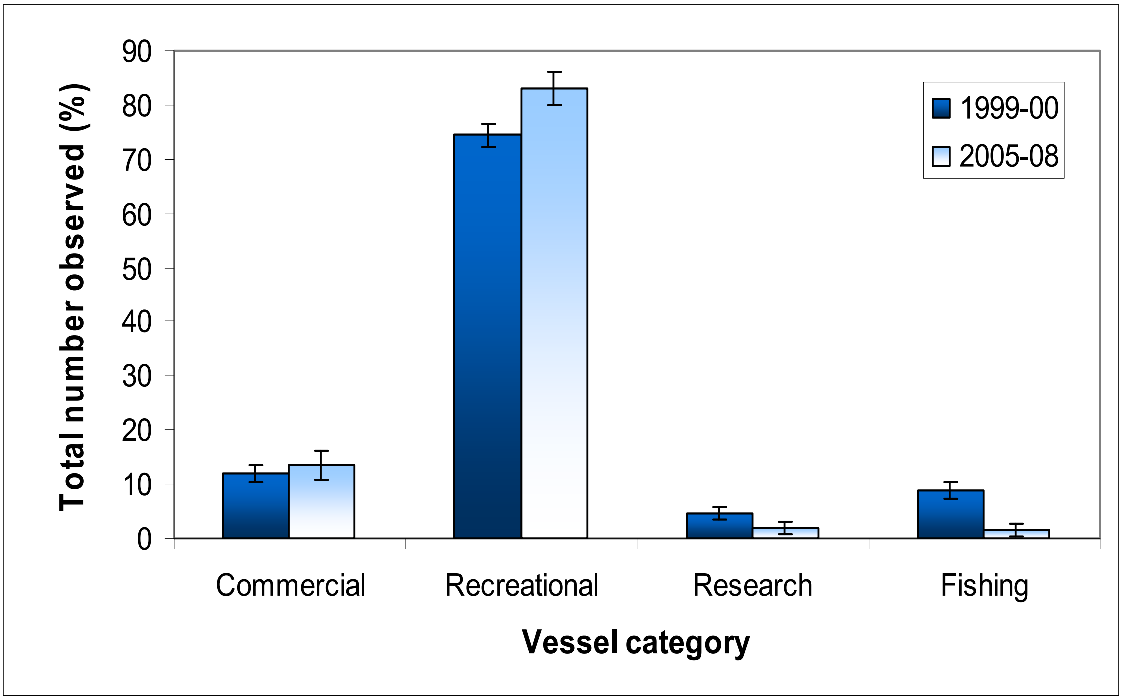


Fig. 3.12: Comparison of the percentage of vessel types observed in Akaroa Harbour, New Zealand, between 1999-2000 (Nichols *et al.*, 2001) and between 2005-2008 (this study). Bars represent the 95% confidence intervals.

3.4.3. Correlation between SPUE and vessel traffic levels

No statistical evidence of a correlation was detected between the number of vessels and dolphins (SPUE) within Akaroa Harbour across all three field seasons (Spearman rank correlation test- 2005/2006: $n = 54$, $r_s = -0.004$, $p = 0.975$; 2006/2007: $n = 56$, $r_s = -0.135$, $p = 0.321$; 2007/2008: $n = 52$, $r_s = -0.037$, $p = 0.789$; Fig. 3.13).

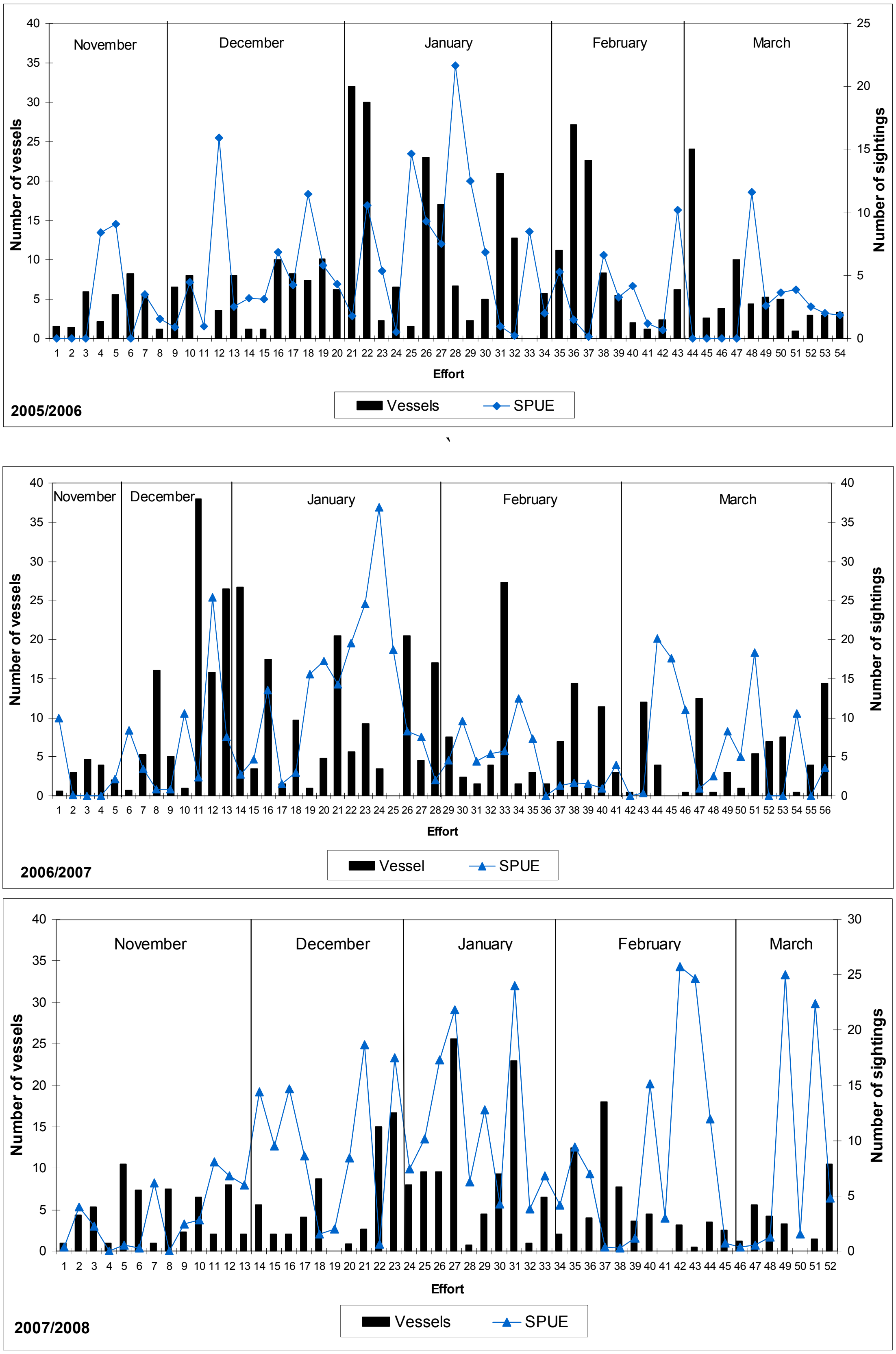


Fig. 3.13: Number of Hector's dolphins and vessels in Akaroa Harbour, New Zealand, over the 54, 56, and 52 days spent in the field during 2005/2006, 2006/2007, and 2007/2008, respectively.

The diurnal presence of dolphins did not appear to be correlated with the presence of vessels (Kendall's tau correlation test: $n = 12$, $\tau = 0.333$, $p = 0.131$; Fig. 3.14).

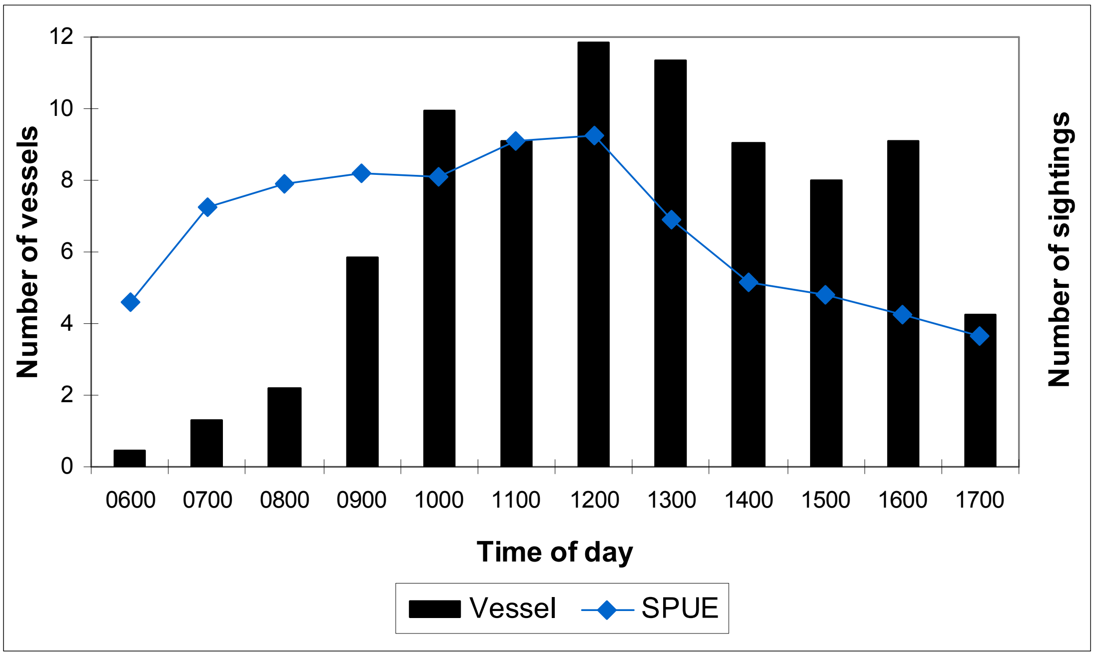


Fig. 3.14: Number of Hector's dolphins and vessels according to time of day in Akaroa Harbour, New Zealand, averaged across November 2005 and March 2008.

3.4.4. Encounters between Hector's dolphins and vessels

Out of the 415 encounters recorded between Hector's dolphin groups and vessels from the different land-based stations, the majority (70.4%) involved commercial vessels (Table 3.7). Although recreational vessels comprised the majority of the vessel traffic, this vessel type corresponded to only a quarter of the total encounters observed. Not only were commercial vessels more likely to interact with Hector's dolphins, their interactions were significantly longer (Table 3.7; Kruskal-Wallis: $H_3 = 19.401$, $p = 0.0002$), more than double that of recreational vessels.

Table 3.7: Percentage of vessel traffic and encounters observed as well as mean interaction time with Hector's dolphins according to vessel type in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Note: S.E. = Standard error of the mean.

Vessel type	% of traffic	% of encounters	Mean time (min)	S.E.	n
Recreational	72.9	25.4	7.55	0.763	89
Commercial	21.6	70.4	14.01	0.858	303
Fishing	4.0	0.4	2.60	0.400	2
Research	1.5	3.9	3.83	0.546	21

The amount of time vessels spent with Hector's dolphin groups varied significantly ($H_4 = 152.31$, $p < 0.0001$) across the different categories of both commercial and non-commercial vessels. Both commercial swim-with-dolphin and kayak encounters tended to average 20 min or more (Fig. 3.15). Dolphin-watching tours in general were significantly shorter than swim-with-dolphin interactions ($p < 0.01$). The shortest interactions were when swim trips were forced (due to weather or inappropriate dolphin groups) to simply watch dolphin groups rather than swim with them (Dunn's multiple comparison test: $p < 0.001$).

The length of encounters also varied significantly between all the different non-commercial vessels ($H_4 = 17.272$, $p = 0.002$; Fig. 3.15). Encounters with sailing vessels lasted significantly longer than with jet-skis ($p < 0.01$), research vessels ($p < 0.01$), and recreational motor vessels ($p < 0.05$).

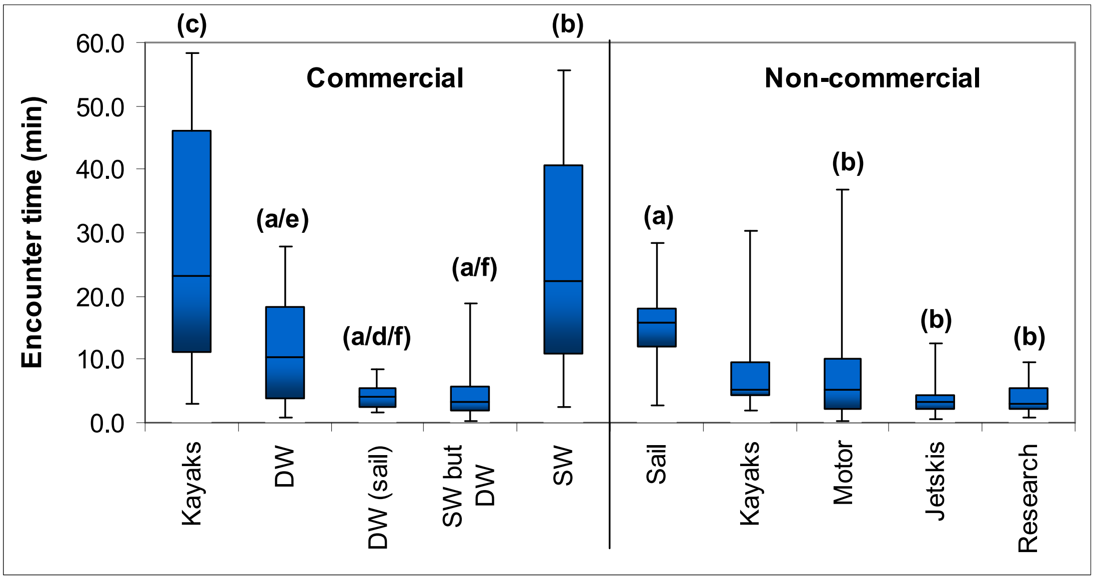


Fig. 3.15: Encounter time (min) between Hector's dolphins and vessel type, both commercial and non-commercial, in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: DW = Dolphin-watching; SW = Swimming-with-dolphins. Note: (a) (b), (c) (d), and (e) (f) indicate encounter times that were significantly different to other groups.

Monthly observations from vessel platforms

From the 671 commercial swimming and 351 dolphin-watching encounters observed, their duration decreased over the austral summer months as the longest encounters occurred in November and December, and shortest took place in March (Fig. 3.16). This monthly variation was significant for swim-with-dolphin tours ($H_4 = 11.905$, p =

0.018), however, no significant differences in monthly encounter rates were detected with dolphin-watching tours ($H_4 = 4.379$, $p = 0.357$).

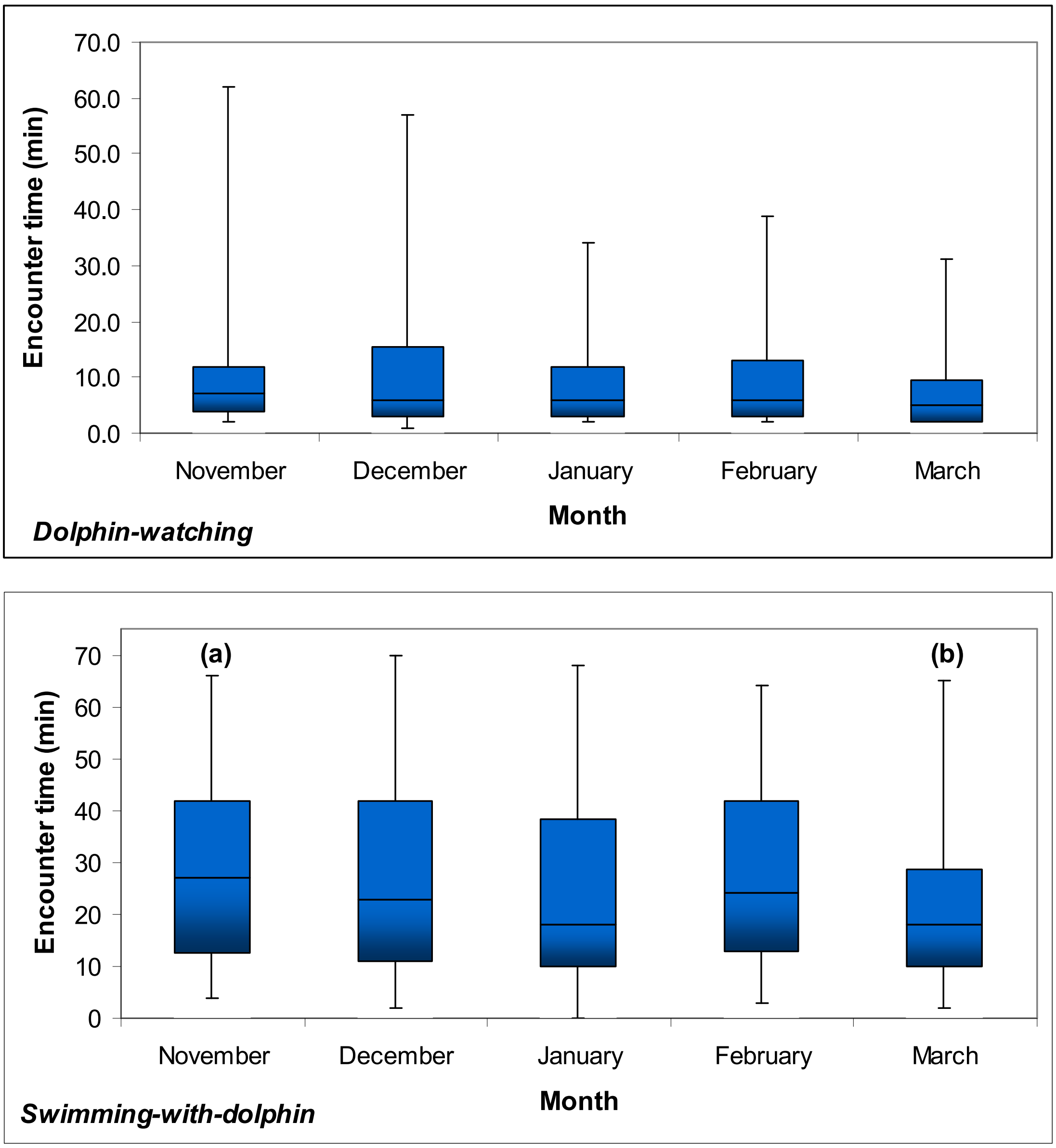


Fig. 3.16: Encounter time (min) per month between Hector's dolphins and either dolphin-watching tours or swimming-with-dolphin tours, in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate encounter times that were significantly different to other groups.

Cumulative time

Of the 12 cases of cumulative encounters observed from land-based observations, 83% involved only commercial tour vessels. In the remaining 17%, a recreational vessel was joined by one or more vessels including commercial vessels. Only one case went over the permitted time of 90 min, in an encounter on 22/11/07 that lasted for 98.73 min. On average cumulative interactions lasted 71.25min (S.E. = 3.848 min, range 50- 98 min).

3.4.5. Reaction of Hector's dolphins to vessel speed

The different vessel types recorded within Akaroa Harbour travelled at significantly different speeds (Kruskal-Wallis: $H_{10} = 161.91$, $p < 0.0001$), with kayaks being the slowest and Akaroa Jet (a commercial operator not legally permitted to target dolphins), the fastest (Table 3.8). A Dunn's multiple comparison test indicated that recreational vessels with a motor engine were significantly faster than most other vessels (sailing vessels - commercial and non-commercial, $p < 0.001$, kayaks $p < 0.001$, commercial dolphin-watching vessels $p < 0.05$, and commercial fishing vessels $p < 0.001$), with jet-skis recorded as the second fastest vessel type.

Table 3.8: Descriptive statistics of vessel speed (km/hr) according to vessel type using Akaroa Harbour, New Zealand, between November 2005 and March 2008. Letters (a/b) and symbols (*/[#]) indicate vessel speeds that were significantly different to other groups.

Vessel type	Median	Range	25^{th} and 75^{th} interquartile range	n
Commercial tour vessels				
Dolphin-watching [b]	14.3	2.7 - 21.0	12.5 - 15.4	61
Swimming-with-dolphins	16.9	4.9 - 25.3	12.6 - 19.0	68
Dolphin-watching (sailing) [b, *]	5.7	4.4 - 6.6	5.5 - 6.3	13
Akaroa Jet	37.4	34.9 - 39.2	35.3 - 38.9	4
Other commercial	13.1	8.1 - 22.2	8.4 - 18.8	4
Fishing vessels [b, *]	8.2	20.0 - 25.1	7.1 - 14.4	53
Research vessels	16.2	8.5 - 25.0	11.3 - 20.8	20
Recreational vessels				
Motor engine [a]	18.9	2.3 - 36.5	12.7 - 22.9	117
Jet-ski [#]	26.3	14.3 - 37.0	21.3 - 32.0	10
Sailing [b, *]	6.0	2.3 - 11.6	4.8 - 6.4	12
Kayaks [b, *]	2.1	1.4 - 5.8	1.6 - 2.6	13

Vessel speeds for all vessel types prior to an encounter (> 300 m away from a dolphin group) were similar for all motorised vessels, with the exception of kayaks (H_3 = 24.789, p = < 0.0001; Fig. 3.17a). No significant difference was detected across motorised vessels when kayaks were excluded from analysis ($H_3 = 2.821$, $p = 0.244$). Once within 300 m, speed remained low and analogous for all vessels whether these were engaged in viewing ($H_3 = 6.529$, $p = 0.089$) or swimming with dolphins (Mann-Whitney U: $W = 239.0$, $p = 0.664$; Fig. 3.17b).

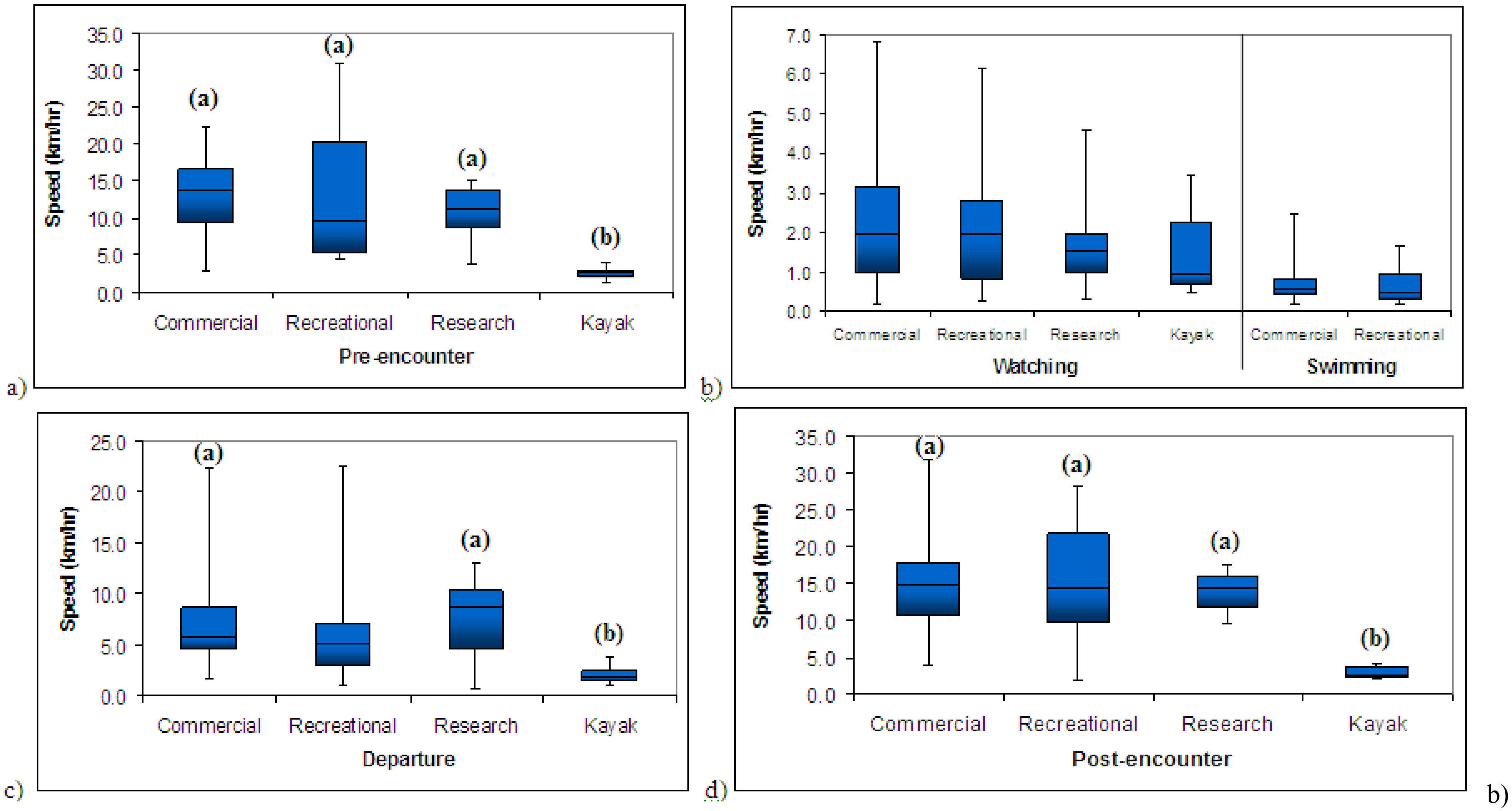


Fig. 3.17: Vessel speed (km/hr) in relation to vessel type during the different stages of an encounter (a, b, c, d) with Hector's dolphins in Akaroa Harbour, New Zealand, between November 2005 and March 2008. During the departure stage of an encounter, vessels were within 300 m of a focal dolphin group. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate vessel speeds that were significantly different to other groups.

When vessels left the vicinity of a dolphin group (< 300 m from a dolphin group), vessel speed varied significantly between vessels (H_3 = 15.884, p = 0.001), yet remained below the recommended 9.3 km/hr or 5 kts (Fig. 3.17c). This difference and that in post-encounter speeds (H_3 = 15.893, p = 0.001) was attributed mainly due to kayaks being significantly slower than all other vessel categories (Dunn's multiple comparison test: p < 0.05). When kayaks were excluded from analysis, no difference was found among the remaining motorised vessels (H_2 =5.381, p = 0.068)

Hector's dolphin reactions to vessel speed

Vessel speed had a significant effect on the responsiveness of Hector's dolphins towards vessels (Fig. 3.18; H_2 = 11.318, p = 0.004), causing dolphins to avoid vessels travelling significantly faster than a median speed of 10 km/hr (*ca.* 6 kts).

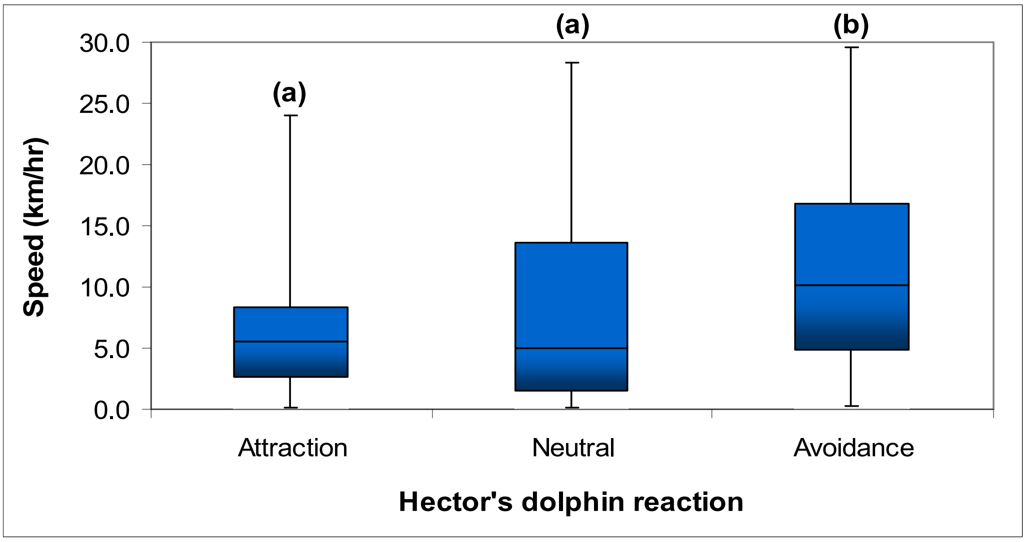


Fig. 3.18: Reaction of Hector's dolphin groups in relation to median speed (km/hr) of vessels in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate vessel speeds that were significantly different to other groups.

3.4.6. Occurrence of encounters

3.4.6.1. Encounters with different vessel types

The location of vessel encounters and Hector's dolphins within Akaroa Harbour, as indicated by distance from arbitrary line, varied significantly by month (Fig. 3.19) regardless of vessel type (Kruskal-Wallis, recreational: H_4 = 53.703, p < 0.0001; commercial dolphin-watching: H_4 = 109.99, p < 0.0001 and swimming vessels: H_4 = 89.878, p < 0.0001).

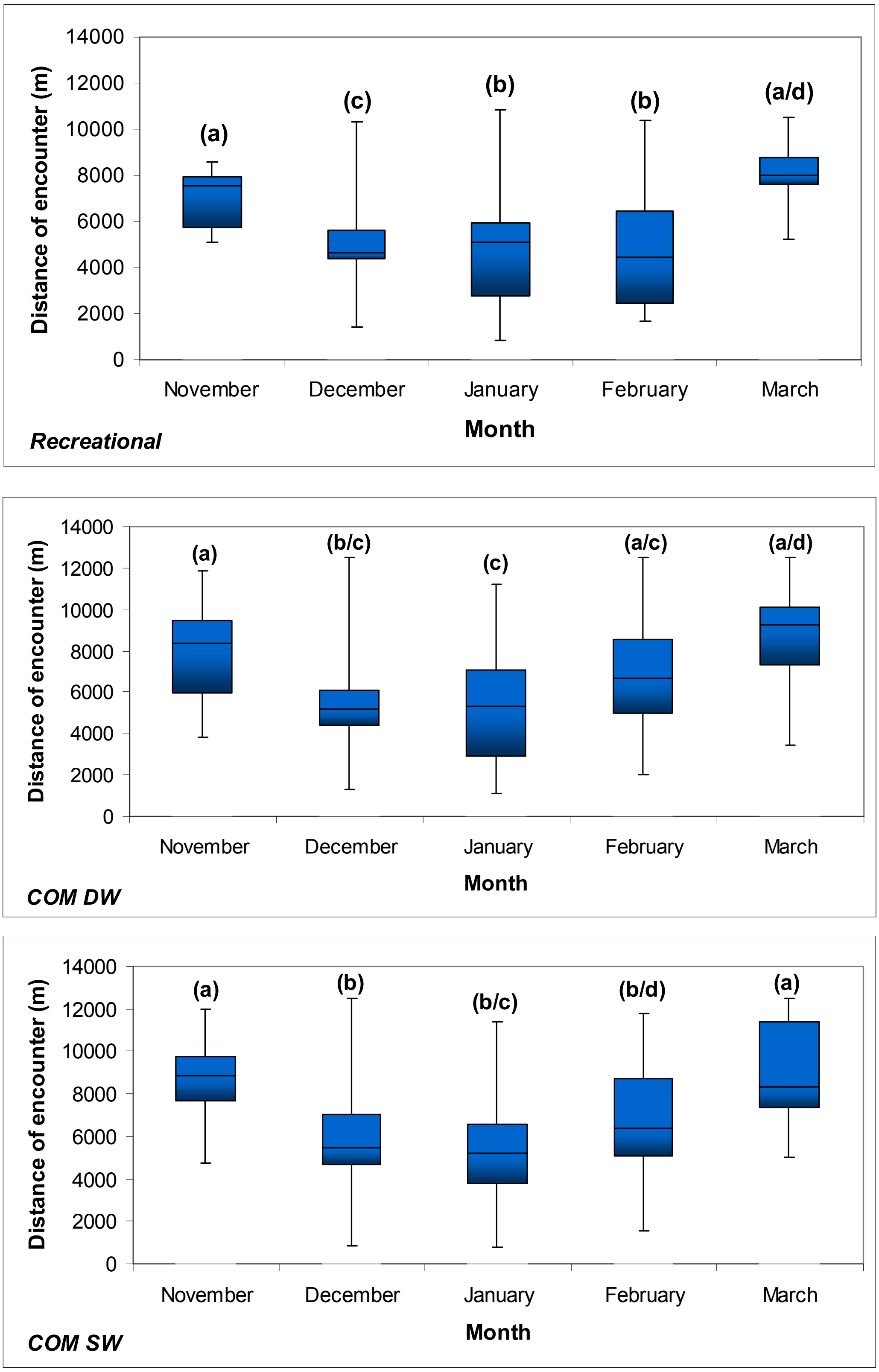


Fig. 3.19 Distance (m) of encounters from Akaroa township between Hector's dolphins and vessel type in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) (b) and (c) (d) indicate vessel speeds that were significantly different to other groups. COM = Commercial; DW = Dolphin-watching tours; SW = Swimming-with-dolphin trips.

In general, dolphin encounters with all vessels occurred significantly further away from Akaroa township in November, and again later in March, compared to other austral summer months ($p < 0.05$ or less).

Monthly differences were also evident when separately examining visually the distribution of encounters on density grid maps by each vessel type (Figs. 3.20 and 3.21). Encounters primarily occurred within the *mid* and *outer* harbour. Commercial vessels in particular, appeared to view and swim with Hector's dolphins more often between *9 Fathom* and the Kaik (Fig. 3.20). A similar trend was confirmed by density maps of encounters between dolphin groups and recreational vessels (Fig. 3.21).

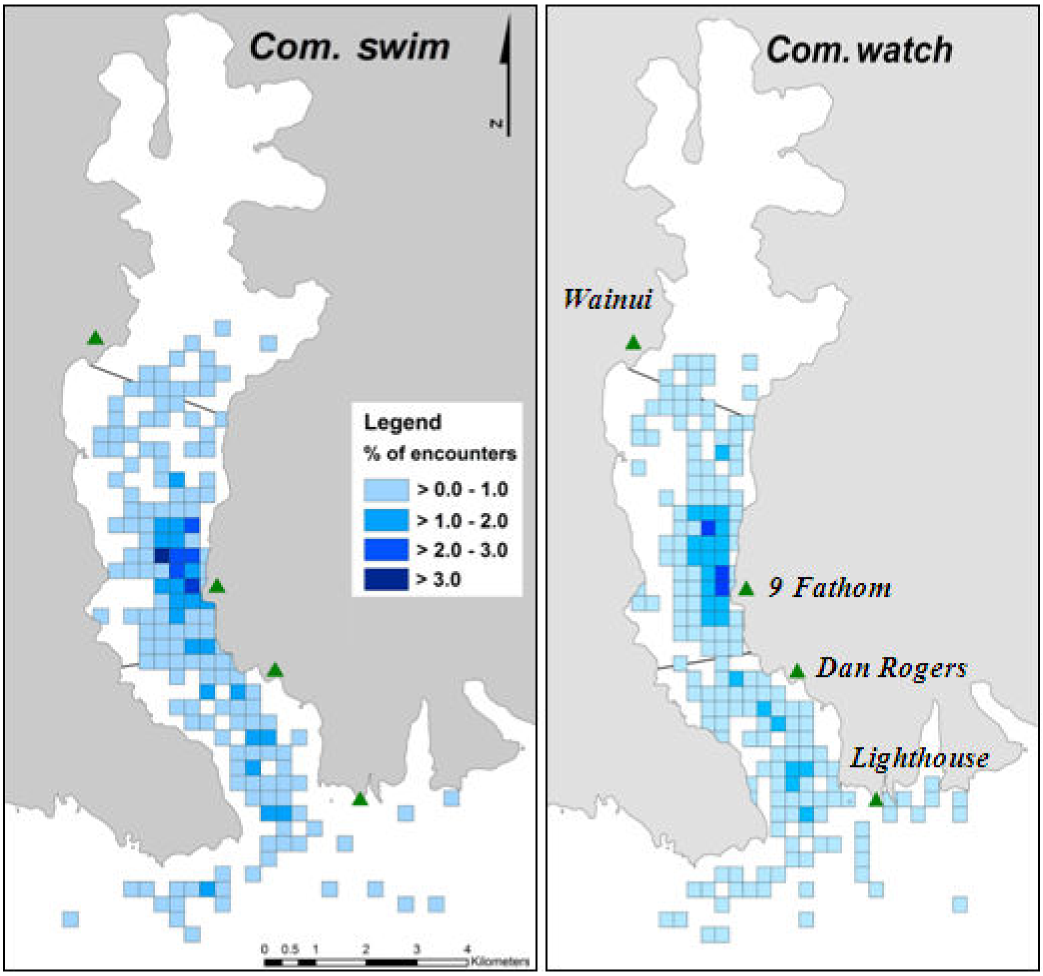


Fig. 3.20: Locations of swimming and dolphin-watching encounters with commercial tour operators in Akaroa Harbour, New Zealand, between November 2005 and March 2008. The colour of each quadrat varied in intensity according to the proportion of encounters within each cell. The four land-based stations are symbolised by green triangles. Note: COM = Commercial.

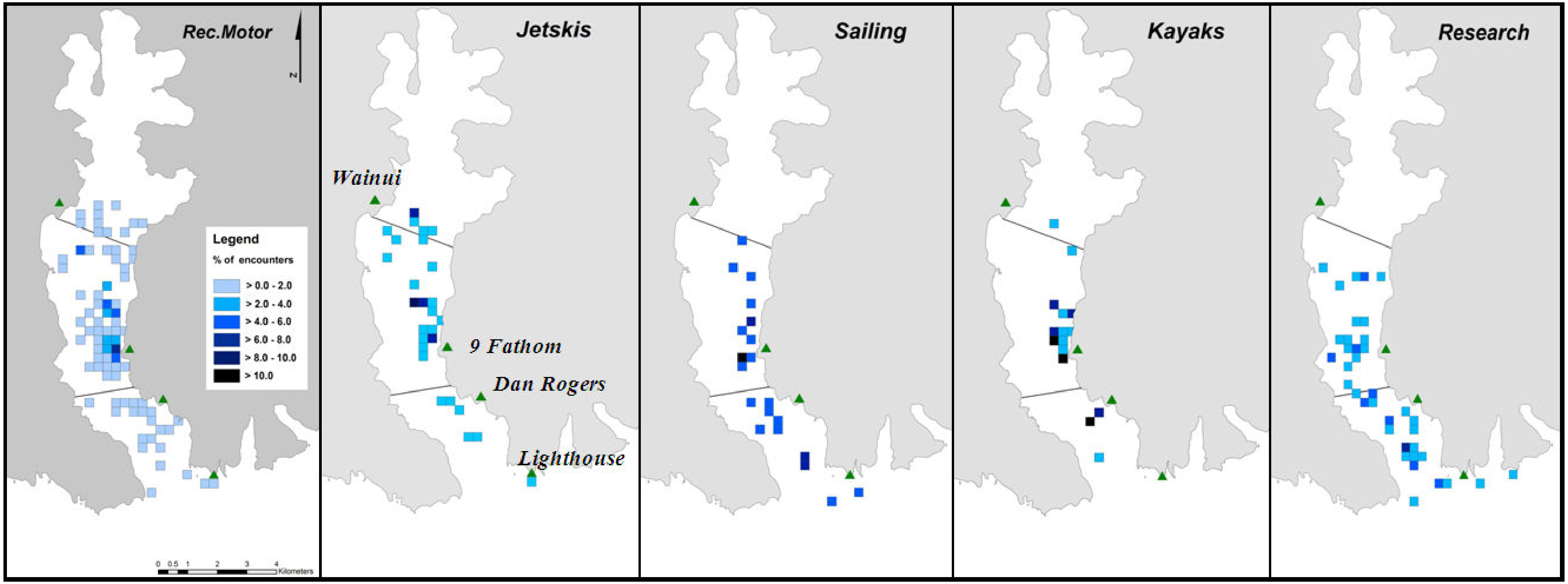


Fig. 3.21: Locations of encounters between Hector’s dolphins and different types of recreational and research vessels in Akaroa Harbour, New Zealand, between November 2005 and March 2008. The colour of each quadrat varied in intensity according to the proportion of encounters within each cell. The four land-based stations are symbolised by green triangles.

Pearson's χ^2 tests also indicated significant differences in the distribution of encounters within the harbour according to vessel type (χ^2_2 = 512.96, p < 0.0001). Overall, encounters were more likely to occur within the *mid* harbour and less so in the *inner* harbour as indicated by Freeman-Tukey deviates (Fig. 3.22).

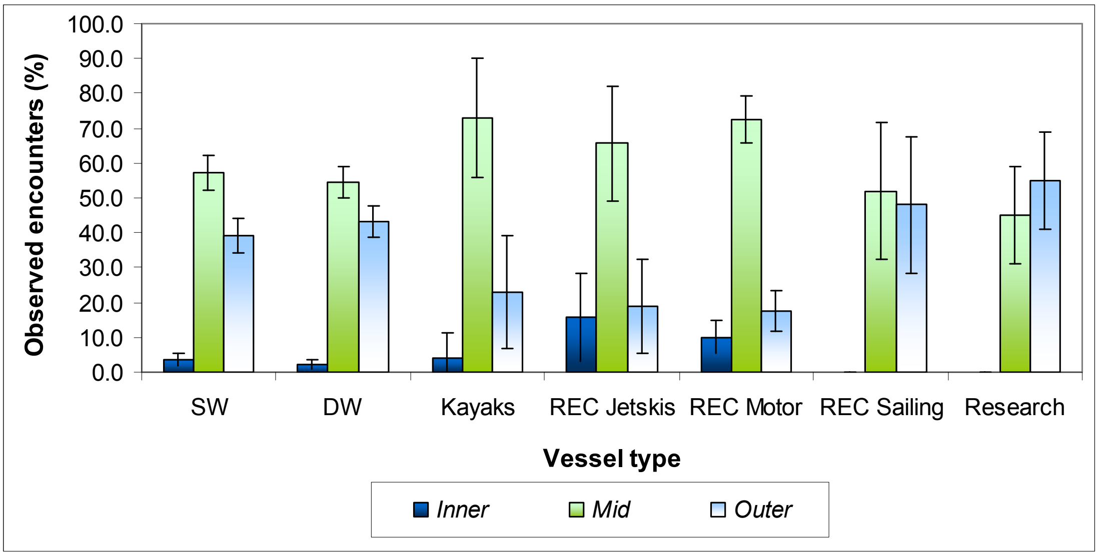


Fig. 3.22: Observed encounters (percentage) between Hector's dolphins and different categories of vessels in Akaroa Harbour according to the location within Akaroa Harbour, New Zealand between November 2005 and March 2008. Bars represent the 95% confidence intervals. Note: DW = Dolphin-watching tours; SW = Swimming-with-dolphin trips; REC = Recreational.

In the *outer* harbour, fewer encounters than expected occurred with all recreational vessel types (Freeman-Tukey deviates < -1), except sailing vessels. The converse was true for all commercial and research vessels (Table 3.9).

Table 3.9: Results of Pearson's χ^2 tests calculated for each vessel type, which encountered Hector's dolphins in Akaroa Harbour, New Zealand, between November 2005 and March 2008. Note: DW = Dolphin-watching; SW = Swimming-with-dolphins; RC = Recreational; and d.f. refers to statistical degrees of freedom.

Vessel type	χ^2 value	d.f.	P value*
SW	175.98	2	< 0.0001
DW	207.48	2	< 0.0001
Jetskis	15.06	2	0.0005
Kayaks	19.92	2	< 0.0001
RC Motor	111.8	2	< 0.0001
Sailing	12.56	2	0.0019
Research	25.27	2	< 0.0001

3.4.6.2. Monthly encounters with commercial tour operators

The monthly distribution of encounters between commercial tour vessels and Hector's dolphins was not homogeneous (Figs 3.23 and 3.24). Whether considering swimming (Fig 3.23) and dolphin-watching tours (Fig 3.24), density patterns clearly showed an inshore movement of encounters between November and March, with a higher occurrence of encounters within the *inner* harbour in January. Skippers of swim-with-dolphin trips had the tendency to initiate the search for dolphin groups on the eastern side (Fig. 3.25-3). As a consequence, more encounters were recorded on that side of the harbour as opposed to the western side (Fig. 3.25).

This monthly pattern in the distribution of encounters between Hector's dolphins and commercial dolphin-watching tours was further confirmed via a Pearson's test (χ^2_8 = 141.720, $p < 0.0001$) and was consistent with Fig. 3.19. The Freeman-Tukey deviates indicated encounters were more likely to occur within both the *inner* and *mid* harbour in December and January and less so in November, February, and March. A reverse trend applied to the *outer* harbour, with less encounters occurring in that area in January yet more than expected in November and March.

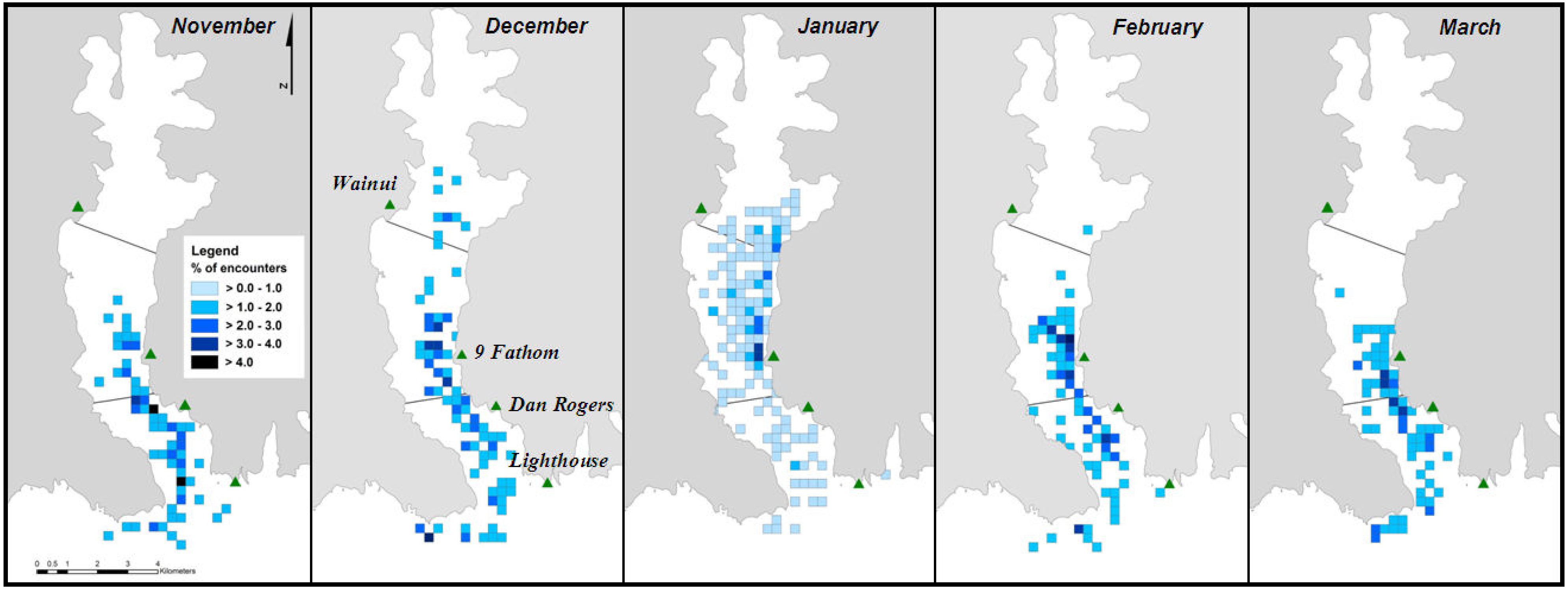


Fig. 3.23: Locations of commercial swim-with-dolphin encounters according to month in Akaroa Harbour, New Zealand, between November 2005 and March 2008. The colour of each quadrat varied in intensity according to the proportion of encounters within each cell. The four land-based stations are symbolised by green triangles.

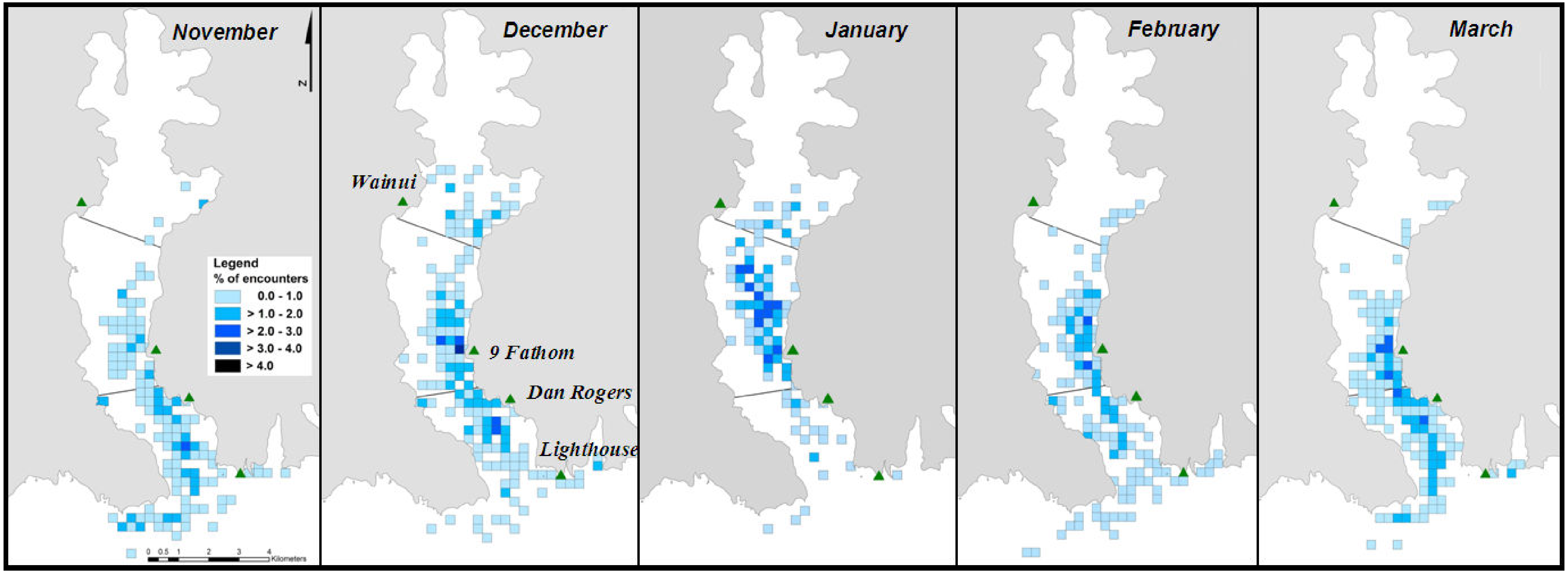


Fig. 3.24: Locations of commercial dolphin-watching encounters according to month in Akaroa Harbour, New Zealand, between November 2005 and March 2008. The colour of each quadrat varied in intensity according to the proportion of encounters within each cell. The four land-based stations are symbolised by green triangles.

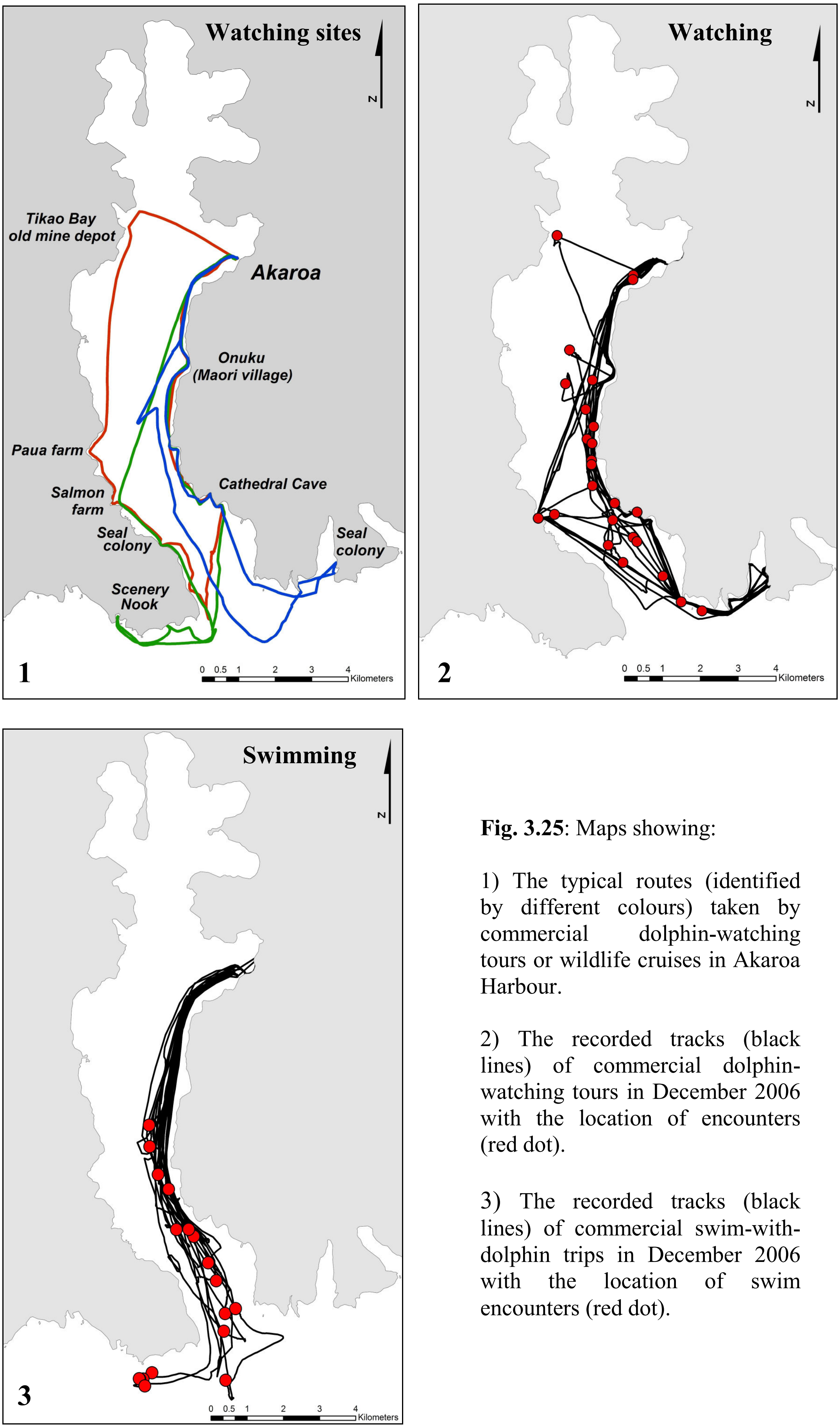


Fig. 3.25: Maps showing:

1) The typical routes (identified by different colours) taken by commercial dolphin-watching tours or wildlife cruises in Akaroa Harbour.

2) The recorded tracks (black lines) of commercial dolphin-watching tours in December 2006 with the location of encounters (red dot).

3) The recorded tracks (black lines) of commercial swim-with-dolphin trips in December 2006 with the location of swim encounters (red dot).

Encounters between commercial swim-with-dolphin trips and Hector's dolphins (Fig. 3.26) also varied significantly between months with location (χ^2_4 = 102.516, p < 0.0001). As swim-with-dolphin events were only observed in the *inner* harbour during December and January, the *inner* and *mid* sector of the harbour were combined and referred to as the middle harbour. Similarly to dolphin-watching tours, encounters were more likely to occur in the middle harbour in January than in November, December, and March (Freeman-Tukey deviates > 1). Conversely, the opposite trend was apparent in the *outer* harbour.

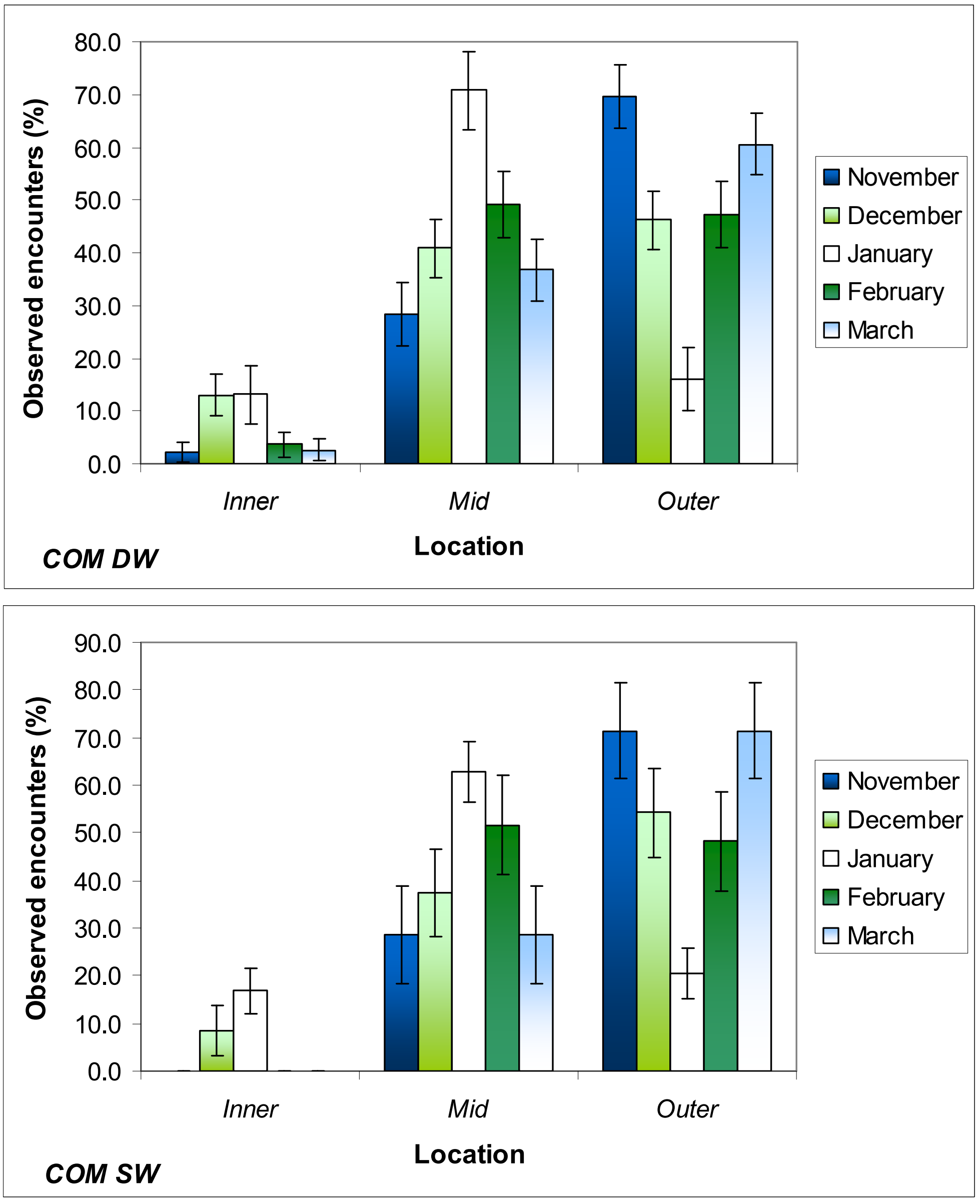


Fig. 3.26: Encounters (percentage) between commercial dolphin-watching or swimming-with-dolphin tours and Hector's dolphins according to month and location within Akaroa Harbour, New Zealand, between November 2005 and March 2008. Bars represent the 95% confidence intervals. Note: COM DW = Commercial dolphin-watching; COM SW = Commercial swimming-with-dolphin.

3.4.6.3. Encounters with mothers and calves

The distribution of encounters between vessels and groups containing calves varied significantly between the three sectors of the harbour (Pearson's χ^2 test: $\chi^2_2 = 72.1$, $p < 0.0001$). Encounters were less likely to occur within the *inner* harbour and more so within both the *mid* and *outer* harbour, as indicated by the Freeman-Tukey deviates. This trend was also evident from the density grid map (Fig. 3.27).

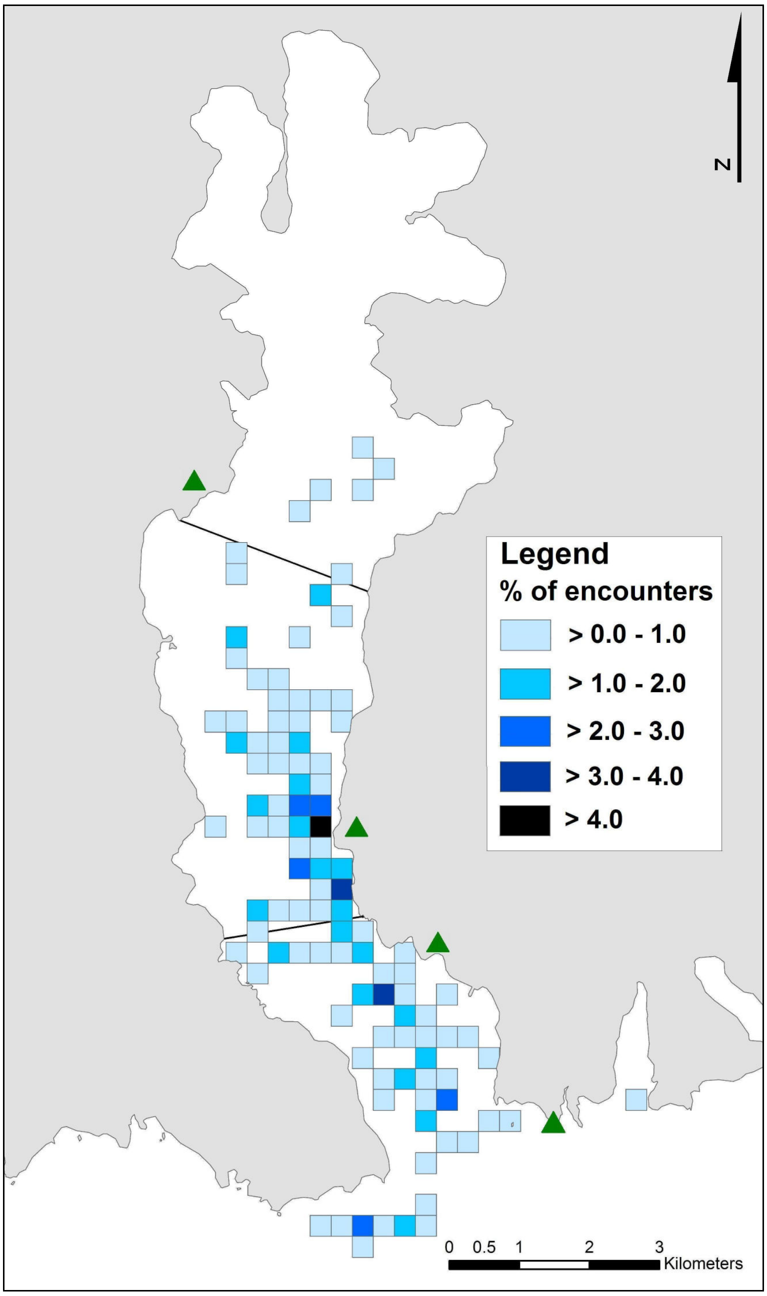


Fig. 3.27: Location of encounters between commercial vessels and Hector's dolphins (from one to multiple mother-calf pairs) in Akaroa Harbour, New Zealand, between November 2005 and March 2008. The colour of each quadrat varied in intensity according to the proportion of encounters within each cell. The four land-based stations are symbolised by green triangles.

A significant monthly variation in the location of encounters with calf groups was also detected (Fig. 3.28; $\chi^2_4 = 36.593$, $p < 0.0001$). In January, more encounters than expected (Freeman-Tukey deviates > 1) occurred in the middle harbour (*inner* and *mid* combined) and less than expected in the *outer* sector (Freeman-Tukey deviates < -1). The reverse trend was evident in March.

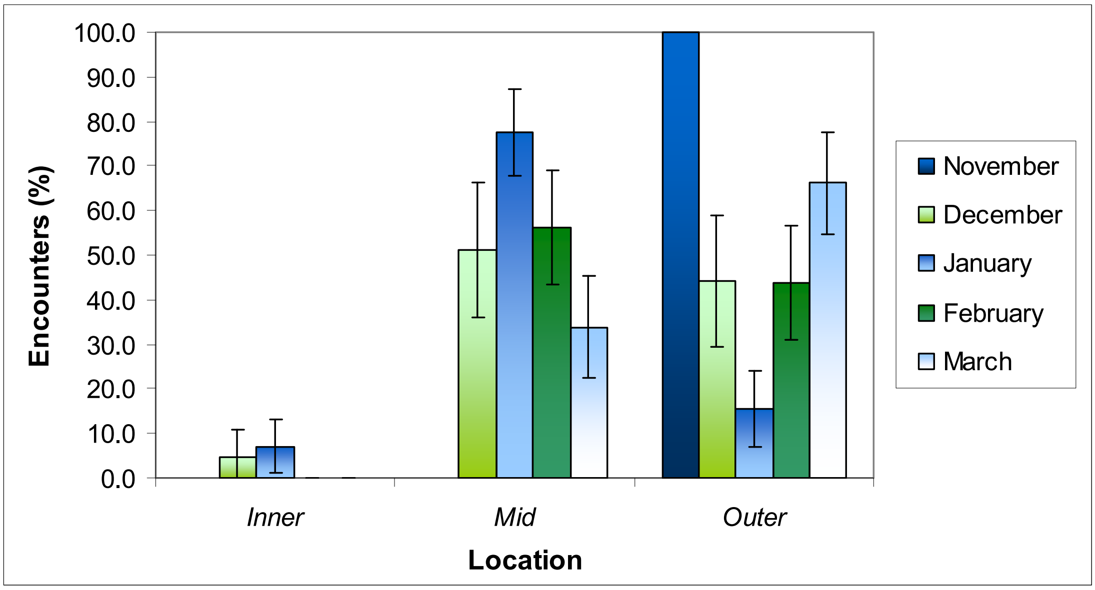


Fig. 3.28: Encounters (percentage) with Hector's dolphin mother and calves according to month and location within Akaroa Harbour, New Zealand, between November 2005 and March 2008. Bars represent the 95% confidence intervals.

3.5. Discussion

This chapter aimed to establish the frequency and intensity of vessel traffic that Hector's dolphins are exposed to in Akaroa Harbour prior to determining, in later chapters, whether the dolphin-based industry may potentially have any detrimental effects on these dolphins. Over the past 25 years, Akaroa has become one of the main destinations on the South Island to offer both dolphin-watching and swimming trips with the endemic and endangered Hector's dolphin (O'Connor *et al.*, 2009; Chapter I). Even though cetacean-watching has historically been considered benign (Hoyt, 1993), according to the IWC (2006a), it is no longer accepted that this is the case based on a growing body of literature demonstrating a variety of impacts in different locations and with a range of species (refer to Parsons *et al.*, 2006a,b; Scarpaci *et al.*, 2008, 2009, 2010 for reviews).

Vessel traffic

Vessel traffic is high within Akaroa Harbour as it is a popular domestic and tourism destination. Subsequently, Hector's dolphins were rarely (*ca.* 14%) observed in this harbour in the absence of vessels. While annual variations were evident, the proportion of time dolphin groups were sighted without vessels present remained below 15%. This proportion of daylight time was much lower than comparable locations, where this species is targeted by tourism activities (67% in Porpoise Bay: Green, 2003; and 73% in Motunau: Martinez, 2003). Regional differences can partially be explained by differences in the number of operators at each site. Only one operator was legally permitted to interact with Hector's dolphins in both Porpoise Bay and Motunau, the former offering up to three daily trips and the latter only one (Green, 2003; Martinez, 2003). In contrast, up to 18 swimming trips and eight dolphin-watching cruises were permitted in Akaroa Harbour by five independent operators. That number has since increased to 32 daily-trips (Allum, pers. comm.).

Unlike Porpoise Bay and Motunau, Akaroa is situated within 78 km of Christchurch, the largest city in the South Island and second largest in the country. The residential population in Akaroa increases from *ca.* 550 inhabitants in the winter to over 10,000 people in the summer (Fountain, 2002). Seventy percent of tourists are day-trippers who arrive just to undertake a particular local activity (including dolphin-watching/swimming trips), before departing to other destinations (Fountain, 2002). In addition, 69% of visitors to Akaroa are holiday homeowners (Fountain, 2002), of which a large proportion own a vessel. Green (2004) estimated that in the summer, approximately 150 vessels per day use Akaroa Harbour.

In the present study, the majority (73%) of the vessel traffic in Akaroa Harbour consisted of recreational vessels followed by commercial operators (21.6%), which is consistent with previous findings (Stone *et al.*, 1998; Nichols *et al.*, 2001). Both commercial and recreational traffic showed a remarkably similar trend in terms of greater vessel numbers between December and February, with a peak in January. This three-month period corresponds to the New Zealand summer holiday, and a corresponding rise in international visitors[1]. In 2008, 5% of overseas tourists to New

[1] http://www.stats.govt.nz/ (January to December 2007)

Zealand (or 111,000 people) took part in cetacean-watching activities (Ministry of Tourism, 2009). In contrast, there was no indication of monthly variation in the number of commercial fishing and research vessels because such platforms were not dependent on tourism or holiday periods.

Vessel traffic exhibited diurnal variations with most traffic occurring between 0900 and 1600 hr and peaking between 1200 and 1300 hr. Commercial fishing and research activities are primarily weather dependent. Consequently, they are more likely to be undertaken in the morning when the prevailing winds are generally more favourable. Most of the commercial vessel activity occurred between 0900 and 1700 hr, consistent with departure times of daily tours. A decline in commercial activity at 0600 and 1100 hr coincided either with a lack of demand and/or permissible daylight or when most vessels were docked and waiting for their next tour, respectively.

Recreational vessel numbers were also higher between 1000 and 1500 hr and during weekends, corresponding to the time when most people are likely to pursue their leisure interest. Stone *et al.* (1998) also reported a higher incidence of vessel activity during summer weekends in Akaroa Harbour, with 60% of the vessel traffic being recreational. As a result, Hector's dolphins' exposure to vessel traffic can be very high and exacerbated by staggered commercial tours and recreational activities, confirming Nichols *et al.* (2001) observations.

The usage of Akaroa Harbour by vessels was not homogeneous, with generally fewer vessels observed in the *outer* harbour sector. Recreational vessels made more use of the middle harbour, likely a consequence of the launching ramps and typically calmer waters. As a result, most encounters between dolphins and vessels occurred within that region of the harbour. Commercial vessels, particularly when providing swim-with-dolphin tours, showed a distinct pattern in their usage of the harbour. These vessels were found more in the *outer* harbour in November and March, but remained within the middle harbour over January.

This trend is consistent with the monthly distribution of Hector's dolphins within the harbour (Chapter II). This species exhibits a distinct inshore movement over the summer months (*e.g*. Dawson and Slooten, 1988; Bräger and Schneider, 1998; Bräger *et al.*, 2002; Clement, 2005; Slooten *et al.*, 2006a; Rayment *et al.*, 2010; Chapter II), which is clearly apparent in monthly locations of encounters between dolphin groups and commercial vessels. Hence, the January peak in vessel traffic coincides with a higher frequency of dolphin occurrence within middle and *inner* harbour regions (Chapter II; Dawson, 1991b).

Overall, this chapter demonstrated that dolphins within Akaroa Harbour were exposed to the greatest number of vessels around midday, during weekends, and in January, especially in the middle harbour. Encounters between commercial vessels and groups containing at least one calf were more frequent within the middle harbour, an area frequented regularly by nursery groups (Chapter II).

Vessel traffic has more than doubled since the 1990s (Stone and Yoshinaga, 2000), with indications that it has further increased since 2000 (Nichols *et al*., 2001). An 11.6% change in recreational traffic between 1999/2000 and 2005/2008 could be due to differences in sampling protocol and/or reflect an increase in human population (between 2001 and 2006, the population of Christchurch increased by 8%[2]) or tourist numbers (Ministry of Tourism, 2010).

International research has demonstrated that cetacean-watching can result in short-term declines in the use of disturbed habitats by particular cetacean species. The abundance of spinner dolphins (*Stenella longirostris*) in Hawaii declined as a result of tourism disturbance (Driscoll-Lind and Ostman-Lind, 1999; Forest, 1999; Samuels *et al.*, 2003). Bottlenose dolphins (*Tursiops* sp.) temporarily moved away during periods of heavy vessel activity near Clearwater, Florida (Allen and Read, 2000) and in Milford Sound, New Zealand (Lusseau, 2005a,b). A shift in the distribution of Hector's dolphins, closer to shore, was also detected in the presence of vessels in Motunau (Martinez, 2003) and in the presence of vessels and swimmers in Porpoise Bay (Green, 2003). Slooten and Dawson (1994), however, suggest that Hector's dolphins do not leave areas of high vessel traffic, concurring with the findings of Nichols *et al.* (2001). Akaroa Harbour is considered a core habitat for the Banks

[2] http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/SubnationalPopulationEstimates_HOTP30Jun07/Tables.aspx

Peninsula population (Bräger *et al.*, 2002; Clement, 2005; Rayment *et al.*, 2009; Chapter VII). Consequently, dolphins are unlikely to discontinue using the area until the costs of tolerance have exceeded the benefits of remaining in that preferred habitat. Indeed, when disturbed, animals must evaluate the costs and benefits of relocating to other less-disturbed locations. Such assessment is analogous to decision making under predation risk. The decision is influenced by availability, distance, and quality of suitable habitat elsewhere and the animal's condition and ability to cope or leave (*e.g*. Gill *et al*. 2001; Frid and Dill, 2002).

These findings raise the issue of individual tolerance to anthropogenic activities and whether de-sensitisation or habituation of dolphin responses to vessels may be occurring in the long-term. For example, as individuals become sensitised to specific stimuli, individual tolerance levels will decrease, while the reverse process applies to habituation. It is also important to consider the possibility that less tolerant individuals might have already been displaced. When individuals switch to long-term site avoidance in response to escalating disturbance, costs of tolerance have likely exceeded benefits of remaining in previously preferred habitat (Bejder *et al.*, 2009). This implies that any subsequent impact assessments would only measure the responses of more tolerant individuals using Akaroa Harbour at the time of sampling.

Encounter time

Stone *et al.* (1998) indicated that commercial vessels had the greatest potential for affecting Hector's dolphin's behaviour due to the extended time periods they spend with dolphin groups. This study concurs. Commercial vessels comprised 70.4% of the encounters observed while representing only 21.6% of the overall vessel traffic in Akaroa Harbour. Due to the nature of the commercial tourism business, their vessels also interacted significantly longer than any other vessel type, for example twice as long as any recreational vessel. Nichols *et al.* (2001) also reported a high rate of associations between commercial vessels and Hector's dolphins, although, the majority of encounters were with kayaks. This difference is probably due to the site location chosen by Nichols *et al.* (2001). Unlike this study, the study site used by Nichols did not encompass the entire harbour, but instead overlapped the area predominantly used by commercial kayak tours.

The constant and increased vessel presence, whether commercial or recreational, over a prolonged temporal scale may affect Hector's dolphin tolerance levels, potentially resulting in habituation as described previously. Baker (1978) and Cawthorn (1988) describe Hector's dolphin associations with vessels as brief while Stone and Yoshinaga (2000) noted that dolphins became more accustomed to the presence of vessels and swimmers over time in Akaroa Harbour. In 1999/2000, Nichols *et al.* (2002) estimated the average length of swim encounters at 23 min. Results of the present study offer no indication that Hector's dolphins have became less tolerant of swim-with-dolphin trips over time, given that this type of interaction lasted on average 25.2 min between 2005/2008.

It is also noteworthy to mention a significant monthly trend in the duration of swim events, with encounters lasting longer in November and gradually declining in duration towards March. In both January and February, dolphins are subject to the highest exposure levels with an average of 15 daily swim-with-dolphin trips out of the 18 permitted. Consequently, it is plausible that Hector's dolphins exhibit lower tolerance levels towards the end of the higher tourism period, a phenomenon also observed with dusky dolphins in Kaikoura (Markowitz *et al.*, 2009c). Alternatively, this monthly difference could be related to operators' decision to terminate an encounter (*i.e.* tighter schedules due to high demand leading to shorter encounters). Green (2004), however, reported that an operator noted that dolphins get "shyer" towards the end of the summer season, from February onwards. Therefore, this observation supports the former hypothesis. Both issues of tolerance and sensitisation towards swimmers during the austral summer months are discussed further in Chapter V.

Within the *Cephalorhynchus* genus, all species have positive reaction towards vessels, except for Chilean dolphins (*C. eutropia*) (*e.g*. Leatherwood *et al.*, 1988; Goodall *et al.*, 1988; Iñiguez, 1991; Iñiguez and Tossenberg, 1995; Ribeiro *et al.*, 2005). This response in addition to their coastal distribution, make Hector's dolphins an attractive target species for commercial tourism operations. Results presented herein quantify earlier anecdotal observations that Hector's dolphins are often associated with slower moving vessels (Baker, 1978; Cawthorn, 1988; Dawson and Slooten, 1988; Slooten and Dawson, 1994). This reaction was confirmed empirically with dolphins significantly avoiding faster vessels (> 6 kts). As described by Nichols *et al.* (2001), encounters lasted significantly longer with slow-moving kayaks or swim-with-dolphin vessel, in addition to sailing vessels. This is also consistent with other recent studies (Williams *et al.* 2002; Constantine *et al.* 2004; Lusseau, 2006; Hawkins and Gartside, 2009), which suggest the key component of a successful dolphin interaction is the constant predictability and non-invasive movement of the vessel during the encounter. Nichols *et al.* (2001) and Stone and Yoshinaga (2000) raised further concerns about the risk of collision with high speed vessels. There is indeed a potential risk in areas of high dolphin densities, such as the zone between the Kaik and *Dan Rogers* (Clement, 2005; Chapter II).

In 91.7% of the observed cumulative events, the maximum time limit of 90 min with the same dolphin group was respected. Compliance levels are, therefore, commendably high. While tour operators mostly adhere to the various conditions on their permits (Allum, 2009; Appendix 3.1), there is a common practice of "handing over" a group of dolphins to other commercial vessel, especially if that group is interactive. When struggling to find an interactive group, a skipper would contact other skippers out in the harbour, irrespective of company, via radio communication. That vessel would then typically join another vessel towards the end of an encounter and continue interacting with that group once the initial vessel had departed (pers. obs.). This practice has occurred since at least 1999 (Nichols *et al.*, 2001) and raises concerns about sustainability (*e.g.* potential cumulative impact).

More than one commercial vessel is likely to be observed interacting with dolphin groups especially between January and March, when vessel traffic is higher and swim encounters tend to be shorter (pers. obs.). Commercial vessels are also easily recognisable and often targeted by recreational vessels, acting as private dolphin-watching tours (Nichols *et al.*, 2001). The effect of multi-vessels encounters on Hector's dolphins is still unknown. However, in Kaikoura, an increase in vessel numbers interacting with dusky dolphins elicited the greatest response by dolphins (Markowitz *et al.*, 2009c). While not technically considered as a cumulative event, if a dolphin group has not been "handed over", the tendency of operators to return to the same area during the next trip, could further increase exposure levels of some individuals to human activities (Chapter VII).

3.6. Conclusion

In Akaroa harbour, the local community of Hector's dolphins is exposed to exceedingly high vessel traffic levels in the austral summer compared to other locations in New Zealand, with daily and monthly peaks in vessel activity coinciding with higher frequency of dolphin sightings. This is typical for delphinids living in coastal areas (*e.g*. Miller *et al*., 2008). An increase in human population may trigger a rise in vessel traffic, as depicted in an increase in the number of recreational vessels in Akaroa Harbour. Although these vessels only represent a quarter of actual encounters with dolphins, they contribute to the increased pressure Hector's dolphins experience. More importantly, recreational vessels are not always aware of the regulations in place to protect marine mammals in New Zealand, or may simply ignore them (Appendix 3.1). Adherence to guidelines has been demonstrated to reduce adverse reactions of dolphins during vessel interactions (*e.g*. Lusseau, 2006), hence their importance. Dolphins are often not the primary interest of most recreational vessels. Nevertheless, as such crafts traverse the harbour, noise pollution and an elevated risk of collision (Stone and Yoshinaga, 2000) can still be experienced by dolphins. The risk of collisions could be high in hot spot areas (Chapter II) if vessels travel at excessive speed.

The maximum number of commercial trips legally permitted has not yet been reached (Appendix 1.1) and, as a consequence, exposure levels are likely to further increase for Hector's dolphins in Akaroa Harbour. This is a concern given that low vessel traffic and tourism levels have been shown to affect Hector's dolphins' distribution, group cohesion and behaviour in other locations (*e.g*. Bejder *et al*., 1999; Green, 2003). Even apparently positive interactions could have long-term consequences for populations if they detract from critical behaviours such as foraging, socialising, and resting (Constantine, 2001). Akaroa Harbour is a critical area within the range of the Banks Peninsula population (*e.g*. Rayment *et al*., 2009). This may explain why Hector's dolphins have not been displaced from this region, despite high and potentially increasing vessel traffic levels. As such, it can be hypothesised that dolphins may remain in an area of vessel disturbance while changing behaviourally to minimise effects (*e.g*. Lusseau, 2003a).

CHAPTER IV

Short-term behavioural responses of the South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) to interactions with vessels in Akaroa Harbour, Banks Peninsula

Photo: A.R.E.V.A. Project © 2007.

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4.1. Introduction

Nature-based tourism is often described as one of the fastest growing sectors of the world's largest service industry (Balmford *et al.*, 2009). Cetacean-watching (herein defined as any commercial vessel tour interacting with cetacean species in the wild) is part of this global phenomenon (refer to chapter I, section 1.1.1., for further details). Responsible cetacean-watching is perceived as the most sustainable, environmentally friendly, and economically beneficial *use* of whales in the 21st century (O'Connor *et al.*, 2009). Research on the effects of cetacean-watching, however, clearly identifies that such tourism is not benign (*e.g.* Bejder *et al.*, 2006b; Lusseau and Bejder, 2007). Understanding and managing the potential effects of human activities such as cetacean-watching is now considered critical to the long-term conservation of targeted species. Consequently, over recent decades, considerable research effort has focused on attempting to detect the effects of tourism activities.

To illustrate, short-term responses of cetaceans to tourism/vessel traffic include variations in behavioural activity (*e.g.* Nowacek *et al.*, 2001; Lusseau, 2003a; Constantine *et al.*, 2004; Ribeiro *et al.*, 2005; Bain *et al.*, 2006; Williams *et al.*, 2006; Dans *et al.*, 2008; Stockin *et al.*, 2008a; Lusseau *et al.*, 2009; Christiansen *et al.*, 2010); group cohesion (*e.g.* Bejder *et al.*, 1999; Nowacek *et al.*, 2001; Ribeiro *et al.*, 2005; Miller *et al.*, 2008); dive intervals (*e.g.* Janik and Thompson, 1996; Nowacek *et al.*, 2001; Lusseau, 2003b; Richter *et al.*, 2006; Miller *et al.*, 2008); whistle production rates/vocalisation (*e.g.* Scarpaci *et al.*, 2000; Van Parijs and Corkeron, 2001; Buckstaff, 2004; Lemon *et al.*, 2006; Sousa-Lima and Clark, 2008); direction of travel (*e.g.* Goodwin and Cotton, 2004; Mattson *et al.*, 2005; Lusseau, 2006; Lemon *et al.*, 2006; Williams and Ashe, 2007), and habitat use (*e.g.* Sorensen *et al.*, 1984; Baker and Herman, 1989; Wells, 1993; Allen and Read, 2000; Ostman-Lind *et al.*, 2004; Lusseau, 2005b; Bejder *et al.*, 2006b).

Short-term responses are, however, usually difficult for managers to consider because their relationship to the biology and ecology of a population is seldom known (Lusseau, 2003a). The identification of the major factors related to the distribution and behaviour of a species is usually required before examining the role of disturbance in altering these relationships (Gill *et al.*, 1996). A prerequisite to comprehensively assess *disturbed* behaviour is detailed knowledge pertaining to *normal* behaviour. Unfortunately, such baseline data are still lacking for almost all cetacean species (Bejder and Samuels, 2003).

The long-term biological significance of these changes is difficult to establish and is a challenge facing tourism impact studies. Recently, a link between short-term effects and long-term biological consequences affecting viability and population fitness has been established, including a decline in dolphin abundance, displacement from preferred habitats or a reduction in energy acquisition potentially causing a decrease in reproductive success (*e.g.* Bejder *et al.*, 2006a,b; Lusseau *et al.*, 2006a; Williams *et al.*, 2006). In most situations, it remains unclear how short-term responses within a population can translate to long-term changes in reproduction or survival (*e.g.* Gill *et al.*, 2001).

Changes in behavioural activity can provide valuable information on the biological significance of an anthropogenic effect because the overall behavioural budget is directly related to the energy budget of individuals and populations. A novel approach using Markov chains can be applied to dependent variables to reveal how these relate in time. As a result, they have proven to be a valuable tool for ecological impact assessment (Hill and Caswell, 2001). Markov chains have recently been successfully applied to tourism impact assessment studies to detect potential effects of vessel interactions on the behavioural budget of the targeted population (*e.g.* Lusseau, 2003a; Bain *et al.*, 2006; Williams *et al.*, 2006; Dans *et al.*, 2008; Stockin *et al.*, 2008a; Lusseau *et al.*, 2009; Lundquist and Markowitz, 2009; Christiansen *et al.*, 2010).

New Zealand-based research indicates that increasing exposure to commercial tourism can be detrimental to coastal (*e.g.* Barr and Slooten, 1999; Bejder *et al.*, 1999; Lusseau, 2003a,b; Constantine *et al.*, 2004; Stockin *et al.*, 2008a) and deeper water species (*e.g.* Richter *et al.*, 2006; Neumann and Orams, 2005, 2006; Markowitz *et al.*, 2009a). Inshore species are particularly susceptible to human threats due to their more accessible distribution. The endangered and endemic (Reeves *et al.*, 2008) South Island Hector's dolphin (*Cephalorhynchus hectori hectori*, hereafter referred to as Hector's dolphin) is no exception.

Banks Peninsula is home to the largest population of Hector's dolphins on the South Island east coast, with an estimated 1,119 individuals (C.V. = 0.21; Gormley *et al.*, 2005). Akaroa Harbour is a key eco-tourism destination with up to 32 daily permitted trips to both view and swim with this species. The harbour is considered as one of the four main hotspots around the peninsula (Clement, 2005), with limited overlap of conspecifics between hotspots (Bräger *et al.*, 2002; Clement, 2005; Rayment *et al.*, 2009). This implies that not all individuals within this population are subject to tourism activities. The growth of this local industry has occurred despite a paucity of information on the effects of tourism on this population (Nichols *et al.*, 2001, 2002). The assessment of the potential effect of both recreational and commercial tourism activities has, therefore, important practical consequences for management. This study represents the first application of Markov chains to investigate the effects of tourism activities on the behaviour of Hector's dolphins.

4.2. Objectives

In order to investigate the effect of vessel traffic and tourism activities on the behavioural budget of Hector's dolphins in Akaroa Harbour, it is important to explore the following questions:

1) How do interactions with vessels affect the temporal dynamics of Hector's dolphin behavioural states?
2) How do these effects impact the dolphins' activity budget?

4.3. Materials and methods

4.3.1. Study site and observation platforms

Akaroa Harbour is situated on the southern side of Banks Peninsula, on the east coast South Island, New Zealand, at latitude 43° 50' S. The harbour is a natural inlet approximately 17 (kilometres) km in length with a predominantly north-south orientation (Heuff *et al.*, 2005; Fig. 2.1). Further details of the study area are provided in Chapter II (section 2.3.1.1). Land-based observations were conducted between November and March 2005/2006 to 2007/2008 from four different vantage points of varying height, covering most of the harbour (Fig. 4.1.; refer to Chapter II, section 2.3.1.2., for further details).

4.3.2. Data collection

Following methods described in Chapter II (section 2.3.2.), the study area was systematically scanned using Nikon or Tasco binoculars (7-10 x 50), a tripod-mounted Acuter spotting field scope (60x magnification), and a Sokkia Set 5 digital total station or theodolite (30x telescope). Observations were made between 0600 and 1800 hr, in six hour-blocks to prevent fatigue. Effort was limited to favourable environmental conditions, *i.e.* restricted to no precipitation and Beaufort Sea State (BSS) of two or less.

While focal individual follows offer clear advantages (Mann, 1999; Mann, 2000), this sampling technique was neither feasible nor appropriate for this study as Hector's dolphins have very few identifying scars (Slooten *et al*., 1992; Chapter VII). Distance from dolphin groups made individual follows impossible. As a result, focal group follows (Mann, 1999) were used to determine the effect of vessel interactions on the behaviour of dolphins. A group was defined as individuals located in close proximity (less than five body lengths or approximately less than 10 metres - m) from one another (Smolker *et al*., 1992).

Once a dolphin group was detected, individuals within a group were observed continuously and the behavioural state recorded at three-minute intervals using focal-group scan sampling (Altmann, 1974; Chapter II, section 2.3.2.1). The predominant behavioural state of the focal group was defined as the activity in which 50% or more of group members were simultaneously engaged. In the present study, widely accepted categories of behavioural states (Shane, 1990a) were adopted to allow inter-species comparisons (Table 4.1). Additionally, discrete behavioural events (*e.g.* aerial, sexual) previously described for Hector's dolphin (Slooten, 1994) were also incorporated in the behavioural state definitions used within this study. All states were defined to be mutually exclusive and cumulatively inclusive, describing the daytime behavioural repertoire of the Hector's dolphins. Resting was only observed on five separate occasions during the study and, therefore, was excluded from analysis. Hector's dolphins might engage in resting at night, however, the nocturnal behaviour of this species is unknown.

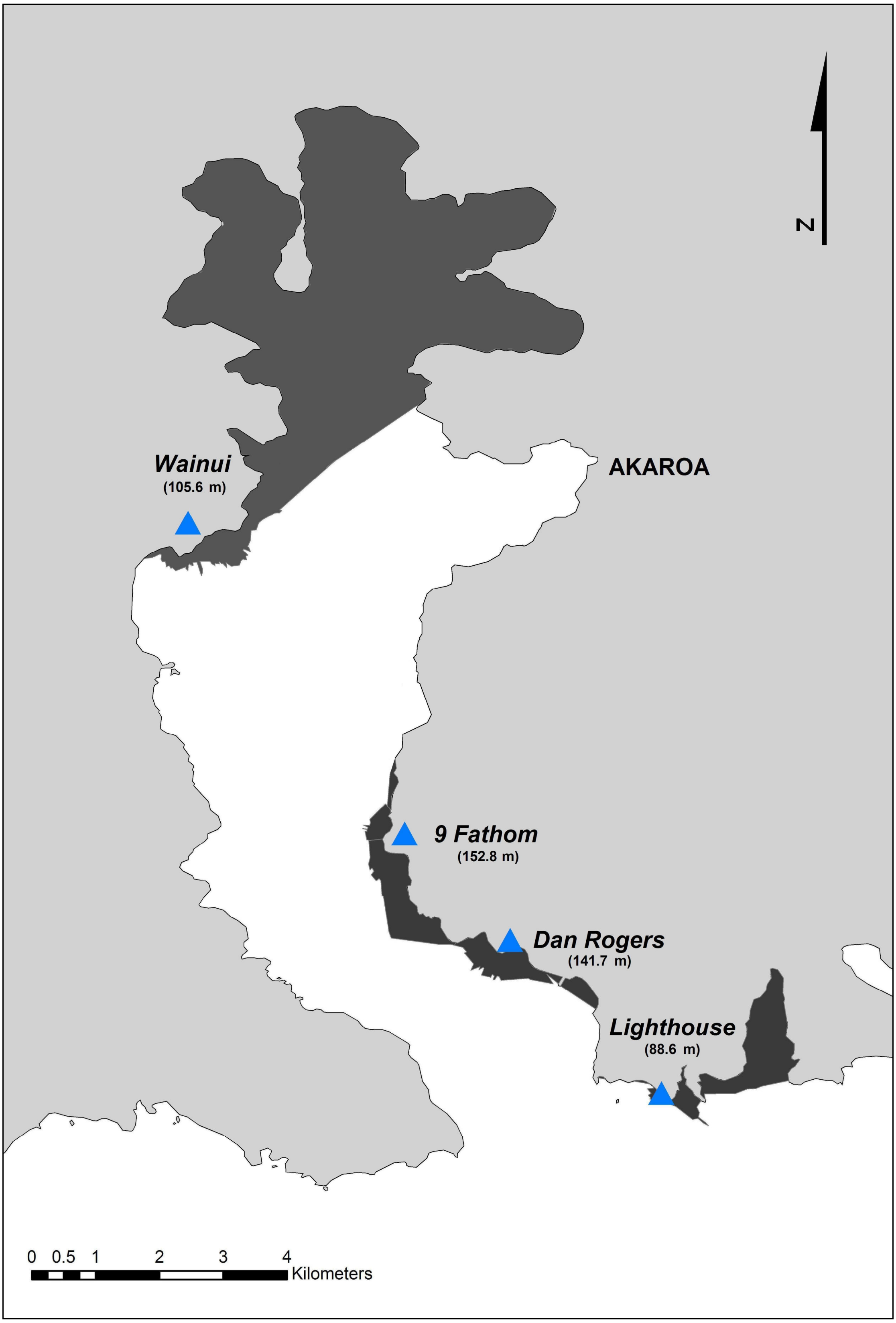


Fig. 4.1: Map showing the location of the four land-based stations (blue triangle) within Akaroa Harbour. The shaded areas represent parts of the harbour that were out of view from the stations. The inner part of the harbour (shaded area furthest north) was not taken into consideration in this study due to low sighting rates (Dawson, 1991b).

Hector's dolphins are attracted to vessels (Slooten and Dawson, 1994; Chapter III) and often engage in bow-riding (9.4% of *close* behavioural sequences recorded). Given that this behavioural event can only be recorded in the presence of vessels and could equally be classified into a socialising or travelling state, it was not included into the analysis.

Group follows ended when the focal group was lost, out of sight or weather conditions prevented data collection. The end of a sequence of observations was, therefore, not dependent on the behaviour of the focal group or the ability to observe more discrete behaviours.

Table 4.1: Definitions of the behavioural state categories used in the present study in Akaroa Harbour, New Zealand (derived from Shane 1990a; Slooten, 1994). Mother-calf pair behaviour was based on the behavioural state of the mother.

State (abbreviation)	Definition
Milling (MIL)	Dolphins exhibited non-directional movement, with frequent changes in heading. No net movement. Group spacing and dive interval vary but are less than 1 min for the latter.
Diving (DIV)	Dolphins' direction of movement varies. Groups dive for prolonged intervals (> 1 min) often arching their backs at the surface to increase speed of descent. Group spacing varies. The presence of birds diving close to a group is also indicative of diving behaviour. Note - this represents the "feeding/foraging" category in other studies.
Socialising (SOC)	Dolphins observed chasing and/or engaged in any other physical contact with other individuals in the group. Aerial, sexual, and aggressive behaviours are frequently observed. Group is often split into small subgroups spread over a large area. Dive intervals vary. No obvious forward movement.
Travelling (TRA)	Dolphins engaged in persistent, directional movement, swimming with short, relatively constant dive intervals. Group spacing varies.
Resting (RES)	Dolphins engaged in slow movements (*i.e.* less than 1.5 km/hr) in a constant direction, with little evidence of forward propulsion. Dolphins were occasionally stationary. Dive intervals were short, relatively constant, and synchronous. Group spacing is tight (*i.e.* less than one body length between individuals). Resting lacked the active components of the other behaviours described.

4.3.3. Description of interactions between vessels and Hector's dolphins

Akaroa (43.81º S, 172.97º E), located within the harbour, is the home-base of five permitted commercial tour operators. During daylight hours between November and March, Hector's dolphins are exposed to high levels of vessel traffic. During that period, traffic in the harbour consists primarily of recreational vessels (72.9%), followed by commercial tour vessels (21.6%) (Chapter III, section 3.4.2). Commercial fishing charters and research vessels represent only a very small proportion of the actual traffic (Chapter III). Consequently, only the effects of both recreational and commercial vessels were examined here.

Behavioural observations were classified into the same three categories defined in Chapter II (Table 2.2), *i.e. control*, *distant*, and *close*[1]. *Close* behavioural sequences corresponded to the time vessels spent within 300 m of a focal dolphin group and were considered to be interacting with the dolphins. When possible, *close* sequences or chains were further divided into several treatments taking into consideration vessel type (commercial and non-commercial) and vessel numbers (one or more than one vessel). The distance of 300 m was selected in accordance with the New Zealand Marine Mammals Protection Regulations to distinguish between the *distant* and *close* categories (MMPR, 1992; Appendix 1.4). Distances were measured between theodolite fixes using the software *Cyclopes 2004* version 3.121 (© 2004, University of Newcastle, Australia). Theodolite fixes were taken at the centre of the focal group approximately every 60 seconds (sec). When vessel(s) were present, fixes were taken alternatively between the vessel and the focal dolphin group (Würsig *et al*., 1991).

4.3.4. Development of Markov chains

Consecutive behavioural observations are unlikely to be statistically independent (Glass *et al*., 1975). As a result behavioural observations in this study were modelled as a series of time-discrete Markov chains (Markov, 1906; Bakeman and Gottman, 1997). First-order Markov chains quantify the dependence of an "event" on preceding "events", here behavioural states (refer to Guttorp, 1995 and Caswell, 2001 for further

[1] *Distant* corresponds to *potential impact* category and *close* to *impact* in other studies (*e.g.* Bejder *et al*., 1999; Lusseau, 2003a).

details). Transition probabilities (*i.e.* the probability of a specific activity occurring, given the occurrence of another activity) can conform to a stochastic matrix model. These models have been recently applied to conservation behaviour, including cetacean tourism impact studies, to detect which behavioural states are more likely to be affected as a result of tourism activities (*e.g.* Lusseau, 2003a; Bain *et al.*, 2006; Williams *et al.*, 2006; Dans *et al.*, 2008; Stockin *et al.*, 2008a; Lundquist and Markowitz, 2009; Lusseau *et al.*, 2009; Christiansen *et al.*, 2010).

Matrices or two-way contingency tables were developed by classifying behavioural states according to the activity at the previous three-minute interval (preceding event), the activity at the interval (succeeding event), and the presence or absence of vessel(s) (*control*, *distant* or *close*), as described in Lusseau (2003a). For example, a transition between two behavioural events was tallied in a *control* matrix if no vessel interaction occurred between these two events. When a situation changed between succeeding events (*e.g.* *control* to *close*), however, the transition between them was discarded because it could neither be considered as part of a *control* or *close* chain. The programme UNCERT[2] was used to facilitate the development of the two-way contingency tables.

4.3.5. Data analysis

4.3.5.1. Assumptions

Before analysing the data using Markov chains, it is necessary to estimate the order of Markov chain. To determine whether a first-order relationship exists in the transitions, the first-order chain must provide more information than a zero-order chain. Following assumptions detailed by Lusseau (2003a), the amount of information contained in zero-order and first-order chains was compared using a Bayes Information Criterion (BIC). A BIC quantifies the amount of data variation explained by the model and penalises models for the number of parameters used to explain the data. A BIC, therefore, quantifies the most parsimonious model. It is a consistent estimate of the order of Markov chain (Katz, 1981). The higher the BIC, the more information the order provides on the sequences (Guttorp, 1995).

[2] available from http://uncert.mines.edu

The fit of each Markov chain model is given by:

$$BIC = 2l(\theta|data) - k\ln(n) \qquad (1)$$

where $l(\theta|data)$ is the value of the maximised log-likelihood over the unknown parameter (θ), given the model and the data set; k is the number of parameters used in the chain, and n is the sample size (Guttorp, 1995). A BIC difference between the chain orders must be equal to or above 2 log 100 (= 9.2) to determine the best chain (Guttorp, 1995).

Log-linear analysis was applied using SPSS 15.0 (SPSS) to assess the independence of the behavioural transitions for all combinations of parameters and interactions between parameters. The maximum likelihood for the model being tested is approximated by G^2. The difference in goodness of fit ($\Delta G^2 = G^2_{2\ way} - G^2_{saturated}$) between the saturated model and the model considering all the two-way interactions approximates the effect of the missing parameter (Lusseau, 2003a). Degrees of freedom represent the difference in degrees of freedom between the two models. Evaluating the significance of this difference determines which parameters compose the most parsimonious model.

4.3.5.2. Markov chain modelling

As reported in Lusseau (2003a), transition probabilities (from preceding to succeeding behaviour) were determined in all chains by:

$$p_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}, \sum_{j=1}^{n} p_{ij} = 1 \qquad (2)$$

where i is the preceding behavioural state, j is the succeeding behavioural state, p_{ij} is defined as the transition probability from behaviour i to behaviour j in the Markov chain, a_{ij} is the number of transitions observed from behavioural state i to j, and n is the total number of behavioural states (in this study four). *Control*, *distant*, and *close* transitions probabilities were calculated separately using equation (2) and compared by pairs using Z-test for proportions (Fleiss, 1981). Assembling matrices by the different number and type of vessels (commercial or recreational) allowed testing for changes relative to these variables.

To assess the effect of vessel interactions on the behavioural states of the dolphins, the average time (minutes) it took the dolphins to return to each initial behavioural state was calculated. The expected number of transitions it took the dolphins to return to a particular behavioural state was first approximated for all chains (Higgins and Keller-McNulty, 1995) using the following equation:

$$E(T_j) = \frac{1}{\pi_j} \tag{3}$$

where (T_j) denotes the time (*i.e.* number of transitions) it takes to return to state j given that the dolphins are currently in state j, and π is the steady-state probability of each behaviour in the chain. The expected number of transitions (Equation 3) was multiplied by the length of each transition unit (*i.e.* three minutes) to calculate the average time it took the dolphins to return to each initial behavioural state. Average times were then compared between *control* and *distant* or *close* conditions.

The average bout length (or period of time spent in each behavioural state) $\overline{t_{ii}}$ was approximated for all chains (in minute) from the mean of the geometric distribution of p_{ii} (Guttorp, 1995) using equation (4):

$$\overline{t_{ii}} = \frac{1}{1 - p_{ii}} \tag{4}$$

with a standard error of:

$$SE = \sqrt{\frac{p_{ii} \times (1 - p_{ii})}{n_i}} \tag{5}$$

where n_i is the number of samples with i as preceding behaviour. The average bout length for each state was subsequently compared for between chains using a Student's *t*-test.

Finally, using Markov chains, it is possible to derive the respective behavioural budget of Hector's dolphins (or proportion of time dolphins engaged in each behavioural state) in *control*, *distant*, and *close* chains (Lusseau, 2003a). Following the Perron-Frobenius theorem (Caswell, 2001), the behavioural budget under each condition was approximated by the left eigenvector of the dominant eigenvalue of the transition matrices using the Excel add-in PopTools (Version 3.0, CSIRO: www.poptools.org). Differences between *control*, *distant*, and *close* behavioural budgets were tested with a binomial Z-test for proportions (Fleiss, 1981) by comparing each behavioural state in a *control* budget to its corresponding state in *distant* and *close* budgets. The 95% confidence intervals (C.I.) were then calculated or the estimated proportion of time spent in each behavioural state. Any observed difference in the budget was inherent to the presence of vessels.

4.3.5.3. Forecast modelling

Using methods detailed in Lusseau (2004a), it was possible to the effects of vessel interactions on the overall daytime behavioural budget of Hector's dolphins. This in turn will assist our understanding of the potential biological significance of these observed effects. From land-observations, it is known how much time dolphins were observed in the presence of vessels (*i.e.* both *distant* and *close* behavioural budgets - Chapter III, section 3.4.1). As a result, a cumulative behavioural budget can be calculated by adding the proportion of time (ranging from 0 to 1) dolphins spent under a *control* (BB_c), *distant* (BB_d), and *close* (BB_{cl}) condition. The dolphin cumulative behavioural budget (BB_{cum}) equals to:

$$BB_{cum} = (T_c \times BB_c) + (T_d \times BB_d) + (T_{cl} \times BB_{cl}) \qquad (6)$$

where T is the percentage of time dolphins were observed within a given condition.

Presuming vessel traffic (T_d) stays constant, then the remaining proportion of time dolphins spend in the absence of vessels (T_c) is equal to $1 - T_d - T_{cl}$. Assuming changes are linear and do not vary with daytime exposure rate, it is then possible to calculate at what level of vessel traffic and interaction intensity the cumulative behavioural budget becomes different from the *control* budget. This was achieved by manipulating the amount of time dolphins spent with vessels from 0% to 100% (Lusseau, 2004). The difference between cumulative behavioural and *control* budgets was tested with a *Z*-ratio test for proportions (Fleiss, 1981) for each behavioural state.

4.4. Results

4.4.1. Field effort

Between November 2005 and March 2008, a total of 631.7 hours (hr) over 166 days was spent searching for Hector's dolphin groups. Overall, dolphin groups were observed for 222.5 hr over 144 days from the different land-based stations. Hector's dolphins spent 13.8%, 51.0%, and 35.2% of the observed time under a *control*, *distant*, and *close* condition, respectively (Chapter III, section 3.4.1). This corresponds to a total of 2,359 behavioural transitions, of which 290, 1,143, and 926 were classified as *control*, *distant*, and *close*, respectively. These transitions were collected over 54 *control*, 183 *distant*, and 93 *close* sequences (consisting of a minimum of four transitions), which varied in time duration (Table 4.2).

Table 4.2: Descriptive statistics of the duration (min) of *control*, *distant*, and *close* sequences collected in Akaroa Harbour, New Zealand, between November 2005 and March 2008.

Chain	**Median (min)**	**Range**	**25th and 75th Interquartile range**	**n**
Control	13.8	10.8 - 42.5	10.6 - 16.0	54
Distant	15.2	10.3 - 62.6	11.3 - 21.8	183
Close	20.8	26.7 - 73.3	12.8 - 41.6	93

4.4.2. Assumptions of Markov chains

All first-order transitions in behavioural state provided more information than the sole frequency distribution of the behavioural states (*i.e.* zero-order chain), except for those recorded in the presence of non-commercial vessels and more than one vessel (Table 4.3).

Transitions in behavioural states were stable over time ($\Delta G^2 = 156.07$, d.f. = 21, p = 0.264) as the likelihood-ratio test between the saturated model and the two-way interaction model (*i.e.* the goodness of fit of the two-way interaction model) was not significant.

Table 4.3: Chain order selection using Bayes Information Criterion (BIC). A higher order chain provides more information than a lower chain order if ΔBIC > 2log100 (= 9.2).

Chain	Chain order	BIC	ΔBIC
Control	0	-340.002	
Control	1	-313.080	26.922
Distant	0	-1362.28	
Distant	1	-1060.32	301.960
Close	0	-882.384	
Close	1	-806.134	76.250
Commercial vessel	0	-535.734	
Commercial vessel	1	-521.077	14.657
Non-commercial vessel	0	-266.912	
Non-commercial vessel	1	-270.275	-3.363
One vessel only	0	-706.81	
One vessel only	1	-643.741	63.069
More than one vessel	0	-175.221	
More than one vessel	1	-203.715	-28.493

4.4.3. Effect of vessel presence and interactions

4.4.3.1. Transition probabilities

Transition probabilities are presented in Fig 4.2. Despite the preceding behavioural state, the most probable succeeding state was the same state, with two exceptions under a *close* condition (refer to the behavioural schematics in Fig 4.2). Milling typically succeeded all other states, but more so under a *close* condition.

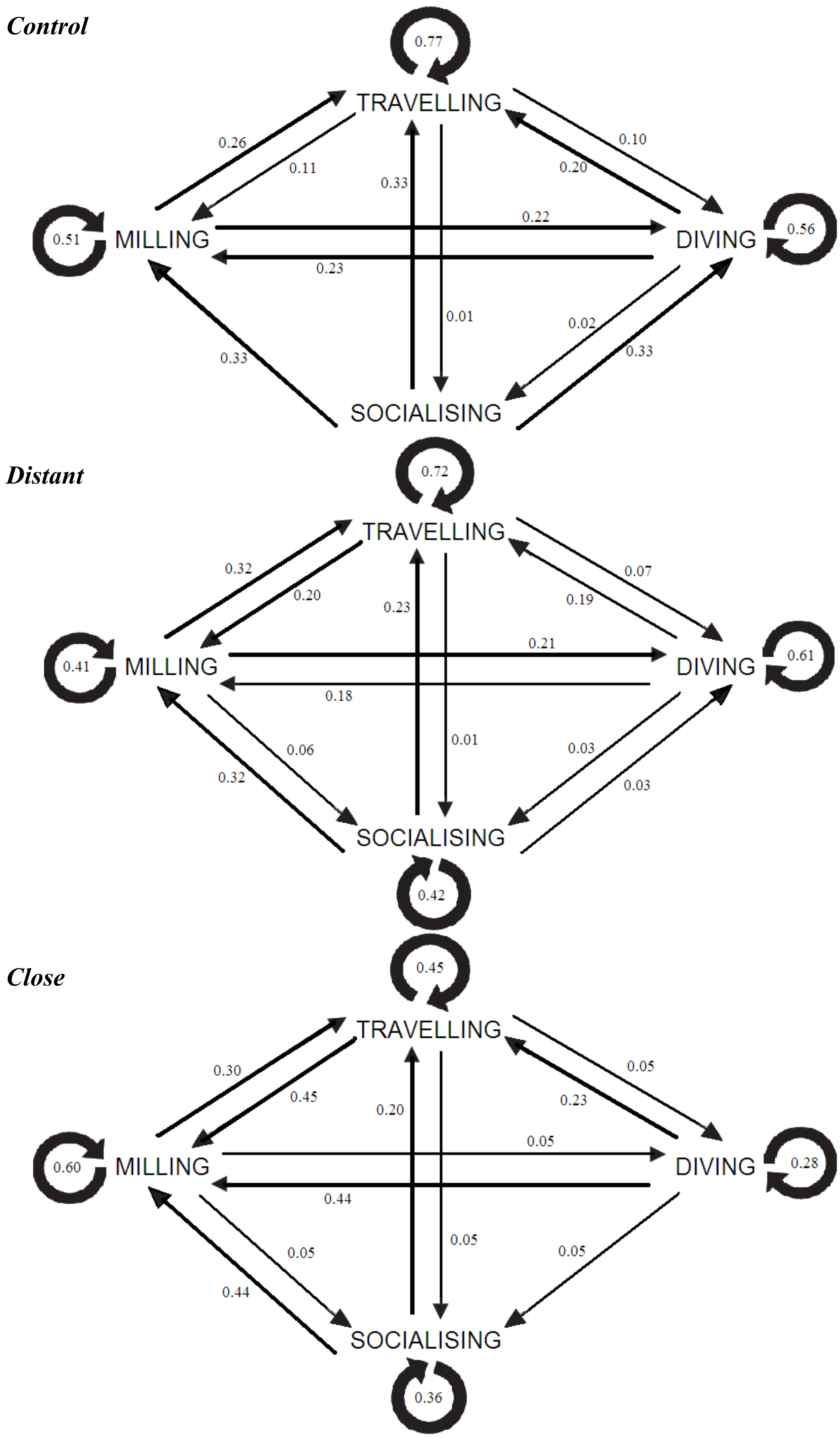


Fig. 4.2: Transition probabilities in *control*, *distant,* and *close* chains. The behavioural states are defined in Table 4.1. Values represent transition probabilities.

Vessel presence and interactions had a significant effect on behavioural state transitions (ΔG^2 = 1189.2, d.f. = 39, p < 0.001). This effect was not homogeneous throughout all transitions and among *distant* and *close* conditions. Overall, the transitions Tra → Mil (Z-test: z = -2.65, p = 0.008), Mil → Soc (z = -4.26, p < 0.0001), and Soc → Soc (z = -6.55, < 0.0001), all significantly increased by 8.2%, 6.2%, and 41.7%, respectively (Figs. 4.3a)

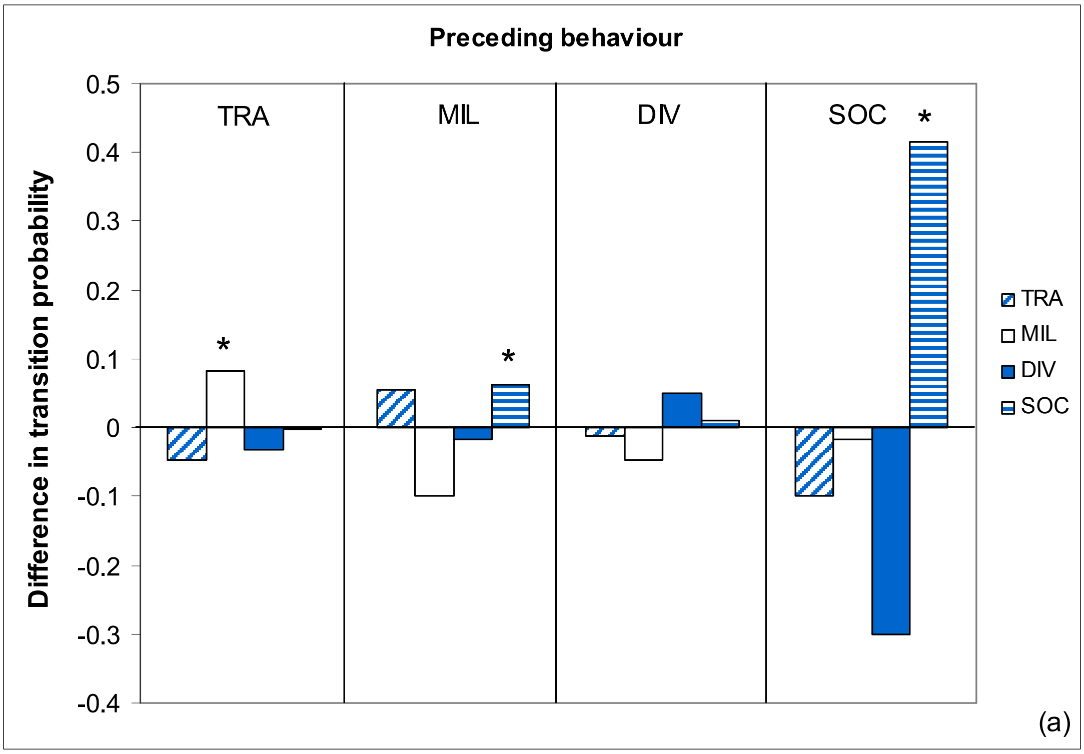


Fig. 4.3a: Effect of vessel presence (> 300 m) on transitions in behavioural state of Hector's dolphins in Akaroa Harbour, New Zealand, based on differences in transition probabilities ($p_{ij(distant)} - p_{ij(control)}$). A negative value means that the behavioural transition of the *control* chain is superior to the *distant* chain. Bars correspond to succeeding behavioural states. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising). Significant differences between transitions (p < 0.05) are denoted by an (*). The behavioural states are defined in Table 4.1.

Under a *close* condition, a further five transitions were significantly affected (Fig. 4.3b). In addition to the transitions already discussed, the transition Tra → Soc increased by 3.4% (z = -2.14, p = 0.033) and Div → Mil by 21.5% (z = -2.34, p = 0.021). Conversely, three transitions significantly decreased Tra → Tra (z = 7.07, p < 0.0001), Div → Div (z = 3.07, p = 0.006), and Mil → Div (z = 3.40, p < 0.001) as a result of vessel interactions by 32.3%, 28.2%, and 17.0%, respectively. These results indicate a shift in the behavioural state of Hector's dolphins from travelling or diving to milling or socialising.

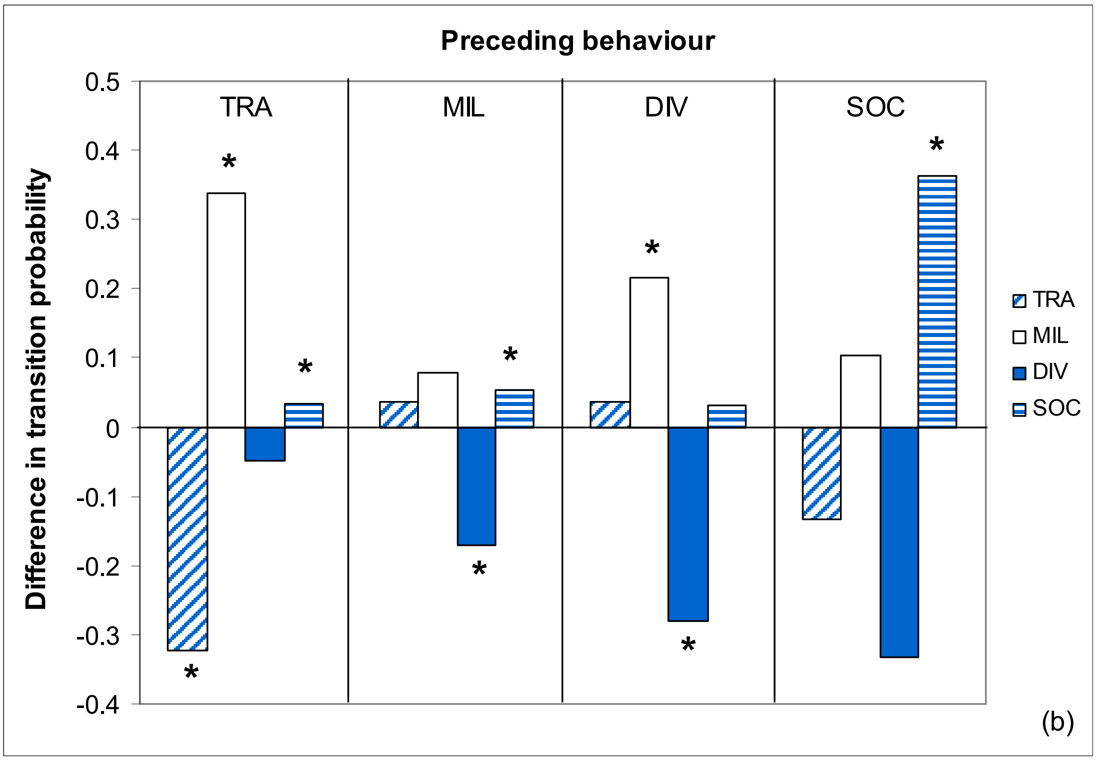


Fig. 4.3b: Effect of vessel presence within 300 m of a group on transitions in behavioural state of Hector's dolphins in Akaroa Harbour, New Zealand, based on differences in transition probabilities ($p_{ij(close)} - p_{ij(control)}$). A negative value means that the behavioural transition of the *control* chain is superior to the *close* chain. Bars correspond to succeeding behavioural states. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising). Significant differences between transitions ($p < 0.05$) are denoted by an (*). The behavioural states are defined in Table 4.1.

4.4.3.2. Probability of staying in a given state and average time required to return to that state once disrupted

The average time taken for Hector's dolphins to return to their initial behavioural state was altered in the presence of vessels (*distant* and *close* conditions). Generally, when travelling or diving, dolphins took longer to return to these particular behaviours as vessels became closer. The time required to return to diving activity increased by 11.3% to 13.6 min under a *distant* condition and by 296.9% to 48.6 min under a *close* condition (Table 4.4). Travelling dolphins took 2.9 min (48.6% increase) to return to that state when vessels were within 300 m (Table 4.4).

Table 4.4: Probability of being in a particular state (π_j), average number of transitions (or 3 min-time units) taken to return to a behavioural state $E(T_j)$, and time (min) required to return to a behavioural state once it was interrupted under *control*, *distant*, and *close* conditions. A negative value in percentage change denotes an extension in time to return to that state when vessels are present. Note: n/a = not applicable.

Behaviour	π_j	$E(T_j)$	Behavioural state resumed (min)	% change from control
Control				
Travelling	0.504	2.000	5.9	n/a
Milling	0.240	4.200	12.5	n/a
Diving	0.245	4.100	12.3	n/a
Socialising	0.010	95.400	286.2	n/a
Distant				
Travelling	0.480	2.084	6.3	- 5.1
Milling	0.253	3.948	11.8	5.2
Diving	0.220	4.544	13.6	- 11.3
Socialising	0.047	21.397	64.2	77.6
Close				
Travelling	0.340	2.945	8.8	- 48.6
Milling	0.524	1.911	5.7	54.2
Diving	0.062	16.204	48.6	- 296.9
Socialising	0.074	13.438	40.3	85.9

4.4.3.3. Mean bout length

The average length of behavioural bouts varied considerably when vessels were present (Fig. 4.4; Tables 4.5 and 4.6).

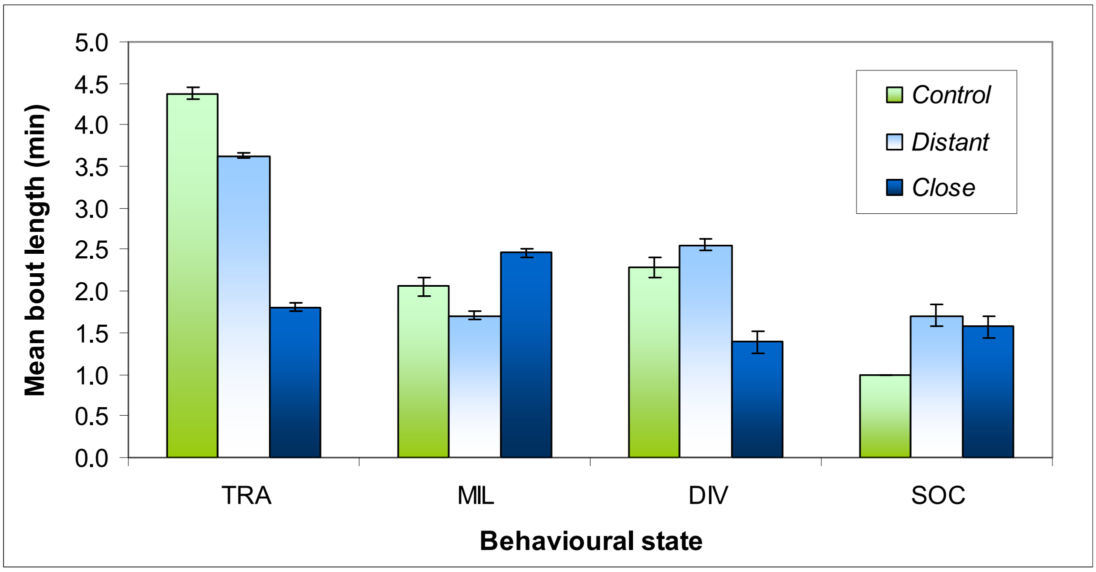


Fig. 4.4: Mean bout length (t_{ii}) for *control*, *distant*, and *close* chains. Bars represent 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising. The behavioural states are defined in Table 4.1.

Under a *close* condition, the duration of travelling and diving bouts was reduced in the *close* chain by 58.6% and 39.1%, respectively. The pattern was reversed for milling and socialising bouts, with a 19.4% and 57.1% increase, respectively (Table 4.6). Differences were not as pronounced between *control* and *distant* conditions (Tables 4.5 and 4.6), although these were still significant.

Table 4.5: Two sample *t*-tests comparing the average bout length of *control* chains against *distant* chains. A negative value indicates an increase in mean bout length in the presence of vessels (*distant* condition). Note: d.f. refers to statistical degrees of freedom.

Behaviour	Difference (min)	% change	95% C.I.	t-statistic	p	d.f.
Travelling	0.75	17.2	0.67 - 0.83	19.17	< 0.0001	241
Milling	0.35	17.1	0.22 - 0.48	5.30	< 0.0001	110
Diving	- 0.28	- 12.5	0.14 - 0.42	- 4.06	< 0.0001	103
Socialising	- 0.71	- 71.4	0.58 - 0.84	- 11.16	< 0.0001	59

Table 4.6: Two sample *t*-tests comparing the average bout length of *control* chains against *close* chains. A negative value indicates an increase in mean bout length in the presence of vessels (*close* condition). Note: d.f. refers to statistical degrees of freedom.

Behaviour	Difference (min)	% change	95% C.I.	t-statistic	p	d.f.
Travelling	2.57	58.6	2.48 - 2.66	56.28	< 0.0001	349
Milling	- 0.40	- 19.4	0.27 - 0.53	- 6.29	< 0.0001	95
Diving	0.89	39.1	0.71 - 1.07	9.70	< 0.0001	96
Socialising	- 0.57	- 57.1	0.30 - 0.56	-6.63	< 0.0001	54

4.4.3.4. Behavioural budget

The behavioural budget of Hector's dolphins differed significantly when vessels were present, although the effects were stronger under a *close* condition (Fig. 4.5). Overall, under a *distant* condition, only socialising increased significantly by 3.6% (95% C.I.: 2.5 - 6%, Z-test: $z = -4.75$, $p < 0.0001$). However, under a *close* condition, the behavioural budget for travelling and diving decreased significantly by 16.5% (95% C.I.: 10.4 - 23.6%, $z = 5.03$, $p < 0.0001$) and 18.3% (95% C.I.: 12.3 - 22.4%, $z = 6.71$, $p < 0.0001$), respectively. Conversely, the time budget for milling and socialising increased significantly by 28.4% (95% C.I.: 22.4 - 34.6%, $z = -9.22$, $p < 0.0001$) and 6.4% (95% C.I.: 3.8 - 8.0%, $z = -5.45$, $p < 0.0001$), respectively.

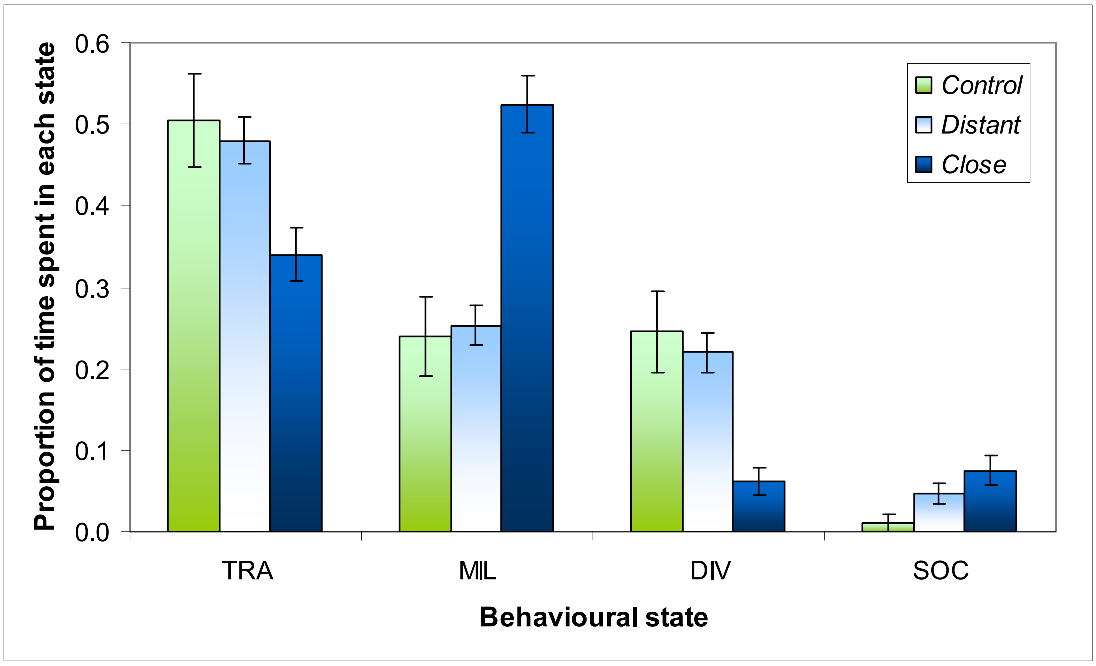


Fig. 4.5: Effect of vessel presence (*distant*) and vessel interactions (*close*) on the behavioural budget of Hector's dolphins in Akaroa Harbour, New Zealand, in relation to when vessels were absent (*control*). Values relate to the proportion of time spent in each state. Bars are 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising. The behavioural states are defined in Table 4.1.

When considering vessel type, a similar trend was apparent. Both commercial and non-commercial vessels significantly affected the dolphin behavioural budget (Z-tests: $p < 0.01$; Fig. 4.6). However, no statistical difference (Z-tests: $p > 0.05$) in behavioural budgets between vessel types was detected.

The number of vessels under a *close* condition, however, did affect the dolphin behavioural budgets. Dolphins spent significantly (Z-tests: $p < 0.001$) more time milling and socialising at the expense of travelling and diving (Fig. 4.7). In the presence of more than one vessel, the diving time budget was significantly reduced by a further 5.1% (95% CI: 2.4 - 7.7%, $z = 3.74$, $p < 0.0001$). None of the other behavioural states were significantly affected (Z-tests: $p > 0.05$; Fig. 4.7).

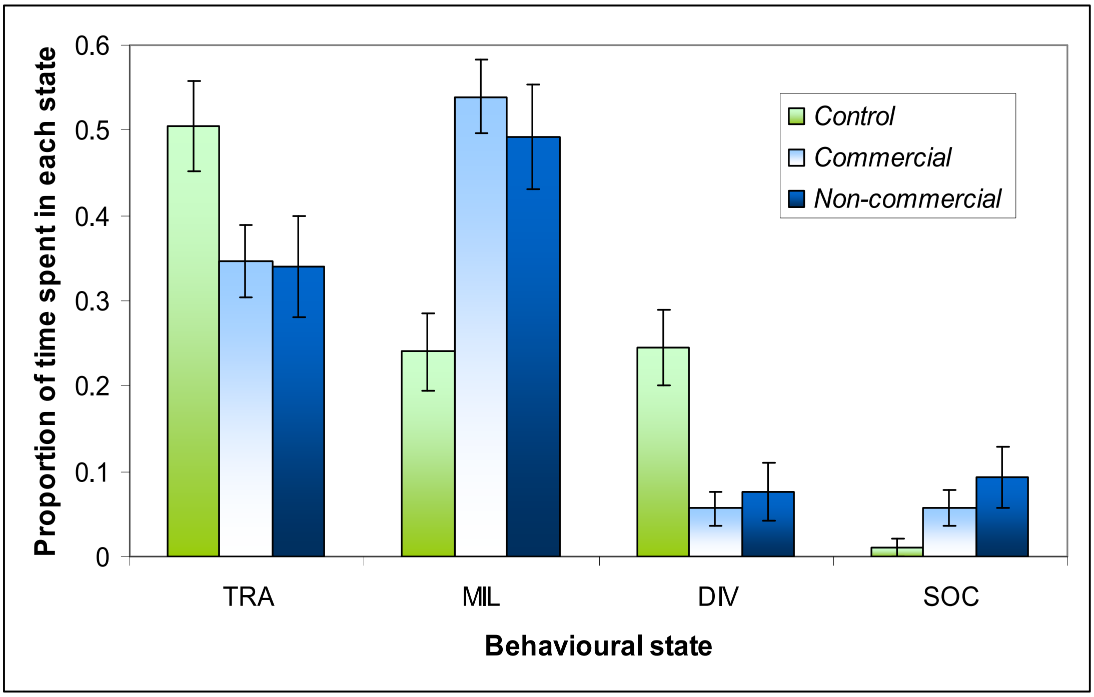


Fig. 4.6: Effect of the presence of commercial and non-commercial vessels on the behavioural budget of Hector's dolphins under a *close* condition in Akaroa Harbour, New Zealand. Y-values represent the proportion of time spent in each state. Bars are 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising. The behavioural states are defined in Table 4.1.

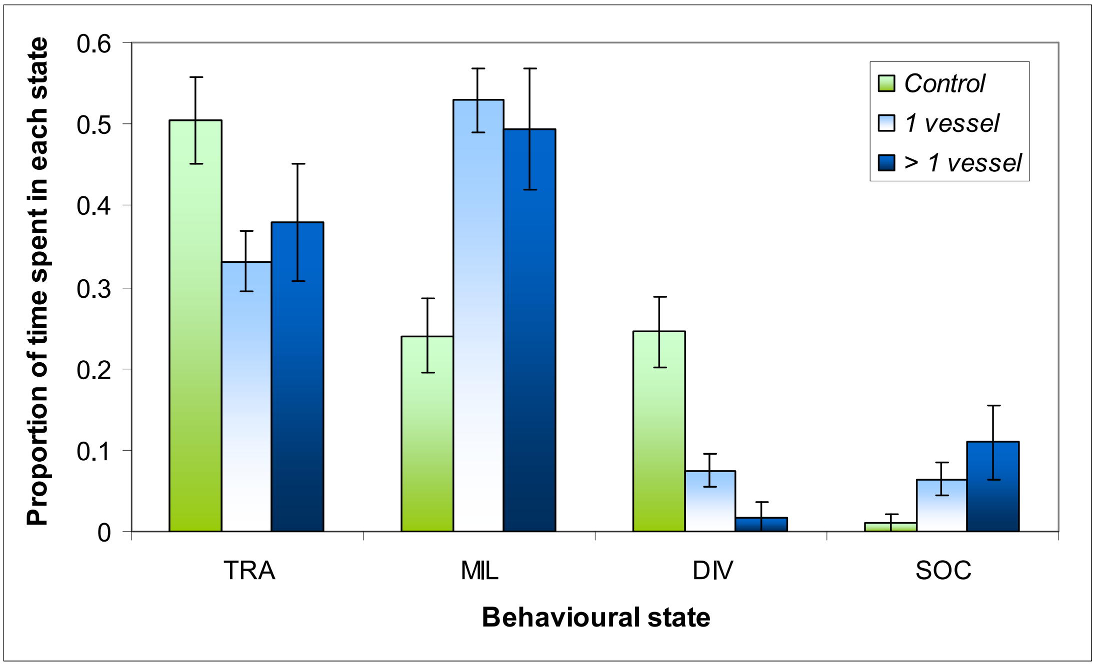


Fig. 4.7: Effect of the presence of one or more vessels on the behavioural budget of Hector's dolphins under a *close* condition in Akaroa Harbour, New Zealand. Values are proportion of time spent in each state. Bars are 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising. The behavioural states are defined in Table 4.1.

4.4.3.5. Modelling the effects

The effects of different levels of vessel presence and interactions on the cumulative behavioural budget (*i.e.* accounting for the time spent in a *control*, *distant*, and *close* budgets) are illustrated in Fig. 4.8. At current tourism levels (*close* condition = 35.2%), there is a significant effect on all four behavioural states. Compared to a *control* condition, the cumulative behavioural budgets predicts a decrease in travelling (16.2%, Z-test: $z = -2.21$, $p = 0.036$) and diving (45.7%, $z = 3.55$, $p < 0.0001$), with an associated increase in milling (30.7%, $z = -2.88$, $p < 0.0001$) and socialising (79.6%, $z = 5.6$, $p < 0.0001$).

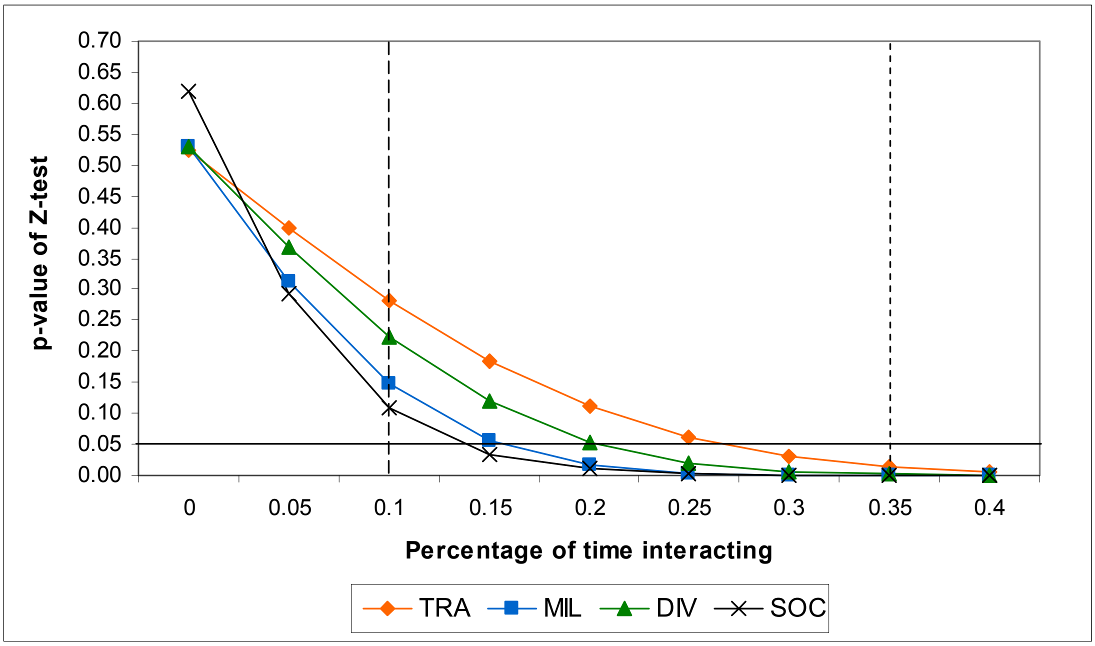


Fig. 4.8: P-value (Z-test of proportion) of the difference between the cumulative behavioural budget and *control* behavioural budget for Hector's dolphin activity in Akaroa Harbour, New Zealand. The proportion of time spent per day (daytime hours) in the presence of vessels was modelled to vary from 0 to 40%. The point at which point all behaviours are significantly affected by vessel interactions at $p < 0.005$) was 30%. The current level of interaction (35.2% of observations were under a *close* condition) is indicated by a vertical dotted line. The ideal level of interaction is also indicated by a vertical dashed line. Each curve corresponds to a behavioural state (see legend). The continuous line represents the statistical level of significance ($P < 0.05$). Note: TRA = travelling, MIL = milling, DIV = diving, and SOC = socialising. The behavioural states are defined in Table 4.1.

Based on the assumption that effects build linearly, tourism activity levels would need to decrease to 25% and 20% for the cumulative travelling and diving behaviour of dolphins not to be significantly affected, respectively. Overall, tourism activity interaction levels of 15% or less per day would be sufficient to prevent the cumulative behavioural budget for Hector's dolphins in Akaroa Harbour being affected (Fig. 4.8).

4.5. Discussion

The current level of vessel traffic and tourism activities in Akaroa Harbour has a significant effect on Hector's dolphin behaviour. Transition probabilities between behavioural states were affected by both the presence of vessels visible anywhere within Akaroa Harbour, especially within 300 m of a focal group. The indirect presence of vessels within the harbour usually caused dolphins to change to milling if travelling or to socialising if milling. While in close contact with vessels, dolphins not only showed a lower probability of continuing to dive, but also a lower probability of initiating a diving bout (*i.e.* changing from milling to diving state). The probability of continuing to travel was also lower.

Vessels presence also affected both the average duration of behaviour bouts and the time taken to return to a behavioural state. Generally, travelling and diving bouts were significantly shorter and dolphins took longer to return to their original behaviour as vessels got closer. The reverse applied to both milling and socialising. If both travelling and diving are associated with detection of prey and foraging, then a disruption of these behaviours may reduce energy uptake. For any population that might be food-limited, a disruption of foraging activities in the short-term linked to energetic consequences in the long-term is a cause of concern (*e.g.* southern resident killer whales, *Orcinus orca*, in Canada; Lusseau *et al.*, 2009; Williams *et al.*, 2009). It is not known if the Banks Peninsula Hector's dolphin population is food-limited. Concerns have been raised, however, about the sustainability of the commercial red cod (*Pseudophycis bachus*) fishery in the east coast of the South Island (MFish, 2009), a species that forms approximately 60% of the Hector's dolphin diet within that region (Dawson and Slooten, 1996).

Disruption in transition probabilities and behavioural states, in turn, led to significantly different activity budgets in the presence and absence of vessels. The simple presence of vessels within the harbour affected the proportion of time spent socialising. However, Hector's dolphins were seldom observed socialising in the area in the absence of vessels. This is in contrast with observations made at the other two control sites, Le Bons Bay and Te Oka Bay (Chapter II), where tourism activities are limited or non-existent. Once vessels were within 300 m of a focal group, the activity budgets of all four behaviours varied markedly with a significant increase in milling and socialising, at the expense of both travelling and diving. While no difference was detected between vessel types (commercial or non-commercial), the addition of more than one vessel significantly reduced the time spent diving by a further 5%.

Small groups of Hector's dolphins (five or less individuals) show a high degree of sex segregation (Webster *et al*., 2009). Dolphin groups often cluster together and display a fusion-fission pattern typical of many small cetaceans (Slooten *et al.*, 1993; Slooten and Dawson, 1994). Slooten (1990) noted that the frequency of social and sexual behaviours (per dolphin per minute) increased when two or more groups fuse. Hector's dolphins are also attracted to vessels (e.g. Baker, 1983; Slooten and Dawson, 1994) and it is not uncommon to observe more groups directly approaching a vessel and/or swimmers during an interaction (pers. obs.). As such, it can be hypothesised that dolphins in Akaroa Harbour might have learnt with time to use the presence of vessel(s) as a cue to find other groups, increasing the likelihood of socialising and probably mating with conspecifics. As a result, Hector's dolphins compensate for high vessel traffic in Akaroa Harbour as well as in Porpoise Bay by adjusting their behavioural budget, *i.e.* mainly socialising in the presence of vessels and waiting to dive in their absence.

In Porpoise Bay, Southland, Green (2003) reported analogous disruption of the behavioural budget of Hector's dolphins, where the amount of time dolphins were observed in the absence of human activity was 68% (*i.e.* five times more than in Akaroa Harbour). Human activity was defined by Green (2003) as a vessel present anywhere in the bay and/or swimmer(s) within 200 m of the focal dolphin group. Local Hector's dolphins increased the time engaged in milling and socialising at the expense of diving in the presence of these human activities. Travelling was apparently the only state unaffected. This difference could be due to the fact that in Porpoise Bay, travelling represented less than 10% of the *control* behavioural budget compared to *ca.* 50% in Akaroa Harbour. Analyses based on Markov chains were not applied in Green's (2003) study. Consequently, it was not possible to determine whether Hector's dolphin short-term behavioural responses, as indicated by transition probabilities, were similar between the two locations.

Overall, by demonstrating that vessel presence in Akaroa Harbour has affected Hector's dolphin behaviour, this study provides evidence that tourism activities within this region need to be carefully managed to ensure future sustainability. These observed changes raise the possibility that they may have important long-term implications for Hector's dolphins using Akaroa Harbour. Of particular concern is the disruption of diving behaviour, which could have significant biologically consequences (*e.g.* Boggs, 1992; Williams *et al*., 2006; Lusseau *et al*., 2009).

Comparison with other species

There is no consensus when it comes to determining which wildlife behaviours are more likely to be affected by human activities and, therefore, could be used as a general proxy for impacts and/or threshold levels across species. Variation in behavioural responses to human activities is highly dependent on a species life history characteristics, local population dynamics, and even individual traits such as age or gender. For instance, the current study provides evidence that diving activity is disrupted by the presence of vessels, which could lead to a substantial decrease in opportunities for energy gain (Williams *et al*., 2006; Lusseau *et al*., 2009). In Kaikoura, however, foraging activity of dusky dolphins does not appear to be affected by vessel traffic and tourism activities because this species primarily feeds at night (Benoit-Bird *et al*., 2004). This inter-species difference highlights how inappropriate generalisations can be when assessing the impact of human activities across species or even populations.

Nonetheless, disruption of foraging/feeding behaviour in response to human activities, including tourism and vessel traffic, has been demonstrated in a range of delphinid species. Vessel presence has been found to lead to a reduction in foraging behaviour within bottlenose dolphins (*Tursiops aduncus*) in Zanzibar (Christiansen *et al*., 2010), killer whales in Canada (Williams *et al*., 2006; Lusseau *et al*., 2009), common dolphins (*Delphinus* sp.) in New Zealand (Stockin *et al*., 2008a), and dusky dolphins (*Lagenorhynchus obscurus*) in Argentina (Dans *et al*., 2008). Williams *et al.* (2006) estimated that the lost feeding opportunities for killer whales could have resulted in an 18% decrease in energy intake. A disruption of feeding activity as a consequence of increased vigilance caused by human activity, including tourism, has also been found in many bird species (*e.g.* Burger *et al*., 1997; Ronconi and St Clair, 2002), as well as terrestrial mammals (Grizzly bears *Ursus arctos*: White *et al*., 1999; Amur tigers *Panthera tigris altaica*: Kerley *et al*., 2002).

Hector's dolphins spent less time travelling in the presence of vessels. In contrast, other species such as bottlenose, common, and dusky dolphins were more likely to travel (Lusseau, 2003a; Stockin *et al*., 2008a; Lundquist and Markowitz, 2009; Christiansen *et al*., 2010). The inshore Hector's dolphin is less streamlined than oceanic species. It has been described as "chunky" and appears unable to sustain swimming speed of more than 10 kts (Dawson, 2002), preferring to approach slow moving vessels (Chapter III). The Hector's dolphin is also one of the smallest marine dolphins (Dawson, 2002). Smaller marine mammals tend to surface more frequently to breathe than their large sized counterparts because there is a correlation between respiration rates and energetic costs, *e.g.* swimming speed (Berta and Sumich, 1999; Williams and Noren, 2009). Higher breathing rates indicate more elevated metabolic rates required by a greater surface to volume ratio and an increased rate of heat loss (Berta and Sumich, 1999). This could explain the difference in travelling response observed between this and other examined delphinid species. In addition, a proportional increase in milling behaviour has also been recorded as a response for several species of small delphinids (Dans *et al*., 2008; Stockin *et al*., 2008a; this study) in the presence of vessels. A plausible reason to switch to a lower energy activity, for example from travelling to milling, is to reduce energy expenditure in the presence of vessels, as suggested with killer whales by Williams *et al*. (2006).

Changes in activity budget, or any adjustment, can potentially affect the energy balance of dolphins (Williams *et al*., 2006). The energetic cost of each activity was not considered in this study as it was considered beyond the scope of this study. However, a substantial decrease in energy translating from the decrease in time spent diving has the potential to lead to biologically significant effects in the long-term (*e.g.* a decline in reproductive success) if the animals are unable to compensate for a reduced energy intake (*e.g.* Boggs, 1992; Williams *et al*., 2006; Lusseau *et al*,, 2009). This potential energy reduction is of particular concern for Hector's dolphin in Akaroa Harbour, given that this species is not only endemic but also endangered (Reeves *et al*., 2008). As suggested by Williams *et al*. (2006), the real issue may not be increased energetic cost in the presence of vessels (*i.e.* avoidance behaviour) but instead, the potential for vessels to cause a reduction in overall energy acquisition by the interruption of diving bouts for example. Changing from short-term behavioural responses to avoidance of regions (implying that costs outweigh the benefits) has been linked to increasing vessel traffic levels for both bottlenose dolphins (Lusseau *et al*., 2002) and killer whales (Williams *et al*., 2002a). However, there is no indication that high traffic levels are displacing Hector's dolphins in Akaroa Harbour (Chapter II). Given the experience of other small delphinids subject to high vessel traffic levels at other locations (*e.g.* Bejder *et al.*, 2006b), a similar consequence cannot be ruled out for Hector's dolphins in Akaroa Harbour should the level of tourism activities continue to increase.

What is the effect of current traffic levels on the behavioural budget of Hector's dolphins?

For management purposes, it is important to relate these short-term behavioural changes to the issue of sustainability of tourism activities around Akaroa Harbour. With a maximum of 32 dedicated permitted daily commercial trips between November and March, there is little gap in commercial tourism activity during these months. Dolphin-watching and swimming tour vessels operate between 0600 to 1800 hr (at the peak of the tourism season), with the exception of one hour (0800-0900 hr) due to the *staggered* departures times. Consequently, Hector's dolphins currently spend 35 to 86% of their time with vessels present within 300 m of a group, or anywhere within the harbour, respectively. Translating this level of interaction into a cumulative behavioural budget clearly indicates that dolphins vary their expected behavioural budgets (*control*) significantly when in the presence of vessels. Sustaining such levels of interaction in the long-term may be an issue because threshold levels appear to have been not only reached, but surpassed. These levels would need to be reduced below 15%, although ideally 10%, to no longer significantly disrupt their behavioural budget. Even in November, when vessel activity is lower than the other months (Chapter III), Hector's dolphins were still observed 25.1% of the time with vessels within 300 m, exceeding the 10% level (no-disruption) required. Finally, although the effects of tourism activities may not appear as important as other more pressing anthropogenic influences such as by-catch, pollution or prey depletion, such effects should also be considered in a integrative and adaptive management framework (Lusseau, 2004b; Higham *et al*., 2007). Effects of tourism when added to other human pressures on a population may, indeed, be sufficient to tip that population towards a decline. Lusseau (2004b) further argued that managing the tourism industry separately might, therefore, have very little effects.

4.6. Conclusion

Hector's dolphins in Akaroa Harbour are exposed to very high levels of tourism activities. It is, therefore, not surprising that the current level of vessel activity in the harbour significantly disrupts the behaviour of the dolphins. The common practice by commercial operators of "handing over" a dolphin group they are interacting with (Nichols *et al*., 2001; Appendix 3.1) to another vessel likely exacerbates responses reported here. When more than one vessel is present within 300 m, diving is further reduced. Of concern, is the fact that anthropogenic pressure on this endangered and endemic species (Reeves *et al*., 2008) is very likely to rise further in future years (one company is yet to commence operations, while others are only using a proportion of their permitted allocation). This does not consider recreational vessel traffic, which adds yet further pressure to Hector's dolphins in the harbour.

Stone and Yoshinaga (2000) state that "the less obvious potential effects of human contact changing dolphin behaviour and habituating animals to people is another threat to the population of Hector's dolphins in Akaroa". Despite the lack of baseline data, changes in the behaviour of Hector's dolphins have been observed as the local tourism industry has grown. What is now apparent is that the modification of activity patterns and time budget observed here could potentially produce significant effects in the long-term. These effects could include displacement from preferred habitats or reduced reproductive success, as demonstrated with other species (*e.g.* Bejder *et al*., 2006b). Akaroa Harbour has been identified as one of the four main hotspots for Hector's dolphins around Banks Peninsula (Clement, 2005). These can be considered as critical habitats, with limited overlap of conspecifics between adjacent hotspots (*e.g.* Rayment *et al*., 2009). This suggests that the importance of Akaroa Harbour might force some individuals to remain in proximity to a disturbance (here intensive tourism pressure) they would otherwise avoid regardless of the possible long-term consequences (Gill *et al*., 2001; Frid and Dill, 2002; Dyck and Daydack, 2004).

Under the Department of Conservation (DOC) Marine Mammal Action Plan 2005-2010, Hector's dolphins have been identified as a priority species (Suisted and Neale, 2004). Minimising the effects of tourism on the Hector's dolphin and protecting it against present or future tourism effects were part of the objectives set for this species (Suisted and Neale, 2004). In 2007, a Threat Management Plan (TMP) for Hector's dolphins was released presenting a range of management options to provide better protection for Hector's dolphins (DOC and MFish, 2007). Under the TMP, proposed actions included recommendations to: a) not grant further additional permits for swimming with Hector's dolphins to commercial operators; and b) not permit any increase in the level of swimming or viewing activity by commercial operators with existing permits. In the light of findings presented here, it is recommended that the management agency responsible for marine mammal conservation in New Zealand grants no further permits within Akaroa Harbour (*i.e.* keep the moratorium in place). In addition, reducing the level of exposure of Hector's dolphins to tourism activities should be seriously considered and the effectiveness of any management decision measured.

CHAPTER V

Effects of swim encounters on the South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) in Akaroa Harbour, Banks Peninsula

Photo: A.R.E.V.A. Project © 2006

Chapter V draws on material that also appears in:
Martinez, E.; Orams, M.B.; Stockin, K.A. (in press). Swimming with an endemic and endangered species: Effects of tourism on Hector's dolphins in Akaroa Harbour, New Zealand. *Tourism Review International*.

5.1. Introduction

Worldwide, the number of cetacean-watching operations (whale and dolphin viewing as well as swimming) focusing on dolphins is growing (O'Connor *et al.*, 2009; Chapter I). Human fascination for dolphins and the modern belief that interacting with them improves physical and spiritual well-being has led to the rapid expansion of swim-with-dolphin opportunities, not only in captivity but also with free-ranging populations (Curtin, 2006). New wild dolphin swimming programmes (swim-with-dolphin hereafter) are being initiated on a regular basis (*e.g.* Samuels *et al.*, 2003; O'Connor *et al.*, 2009). In 2008, 14 out of 119 countries and territories offered such programmes, some of them on a very small scale (*e.g.* Fiji, Niue; O'Connor *et al.*, 2009).

The majority of swim-with-dolphin encounters occur from commercial tours and involve wild and non-provisioned populations (Samuels *et al.*, 2003). In a review, Samuels *et al.* (2003) reported at least 11 species of delphinids were the focus of such tourism activities, including bottlenose dolphins (*Tursiops* sp.), common dolphins (*Delphinus* sp.), dusky dolphins (*Lagenorhynchus obscurus*), killer whales (*Orcinus orca*), and spinner dolphins (*Stenella longirostris*). Less typical species consisted of striped dolphins (*S. coeruleoalba*), Atlantic spotted dolphins (*S. frontalis*), short-finned pilot whales (*Globicephala macrorhynchus*), Risso's dolphins (*Grampus griseus*), rough-toothed dolphins (*Steno bredanensis*), and the South Island Hector's dolphins (*Cephalorhynchus hectori hectori*, Hector's dolphins hereafter).

It has been suggested that close encounters with wild dolphins may enhance respect for wildlife (*e.g.* Orams, 1997) and that animals have a choice as to whether or not they interact with swimmers (*e.g.* Dudzinski, 1998). The assumption is that if dolphins choose to do so, then interactions are unlikely to be detrimental. The stereotypical response that "if they do not like it they can just leave" is common and appears to be rational (Martinez and Orams, in press).

Concerns have been raised, however, about swim-with-dolphin activities and their potential harmful, beneficial, and/or neutral effects on targeted species (Samuels and Bejder, 2004) as no tourism activity is considered ecologically benign (*e.g.* Isaacs, 2000; Chapter I, section 1.2.4.4.). Although swimming with wild dolphins can be viewed as an activity of low risk (Perrine, 1998), it can actually be harmful for both humans and animals, resulting in serious injury and even mortality in extreme cases (Shane *et al.*, 1993; Shane, 1995; Santos, 1997; Goodwin and Dodds, 2008). Changes in habitat use, decreased encounter times, and unsuccessful swim attempts are often used to detect and/or infer species avoidance of tourism activities (*e.g.* Danil *et al.*, 2005, Ritter, 1996; Weir *et al.*, 1996; Bejder *et al.*, 1999; Constantine, 2001; Leitenberger, 2001; Neumann and Orams, 2006), which over time can lead to sensitisation (*e.g.* Ransom, 1998; Constantine, 2001; Würsig *et al.*, 1997).

Empirical research indicates that even if avoidance is not a consequence, dolphins can still be detrimentally affected by swim-with-dolphin operations (Samuels *et al.*, 2003). Over the past two decades, behavioural changes have been linked to vessel approach (*e.g.* Würsig *et al.*, 1997; Ransom, 1998; Constantine, 2001; Neumann and Orams, 2006), the presence of swimmers/vessel(s) (*e.g.* Barr and Slooten, 1999; Danil *et al.*, 2005; Courbis and Timmel, 2009; Lundquist and Markowitz, 2009; Christiansen *et al.*, 2010) or swimmer placement (Weir *et al.*, 1996; Constantine, 2001). Other identified effects include changes in whistle production (Yin, 1999; Scarpaci *et al.*, 2000) and group cohesion (*e.g.* Bejder *et al.*, 1999; Markowitz *et al.*, 2009c; Green, 2003).

Most studies have focused on short-term responses, especially group responses to vessel approaches. However, longitudinal research is required to demonstrate the potential detrimental effects of long-term exposure to swim-with-dolphin tourism activities on targeted species (*e.g.* Constantine, 2001; Bejder and Samuels, 2003; Samuels *et al.*, 2003). Problems associated with this type of research include the difficulty to isolate the response of dolphins to swimmers from the confounding effect of vessel presence (Constantine, 1999), because most commercial swim-with-dolphin encounters occur from such a platform.

In New Zealand, considerable research has been conducted to investigate the effect of swim-with-dolphin tourism on targeted species (Orams, 2004). Studies include dusky dolphins in Kaikoura (*e.g.* Barr and Slooten, 1999; Yin, 1999; Markowitz *et al.*, 2009c), bottlenose dolphins in the Bay of Islands (*e.g.* Constantine and Baker, 1997;

Constantine, 2001), common dolphins in the Bay of Islands, Bay of Plenty and the Hauraki Gulf (*e.g.* Leiternberger, 2001; Constantine and Baker, 1997; Neumann and Orams, 2006), and Hector's dolphins in Porpoise Bay and Akaroa Harbour (*e.g.* Bejder *et al*., 1999; Nichols *et al*., 2002; Green, 2003). While in some studies swim attempts from shore caused only weak, non-significant effects (Bejder *et al*., 1999), in others studies, sensitisation to swimmers was detected over a five-year period (Constantine, 2001).

In terms of legislation, few countries have regulations in place to protect free-ranging cetaceans (Carlson, 2008). New Zealand has often been exemplified as a model country (Hoyt, 2001), having both a Marine Mammals Protection Act (MMPA, 1978, Appendix 1.3) and the Marine Mammals Protection Regulations (MMPR, 1992, Appendix 1.4). Generic management regimes are, however, seldom appropriate because research has shown that impacts vary greatly between species, location and type of tourism activity (Orams, 2004). The International Whaling Commission (IWC) Scientific Committee (IWC, 2000) noted that because "the impact of swim-with-programmes in the wild will vary among species, populations and locations […], the impacts of such programmes should be assessed on a case by case basis". Sound management must, therefore, be based on comprehensive research that provides information regarding the requirements and sensitivities of specific targeted populations (Orams, 2004).

Akaroa Harbour, Banks Peninsula, is the only location in New Zealand where commercial swim-with-dolphin operations have been permitted to target the endemic and endangered Hector's dolphins since 1990. The development and growth of this industry (with currently up to 18 daily permitted trips) has been built on limited scientific data (Stone *et al*., 1998; Nichols *et al*., 2001, 2002), although most of the known information on this species is based on the Banks Peninsula population (Martinez and Slooten, 2003). In the late 1990s, permits were renewed on the basis that activities were not having a significant adverse effect on the Hector's dolphins, albeit based on limited scientific data. However, the Department of Conservation (DOC) recommendation to limit the existing level of permits until effects were known, in addition to concern expressed by researchers, resulted in the implementation of an *informal moratorium* (Allum, 2009).

New applications for permits to target Hector's dolphins in Akaroa Harbour lodged with DOC in 2007 could potentially increase the current number of swim trips by 78% (Allum, 2009). Consequently, it is vital to determine whether the current levels of swim-with-dolphin trips in Akaroa affect Hector's dolphin behaviour. This is particularly important because this type of tour: a) interacts the longest with the dolphins (Chapter III); b) can potentially be more invasive due to the presence of swimmers in the water with the dolphins; c) the level of vessel traffic is affecting the dolphin behavioural budget (Chapter IV); and d) there is pressure to expand swim-with-dolphin operations in Akaroa harbour (Allum, 2009).

5.2. Objectives

For management purposes, it is important to ascertain what the potential long-term effects of swim-with-dolphin activities might have on a targeted population (Samuels *et al*., 2003). Longitudinal studies are, therefore, essential to ensure an effective protection of Hector's dolphins and the sustainability of the industry. The first provisional assessment of the potential swim-with-dolphin impacts in Akaroa Harbour was limited to only one austral summer (2001/2002 - Nichols *et al*., 2002). However, this research does provide some useful baseline data for future comparisons. Following on from Nichols *et al*. (2002) work, this study assesses whether Hector's dolphins show any signs of habituation, sensitisation, or tolerance over time (refer Appendix 5.1 for definitions).

This chapter aims to:

1) Quantify basic characteristics of swim-with-dolphin trips, including: group size of dolphins encountered, number of swimmers per swim attempt, number of swim attempts per trip, and encounter ratings.
2) Provide detailed information on this type of encounter; such as trip duration, time to first encounter, sighting cues used by operators to detect dolphin groups, and reasons to end an encounter.
3) Assess the effect of swim-with-dolphin encounters on dolphin groups by assessing a) the time dolphins actually spent interacting with swimmers in relation to several variables; b) whether numerous swim attempts with a

same group influenced encounter time; c) the dolphins' response to vessel approach type and swimmer placement; d) their orientation according to time into an encounter; and e) their behavioural budget according to commercial tour type, swimmer numbers, and departure time (*staggered vs. discrete*; refer to section 5.3.2.2. for definitions).

5.3. Materials and methods

5.3.1. Survey platforms, effort, and survey protocol

5.3.1.1. Survey platforms

Opportunistic vessel surveys were conducted within the permitted swimming and viewing area of operation for the commercial tour operators based in Akaroa (Fig. 5.1; refer to Chapter II, section2.1, for further details of the study area).

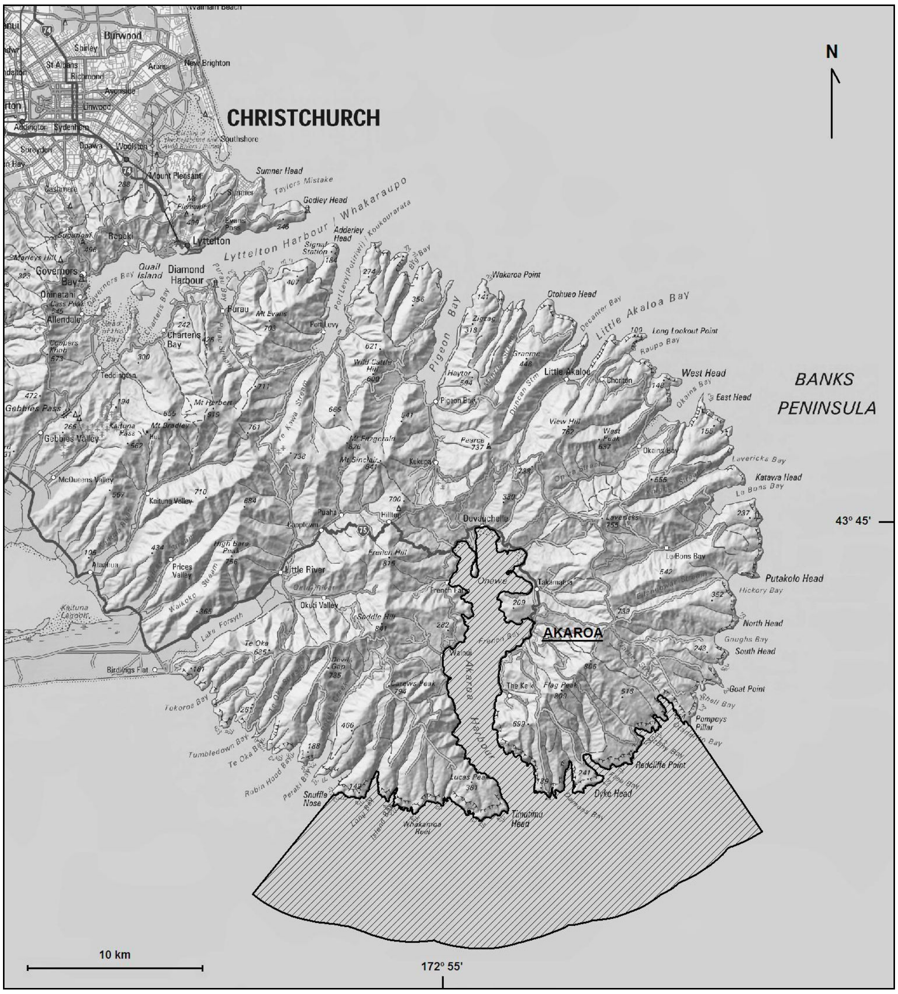


Fig. 5.1: Permitted area of operation for commercial tour operators based in Akaroa, Banks Peninsula, New Zealand (Source: Department of Conservation, Canterbury, New Zealand).

The same six commercial vessels described in Chapter III (refer to section 3.3.2.1. for further details on each vessel) were used as platforms of opportunity in addition to land-based theodolite surveys. These vessels were deemed as suitable platforms based on their size, the likelihood to have available space on board, and the practicability to collect data. All of these were permitted to provide swim-with-dolphin tours, with the exception of *Akaroa Dolphins* (Dolphin-watching only).

5.3.1.2. Survey effort

The research period comprised three consecutive field seasons between November and March, commencing in November 2005. This five-month period was particularly chosen as it corresponds to the known distribution of Hector's dolphins within Akaroa Harbour (*e.g.* Dawson, 1991b; Clement, 2005; Rayment *et al.*, 2010) and encompasses the high tourism season (Chapter I). During this study period, Hector's dolphins were exposed to nine vessels operating daily up to 18 swim-with-dolphin trips as well as eight dolphin-watching cruises (refer to chapter I for further details).

Commercial swim-with-dolphin trips from which data were collected departed at 0600 hours (hr), 0900 hr, 1200 hr, 1400 hr, and 1600 hr. Swim trips at 0600 hr and 1600 hr were only offered if there was demand and/or in sufficient daylight (pers. obs.). In addition, *Akaroa Dolphins* left Akaroa at 1045 hr, 1215 hr, and 1515 hr. An attempt was made to undertake equal sampling effort between the different departure times so as to cover most of the commercial daily activities.

Observation effort varied and was limited to favourable environmental conditions (no rain and Beaufort Sea State (BSS) of two and three or less for vessel- and land-based observations, respectively). Data collection was terminated if BSS increased above the set level or if weather conditions deteriorated to prevent sighting rates and observations being negatively affected (Elwen *et al.*, 2009). Environmental variables such as BSS, wind speed and direction, temperature, percentage glare and cloud cover, were all recorded at the start of each opportunistic survey or when noticeable change in conditions occurred.

5.3.1.3. Survey protocol

Upon the departure of a trip, several variables including date, operator, vessel name, departure time (hh:mm), skipper, crew, and number of passengers (watchers and swimmers) were recorded. Return time (hh:mm) was also noted upon arrival. The route taken for all tours was largely based on the skipper's discretion and influenced by sea conditions, prevailing weather in addition to previous sightings, when applicable (refer to Chapter III, section 3.3.2.3., for further details).

Operator procedures for swim-with-dolphin trips

Vessels typically travelled at speeds of 10-15 knots (kts) until a group of dolphins was encountered. At this point, the skipper would slow the vessel to first observe if the dolphin group would approach before the swimmers were placed in the water. Swim trips were only attempted with dolphin groups in the absence of calves, in compliance with section 20(b) of the MMPR (Appendix 1.4). A *calf* was defined as an individual that was approximately 50% or less than the size of an adult, and was consistently observed in association with an adult presumed to be the mother (Fertl, 1994).

Operators and skippers used different methods to place their swimmers in the water with dolphins. Some asked swimmers to enter the water as soon as the dolphins approached, while others would wait and see if dolphins indicated and maintained an interest in the vessel before swimmer placement. Swimmers were also advised not to splash when entering the water and to spread out so as to encourage the dolphins to move among them. Skippers usually placed their engines into idle to maintain a safe distance with the swimmers and on occasion, moved slowly in a circle around swimmers in an effort to coerce the dolphins back towards them. Operators also had a tendency to first target the same area of the harbour if an encounter on a prior trip had been successful (Nichols *et al*., 2002; pers. obs.).

Encounters

An encounter was initiated whenever a vessel of any type approached within sight of a dolphin group (300 m or less) with the intention of viewing or swimming with the dolphins, as determined by a reduction in speed. This distance is consistent with the MMPR (1992) and land-based observations (Chapters II to IV). A group was defined as individuals located in close proximity (less than five body lengths or approximately less than 10 m) from one another (Smolker *et al*., 1992).

A typical viewing or swimming encounter consisted of several interactions unevenly distributed and of varying duration. An *interaction* was defined as when at least one dolphin swam within 10 m of a vessel or swimmer and remained within its proximity for at least five seconds. There was no minimum or maximum time period defining an encounter. In the case of swim-with-dolphin events, an encounter was judged to have commenced when the first swimmer entered the water and ended when the last swimmer got back onboard the vessel. The same protocols used for land-based observations were adhered to (Chapters II to IV).

Characteristics of encounters

For each trip, the start and end time of each encounter were recorded (hh:mm) in addition to the initial dolphin group size and the number of swim attempts. When more than one swim attempt took place, it was also noted whether it occurred with the same initial group. Under their permits, operators must restrict their number of approaches to a maximum of three when interacting with *reluctant* dolphin groups. *Reluctant* groups were defined as dolphins, which actively avoided a vessel (Code of Conduct, Canterbury Conservancy).

Initial observation of encounters indicated that there were four primary methods used to locate Hector's dolphins: a) *Unassisted*, *i.e.* no external help provided; b) *information from another vessel*, *i.e.* location given via radio communication, phone, etc.; c) *Other vessel(s)*, *i.e.* a vessel was stationary and already interacting with a dolphin group giving away the location of that group; and d) *birds*, *i.e.* the presence of white-fronted terns (*Sterna striata*), especially when diving, can indicate the presence of dolphins. Hector's dolphins are known to associate with this particular species (Bräger, 1998b).

The different possibilities of ending an encounter were as follows: a) *dolphins left*, *i.e.* the focal group moved away from the vicinity of the swimmers and/or vessel(s); b) *time*, *i.e.* the maximum time allowed for swim encounters was reached; c) *operator left*, *i.e.* the skipper decided to stop the encounter because swimmers were tired/cold, or a vessel needed to continue the dolphin-watching tour or get to Akaroa in time for the next trip; and d) *other*, *i.e.* any other reason not previously included, primarily weather.

Finally, the definition of encounter ratings (Table 5.1) was based on the data sheets used by commercial operators. Under their permits, commercial operators must provide reports on "species distribution, abundance, all encounters with marine mammals, including the location and type of encounter, number, behaviour, and any concerns regarding marine mammals" (Allum, pers. comm.).

Table 5.1: Definitions of the encounter ratings between Hector's dolphin groups and commercial swim-with-dolphin vessels in Akaroa Harbour, New Zealand (derived from DOC Canterbury Conservancy data sheet for commercial operators).

Rating (abbreviation)	Definition
Very good	Sustained swimming interactions with swimmers. Dolphins stay with swimmers for most of the duration of an encounter (*i.e.* a minimum of 20 min).
Good	Dolphins initially interested in interacting with swimmers but lost interest after a period of between 10 and 20 min into an encounter.
Average	Dolphins come and go and occasionally interact with swimmers. Encounters last between 5 and 10 min.
Poor	Dolphins showing no interest in interacting with swimmers. Encounters last less than 5 min.

Until December 2006, there was no consistency in how this information was conveyed to DOC Canterbury Conservancy. Since then, all commercial tour operators must record information on each trip into the same data sheet compiled by DOC and the author (Appendix 5.2). A similar data sheet was completed independently by researchers after each trip.

Responses of Hector's dolphins to commercial encounters

Responses and changes in response over time were collected using focal group scan sampling methods (Altmann, 1974; Mann, 1999).

Approach type

Several strategies (Fig. 5.2a) were used to approach a dolphin group, with vessel headings considered as: a) *In path*, when in the on-coming path of travel of a dolphin group; b) *Rear*, when behind a dolphin group; or c) *line abreast*, when parallel or to the side of the group. Another technique included *drifting*, which was defined as putting the engines in neutral to let the vessel move with the wind and/or current towards a dolphin group. Finally, when dolphins initiated the approach by moving directly towards the vessel while underway, it was referred to as *dolphin first.*

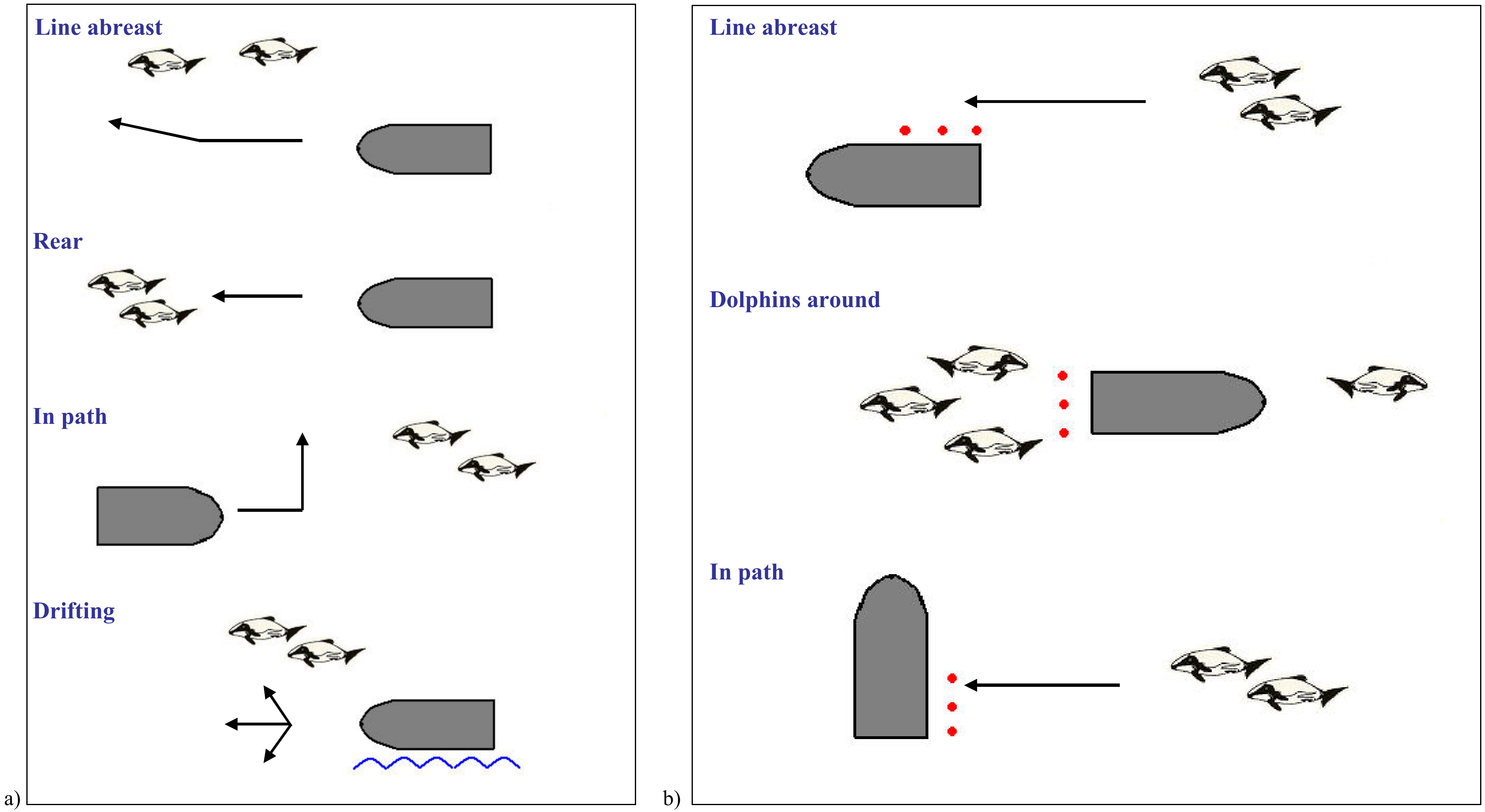


Fig 5.2: Strategies used by commercial vessels in Akaroa Harbour, New Zealand to: a) approach a dolphin group; and b) to place swimmers in the water (adapted from Constantine, 2001; Neumann and Orams, 2005). Paths taken are represented by arrows and swimmers by red dots.

Swimmer placement

Strategies to place swimmers in the water with dolphins (Fig. 5.2b; derived from Constantine, 2001; Neumann and Orams, 2005) were described, based on the swimmer entrance in relation to the position of the focal dolphin groups. These included: a) *line abreast*, *i.e.* swimmers entered the water to the side and slightly ahead of the dolphin group; b) *in path*, *i.e.* swimmers were placed in the dolphins' path of travel; or c) *around the vessel*, *i.e.* dolphins were milling around the wake of the stationary vessel when swimmers enter the water.

The response to swimmers by the focal dolphin group was also adapted from Constantine (2001) as follows: a) *avoidance*, *i.e.* the dolphin group moved away from the swimmers and/or vessel or dived before resurfacing away from them; b) *neutral*, *i.e.* no apparent change in the behaviour of the dolphin group, which remained at a distance of two to three dolphin body length from swimmer(s) (or less than five metres); and c) *interaction*, *i.e.* at least one dolphin from the group remained within five metres of a swimmer for a minimum of 10 seconds.

Behavioural data collection

Behaviour was first assessed when a vessel was within 50-100 m of dolphin group using a focal group scan sampling (Altmann, 1974; Mann, 1999). This assessment was not performed prior due to the possibility of an inaccurate evaluation of the group behaviour due to distance. A focal scan sample was again conducted to determine dolphin behaviour at the onset of a first interaction, as well as every three minutes (min) thereafter until the encounter terminated. Behavioural states were assigned into one of the categories previously described in Chapters II and IV and modelled on Shane (1990a) to allow inter-species comparisons (Table 5.2). These were defined to be mutually exclusive and cumulatively inclusive, describing the diurnal behavioural repertoire of the species. Discrete behavioural events (*e.g.* aerial, sexual) previously described for Hector's dolphins (Slooten, 1994) were incorporated in the behavioural state definitions used herein. Bow-riding, although a behavioural event, was included as a separate behavioural state for the purpose of analysis, to detect if differences existed between the two different types of tours. Resting was not included in the analyses as it was only observed during five independent occasions.

Table 5.2: Definitions of the behavioural state categories used in the present study in Akaroa Harbour, New Zealand (derived from Shane 1990a; Slooten, 1994). Mother-calf pair behaviour was based on the behavioural state of the mother.

State (abbreviation)	Definition
Milling (MIL)	Dolphins exhibited non-directional movement, with frequent changes in heading. No net movement. Group spacing and dive interval vary but are less than 1 min for the latter.
Diving (DIV)	Dolphins' direction of movement varies. Groups dive for prolonged intervals (> 1 min) often arching their backs at the surface to increase speed of descent. Group spacing varies. The presence of birds diving close to a group is also indicative of diving behaviour. Note - this represents the "feeding/foraging" category defined in other studies.
Socialising (SOC)	Dolphins observed chasing and/or engaged in any other physical contact with other individuals in the group. Aerial, sexual, and aggressive behaviours are frequently observed. Group is often split into small subgroups dispersed over a large area. Dive intervals vary. No obvious forward movement.
Travelling (TRA)	Dolphins engaged in persistent, directional movement, swimming with short, relatively constant dive intervals. Group spacing varies.
Resting (RES)	Dolphins engaged in slow movements (*i.e.* less than 1.5 km/hr) in a constant direction, with little evidence of forward propulsion. Dolphins were occasionally stationary. Dive intervals were short, relatively constant, and synchronous. Group spacing is tight (*i.e.* less than one body length between individuals). Resting lacked the active components of the other behaviours described.

Orientation in relation to vessels and swimmers

The response of Hector's dolphins to commercial vessels was further evaluated on the basis of the orientation of the dolphin group with respect to the swimmers and/or vessel. This was assessed at each three-minute time interval, accounting for the behavioural state of the focal group (Table 5.2).

Unlike previous studies (Bejder *et al.*, 1999; Martinez *et al.*, 2002; Green, 2003; Martinez, 2003), orientation was not determined using interpolation. This is a process that controls for time differences between fixes of each target (*i.e.* vessel, swimmer, and dolphin group) taken from a theodolite in order to calculate the angle between the movement heading of a dolphin group and the position of a vessel or swimmer (refer to Bejder *et al.*, 1999). The use of interpolation in this study was considered inappropriate because data were collected from both vessel- and land-based platforms using the same protocol and a theodolite could only be used from the latter. In this study, orientation was, therefore, coded as *towards*, *neutral*, or *away* (see Table 5.3 for definitions adapted from Neumann and Orams, 2005).

Table 5.3: Definitions of sampling protocol terms (adapted from Neumann and Orams, 2005).

Term	Definition
Towards	At least 50% of a dolphin group changed its direction of travel and actively moved towards a vessel or swimmer(s) reducing the distance between them to less than four dolphin body lengths.
Away	More than 50% of a dolphin group changed direction/path and actively swam away from vessel/swimmer(s) more than three times in succession, increasing the distance between them. Also, dolphins dove and surfaced away from the swimmers.
Neutral	No apparent change in behaviour, despite an initial approach within five metres of vessel or swimmer(s), continued swimming and did not appear to be attracted towards them in any way. Also when dolphins were present within more than five metres of a vessel or swimmer(s) but not actively swimming away from them (*i.e.* swimming away no more than three times in succession).

Other information

At each three-minute time interval, the number of vessels present, vessel type (*i.e.* commercial, recreational, or research; refer to Chapter III, section 3.3.2.3. for definition), and the maximum number of swimmers during that time period were recorded. The time dolphins were physically interacting with swimmers was also estimated as a percentage of each three-minute period.

5.3.2. Data analysis

In an effort to ensure maximum independence of each observation, encounters with Hector's dolphins with a similar group size and composition recorded within a 30 min-period and a 500 m-radius were not included in the analyses. In addition, successive view or swim attempts with a same dolphin group were not considered independent and were, therefore, excluded from analyses, except when assessing the effect of successive swim attempts on the duration of swim encounters.

Whenever possible, methods previously used in other studies (*e.g.* Bejder *et al.*, 1999; Constantine, 2001) were selected to allow inter- and intra-species comparisons. Statistical tests were performed using statistical package SPSS version 18 (© IBM SPSS, 2009) for the majority of analyses, unless otherwise stated. All continuous response variables were initially tested for normality and homoscedasticity using Anderson-Darling and Bartlett's and Levene's tests, respectively (Zar, 1996). A series of *post-hoc* (Bonferroni or Dunn's multiple comparison tests) was run when applicable. Significance was accepted at the alpha (0.05) level.

5.3.2.1. Characteristics of encounters

Diurnal and monthly patterns in trip duration and time to first encounter were investigated. Diurnal patterns were examined in relation to departure times (*i.e.* 0600 hours (hr), 0900 hr, 1200 hr, 1400 hr, and 1600 hr for swimming trips and 1015 hr, 1245 hr, and 1515 hr for dolphin-watching tours). The different methods or cues used to detect dolphin groups, as well as the reasons prompting the end of an encounter were compared between dolphin-watching and swimming trips. Pearsons χ^2 tests were used to assess the following categorical data sets: sighting cues and reasons for termination of encounter.

5.3.2.2. Responses of Hector’s dolphins to encounters

Time dolphin spent in the presence of swimmers

Interaction time (*i.e.* the proportion of time Hector’s dolphins spent actively with swimmers) was used as a measure of dolphins’ affinity for the swimmers rather than the entire duration of a swim encounter. The independent sampling unit was taken to be interaction time taking into consideration the behavioural state of dolphins during an entire swim attempt.

To determine if a relationship existed between interaction time and several variables a Generalised Linear Model (GLZ) was run using R version 2.10.0 (R Development Core Team, 2009). The initial saturated model was of the form:

$$Y \sim X_1 + X_2 \ldots. X_i \text{ (family = binomial)}$$

where the response variable Y is the probability of dolphins to interact with swimmers and X_i the following explanatory variables: number of swimmers, month, departure time, group size, and dolphin behavioural state (Table 5.2). The model was then re-run excluding non-significant explanatory variables. Percentage changes were subsequently calculated. Only the number of swimmers was treated as continuous variables, the relationships were assumed to be linear. Errors are assumed to follow a binomial distribution. Departure time was categorised as either *discrete* or *staggered*. *Discrete* departure time was defined as tours departing Akaroa concurrently. In this study, 0600 and 0900 hr swim-with-dolphin trips were considered *discrete* because both companies operated at that time. From 1015 hr onwards, there was an overlap between dolphin-watching and swimming trips. Consequently, trips offered past 1015 hr were deemed *staggered*. Group size categories described in Chapter II were also applied in the present analysis (*i.e.* 1-2, 3-5, 6-10 and >10 individuals). Months were categorised as *early austral summer* (November and December), *mid austral summer* (January and February) and *late austral summer* (March) due to a small sample size.

Swim encounter length according to the number of swim attempts with a same group

In 2007, the legal time limit for a swim was reduced from 60 to 45 min (Allum, pers. comm.). Consequently, only data collected during the 2006/2007 season were used in this analysis because a time reduction in encounter duration after a second attempt could be an artefact of the new time limit. The effect of successive swim attempts, considered here as the sampling unit, with a same dolphin group on encounter duration was tested using one-way analysis of variance (ANOVA) with Bonferroni's *post-hoc* test for multiple comparisons. Data were log-transformed to satisfy normality and homoscedasticity assumptions.

Responses to approach type and swimmer placement

Following Constantine (2001), a Pearson's χ^2 test was applied to detect whether a relationship existed between vessel approach type and dolphin responses (here defined as a behavioural change). The initial behaviour of the focal dolphin group was added as a control variable to assess how dolphins' response changed in relation to vessel approach. A similar analysis was used to determine whether swimmer placement affected dolphin responses and the duration of a swim encounter. For analysis purposes, encounter duration was categorised, using the definition of encounter ratings (Table 5.1), as less than five minutes, five to 20 min, and more than 20 min corresponding to short (poor), medium (average to good) and long (very good) encounters, respectively. Freeman-Tukey cell deviates were also calculated to identity which cells contributed to the significance of the χ^2.

Orientation of Hector's dolphins during an encounter

Of particular interest was the variation in the orientation of a Hector's dolphin focal group with respect to swimmers and/or vessel in relation to time into an encounter, recorded at three-minute intervals from the start of an encounter. Although the same protocol was used, significant differences were detected between data collected from vessel- and land-platforms for both dolphin-watching encounters (Pearson's χ^2 test:

$\chi^2_2 = 42.103$, $p < 0.0001$) and swim-with-dolphins encounters ($\chi^2_2 = 117.536$, $p < 0.0001$). As a result, data set could not be pooled to increase sample size. Instead, only land-based data were used. The likelihood of observing dolphin movement *away* from swimmers and/or vessels was lesser from vessel-based (eye-level observations) than land-based platforms, as indicated by Freeman-Tukey deviates. Owing to a smaller sample size, analyses accounting for the behavioural state of the focal dolphin group in addition to time into an encounter could not be performed.

To allow intra-species comparisons, previously published methods were used (Bejder *et al*., 1999). To reduce the effect of dependence within each encounter, orientations were, therefore, pooled into intervals of 10 min each. In order to account for the effect of a continued interaction with the dolphins, data during swim encounters were scored cumulatively. For example, if swimmers entered the water at the 11th minute, orientation was then scored in the 11 to 20 min time interval and not in the zero to ten minutes interval. Such scoring was deemed necessary since swimmers did not always enter the water immediately after a group had been detected. Additionally, the presence of vessels can not be dissociated from a swim encounter because swimmers are launched from a vessel-platform. Any group not engaging with a vessel or in the presence of a calf (MMPR, 1992, section 20b) were defined as inappropriate for analysis.

Following methods described in Bejder *et al*. (1999), the observed proportions of responses in each time interval were analysed with logistic regression (LR) (Bejder *et al*., 1999) using R version 2.10.0 (R Development Core Team, 2009). LR provides a tool for modelling such changes in proportions in the binomial form (Harraway, 1995). Here, LR models predicted the probability of a dolphin group heading *towards* or *away* from the vessel and/or swimmers, based on the observed proportion of orientations classified as *towards* or *away* in each time interval. LR models were then fitted to the observed proportion of responses in each time interval to evaluate the effect of time into encounter on group orientation (Harraway, 1995). These were in the form:

$$\pi = \frac{\exp(\beta_0 + \beta_1 T + \beta_p T^p)}{1 + \exp(\beta_0 + \beta_1 T + \beta_p T^p)}$$

where π was the probability of movement *towards* or *away* from a vessel and/or swimmer.

LR models involved either a constant only ($ß_0$, Model 1) or a constant with higher powers of T (time into an encounter) up to a cubic (p = 3; Models 2 to 4). These models were as follows:
Model 1: Constant only $ß_0$.
Model 2: Constant ß plus linear term in T.
Model 3: Constant ß plus linear and quadratic terms in T.
Model 4: Constant ß plus linear, quadratic, and cubic terms in T.

Models were further tested for goodness-of-fit using the deviance statistic for each model and the deviance differences (both of which followed a chi-squared distribution). A significant deviance difference indicated that the predictive value of the model was significantly improved by the addition of the new factor. Analysis of residuals between observed and the corresponding predicted proportions (probabilities) confirmed whether a model was a good predictor of the probability of a dolphin group heading *towards* or *away* from swimmers and/or vessel(s) as a function of time into an encounter.

Here, modelling of dolphin responses was based on the assumption that if dolphin movements relative to vessels and/or swimmers were random, the expected proportion of each response (*towards*, *away*, or *neutral*) would be expected to be 0.33. If the 95% confidence intervals for the predicted probabilities are above and exclude the expected value, dolphin groups exhibit significant response to a vessel.

Behavioural budget

Consecutive behavioural observations recorded at three minute intervals are unlikely to be statistically independent (Glass *et al*., 1975). As a result, behavioural observations in this study were modelled as a series of time-discrete Markov chains (Markov, 1906; Bakeman and Gottman, 1997; refer to Chapter IV, section 4.3.4 for further details). Following assumptions detailed in Lusseau (2003a) and described in Chapter IV (section 4.3.5), first-order Markov chains were used to calculate activity budgets given that they provided more information than the sole frequency distribution of the behavioural states (*i.e.* zero-order chain; Table 5.11) and transitions in behavioural states were stable over time ($p > 0.05$). It was then possible to compare the activity budgets of Hector's dolphins to determine whether the type of tour (viewing or swimming), number of swimmers (< 5 or > 5 people) and departure time (*staggered* or *discrete*) had a significant effect on the time Hector's dolphins engaged within each behavioural state. Following the Perron-Frobenius theorem (Caswell, 2001), the activity budget in each condition was approximated by the left eigenvector of the dominant eigenvalue of the transition matrices using the Excel add-in PopTools (Version 3.0, CSIRO: www.poptools.org). Differences between behavioural budgets were tested with a binomial *Z*-tests for proportions (Fleiss, 1981) and 95% confidence intervals (C.I.) calculated using the statistical package *Minitab* version 15 (Minitab Inc., 2007).

The number of vessels has an effect on group behaviour (Chapter IV). Consequently, data analyses were only conducted on encounters with only one vessel present. Encounters lasting ten minutes or less, or where behavioural states were not clear, were also excluded from analysis. Finally, vessels engaged in swim-with-dolphin activities are more likely to be stationary due to the presence of swimmers in the water, as demonstrated by vessel mean speed during an encounter (Chapter III). As a result, bow-riding was excluded from this particular analysis.

5.4. Results

Over the research period (November to March, commencing in 2005), a total of 581 commercial tours were monitored, including 161 wildlife cruises and 420 swim-with-dolphin trips (Table 5.4). In addition, land-based surveys were conducted over a total of 225 days between 0600 and 1800 hr, resulting in a total of 631.7 hr of observations (refer to Chapter II for further details). From December 2006, a total of 112 dolphin-watching and 278 swimming trips were recorded using standardised data sheet provided to all operators.

Table 5.4: Summary of opportunistic vessel observations on-board commercial tours between 2005 and 2008, in Akaroa Harbour, New Zealand.

	Swim-	***with-***	***dolphin***	***trips***		***Dolphin-***	***watching***	***tours***	
Departure	**0600hr**	**0900hr**	**1200hr**	**1400hr**	**1600hr**	**1015hr**	**1245hr**	**1515hr**	**Total**
November	0	32	21	25	1	10	11	18	*118*
December	7	34	22	28	5	19	13	15	*143*
January	13	36	27	22	7	12	7	4	*128*
February	0	30	22	19	9	14	6	4	*104*
March	0	26	15	17	2	16	6	6	*88*
Total	*20*	*158*	*107*	*111*	*24*	*71*	*43*	*47*	***581***

5.4.1. Characteristics of encounters

Swims with Hector's dolphins were attempted on 93.8% (n = 320) of the trips observed in 2006/2007 and 2007/2008. The majority of these (44.9%, Fig. 5.3) were conducted with dolphin groups of six to ten individuals, with an overall mean of 7.5 dolphins (S.E. = 0.24, range = 1 - 27). Swimmers were seldom placed in the water with groups of less than three individuals (Fig. 5.3).

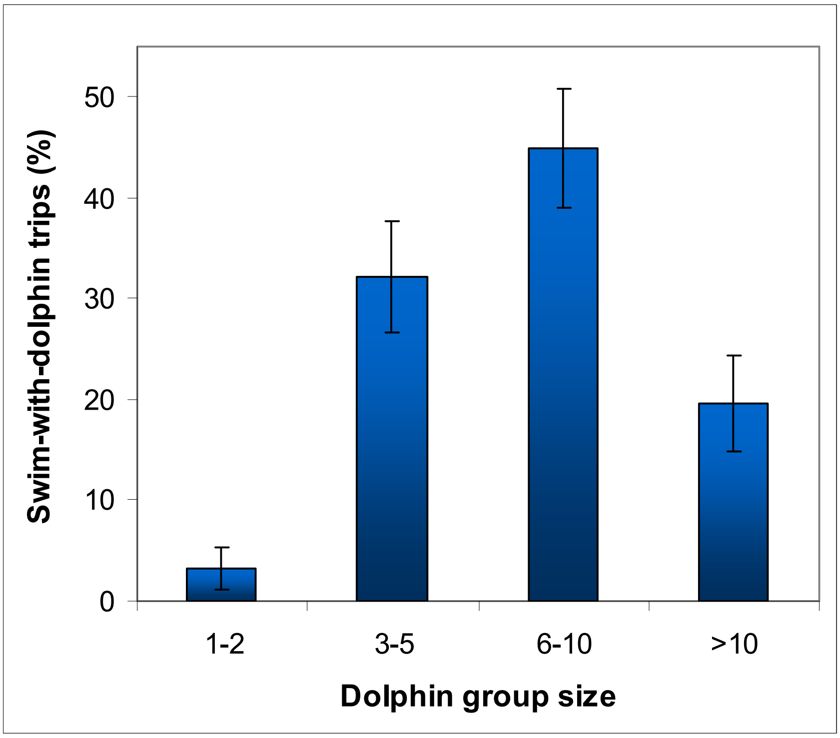


Fig. 5.3: Distribution (percentage) of dolphin group size during swim-with-dolphin trips in Akaroa Harbour, New Zealand. Bars represent the 95% confidence intervals.

Monitoring parameters of swim-with-dolphin trips are presented in Table 5.5. The number of swimmers onboard averaged 8.5, with as many as 19 swimmers aboard at any one time (Table 5.5). As not all of the swimmers actually entered the water (*i.e.* they decided not to swim although they were booked as "swimming"), 7.6 swimmers were present in the water with the dolphins during an average swim attempt. Out of 513 swim attempts, only 3.4% exceeded the legal limit of ten persons (Appendix, 3.1).

Table 5.5: Statistics of swim-with-dolphin trips (n = 320) and swim attempts (n = 513) in Akaroa Harbour, New Zealand. Note: S.E. = standard error of the mean.

Parameters	**Mean**	**S.E.**	**Range**
Swimmers per trip	8.5	0.137	1 - 19
Observers per trip	3.1	0.184	0 - 18
Swimmers per swim attempt	7.6	0.106	1 - 13
Swim attempts per trip	1.6	0.045	1 - 5
Swim encounter duration	25.3	0.639	1 - 70

The majority of trips (55.6%, n = 320) consisted of only one swim attempt (Fig. 5.4), with a mean of 1.6 attempts (Table 5.5) over the course of this study. Overall, 62.2% of swim attempts recorded on DOC data sheets (n = 278) were considered *good* to *very good*. Only 11.6% were deemed as *poor*, *i.e.* dolphins showed no interest in the swimmers. The remaining trips (26.2%) were considered as *average*.

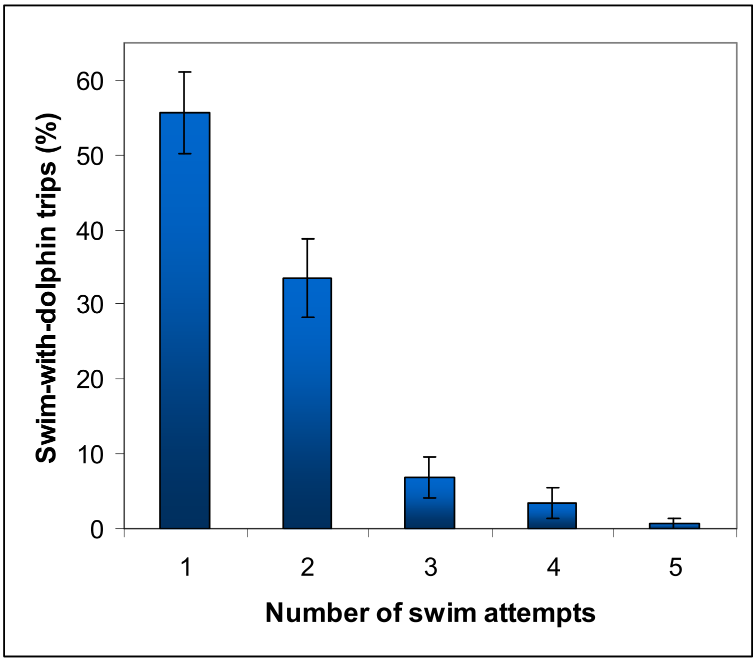


Fig. 5.4: Distribution (percentage) of the total number of swim attempts per swim-with-dolphin trip in Akaroa Harbour, New Zealand. Bars represent the 95% confidence intervals.

5.4.1.1 Total trip time

The duration of swim-with-dolphin trips varied from 61 to 168 min, with a median of 105 min (interquartiles: 97 – 114 min, n = 320), and were significantly shorter (Mann-Whitney *U*: W = 4427, $p < 0.0001$) than dolphin-watching cruises (median = 121 min, n = 122, interquartiles = 119 – 125 min, range = 60 – 176 min). While no significant monthly variation was detected for the latter (Kruskal-Wallis: $H_4 = 6.160$, $p = 0.188$), the total trip duration of swim trips differed significantly between months ($H_4 = 11.028$, $p = 0.026$; Fig. 5.5). Trips in March were significantly longer than in both November and January (Dunn's multiple comparison tests: $p < 0.05$). Departure time (Fig. 5.6) had no significant effect of the duration on either dolphin-watching cruises ($H_2 = 2.428$, $p = 0.2970$) or swimming trips ($H_4 = 6.276$, $p = 0.180$).

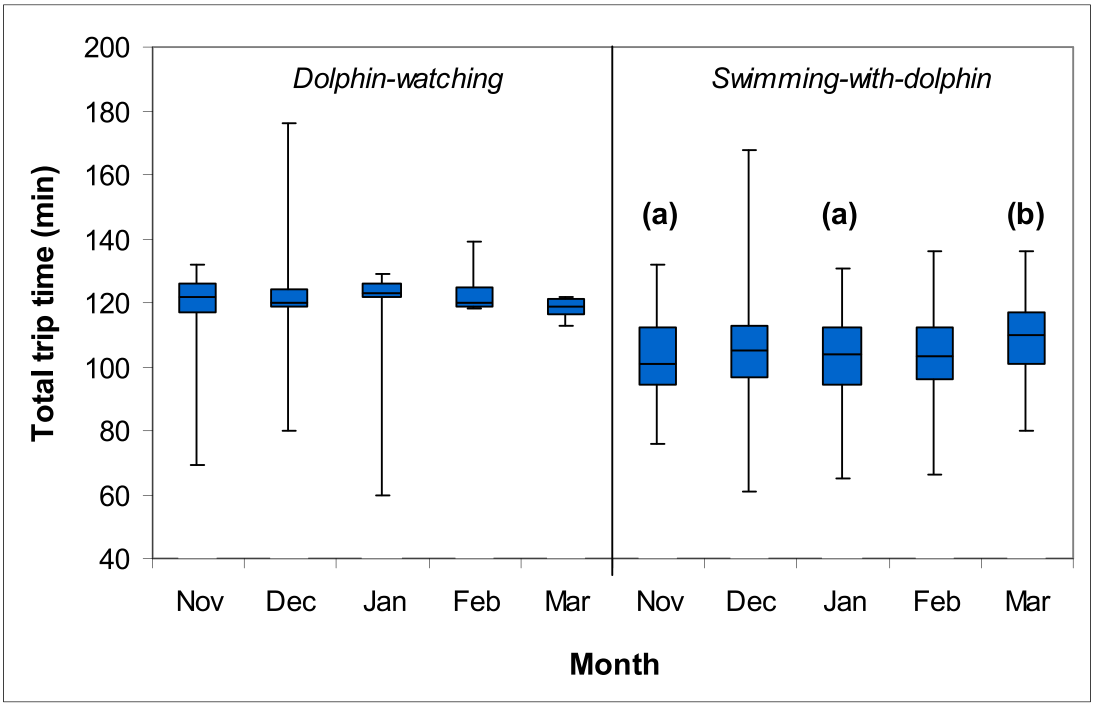


Fig. 5.5: Trip duration (min) of commercial trips according to month in Akaroa Harbour, New Zealand. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: (a) and (b) indicate months that were significantly different from other groups.

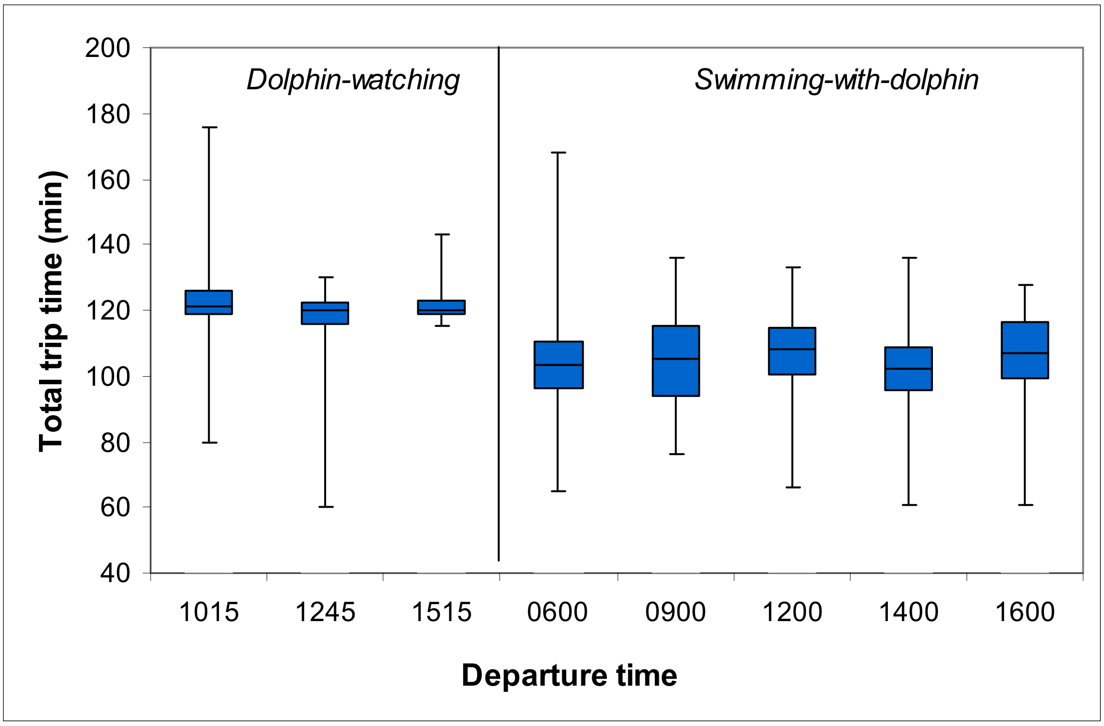


Fig. 5.6: Trip duration (min) of commercial trips according to departure time in Akaroa Harbour, New Zealand. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values.

5.4.1.2. Total search time to first encounter with Hector's dolphins

Crew onboard of swim-with-dolphin trips took on average 16 min to detect the first group of Hector's dolphins (interquartiles: 12 – 20 min, range = 1 – 67 min, n = 320) compared to 23 min (interquartiles: 15 – 40 min, range = 3 – 93 min, n = 122) for dolphin-watching cruises. This difference was significant (Mann-Whitney *U*: W = 12023, $p < 0.0001$). No diurnal variation (Fig. 5.7) in the time taken to first encounter a dolphin group for either swimming (Kruskal-Wallis: $H_4 = 4.434$, $p = 0.350$) or dolphin-watching trips ($H_2 = 3.248$, $p = 0.197$) was detected.

However, both type of tours exhibited significant monthly variation in time taken to first encounter dolphins (Fig. 5.7). In swim-with-dolphin trips ($H_4 = 38.068$, $p < 0.0001$), the first observation occurred significantly earlier in the middle of the austral summer (January) than either at the beginning (November) or towards the end of summer (March) (Dunn's multiple comparison tests: $p < 0.05$; Fig. 5.7). A similar trend was detected in dolphin-watching tours ($H_4 = 11.845$, $p = 0.019$), as it took significantly longer to locate dolphins during November than in January ($p < 0.05$).

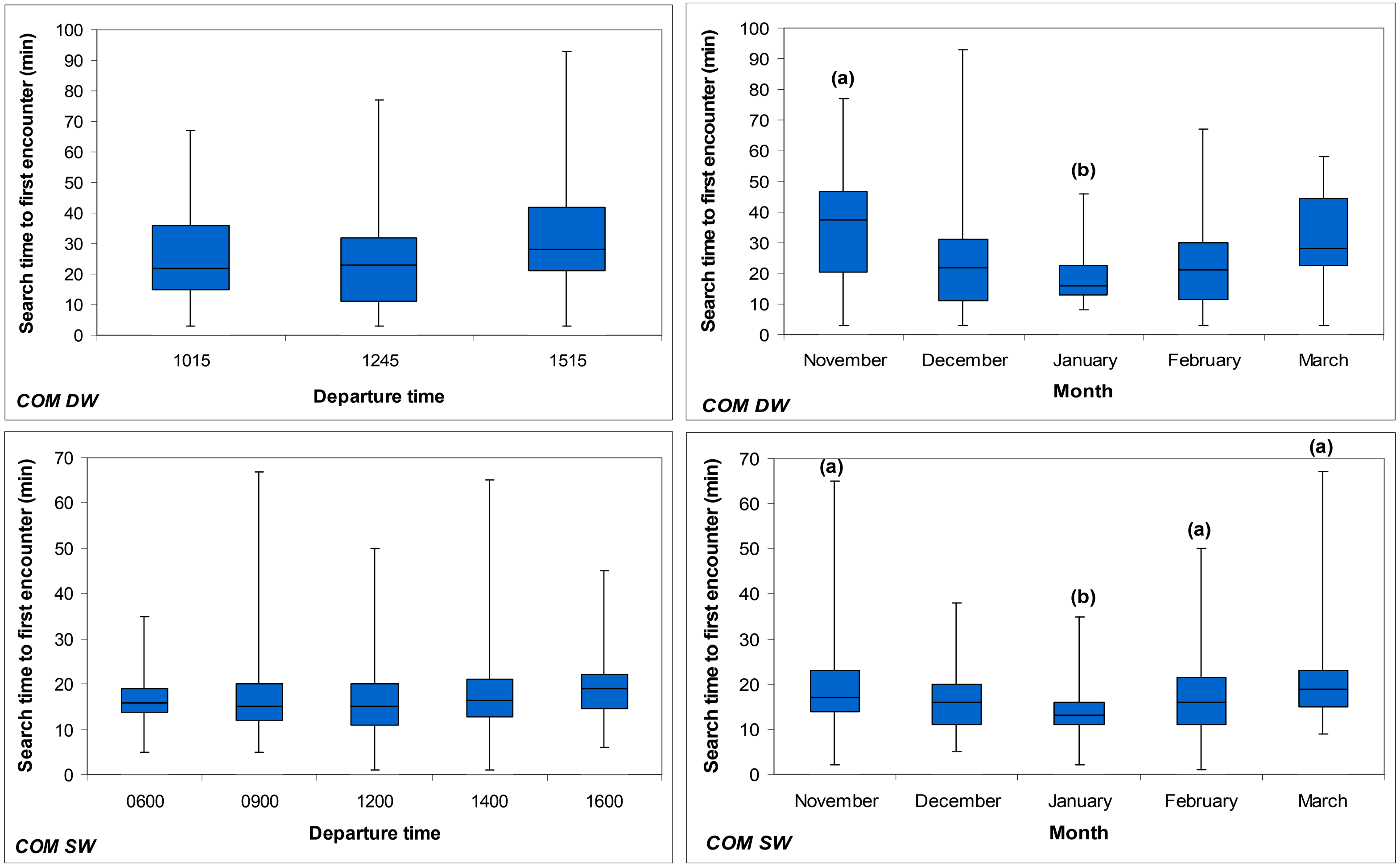


Fig. 5.7: Search time (min) taken to encounter the first dolphin group during a commercial tour according to departure time and month in Akaroa Harbour, New Zealand. Lines represent the median, boxes the 25th and 75th interquartile range, and bars the minimum and maximum values. Note: COM = commercial, DW = Dolphin-watching, SW = swim-with-dolphin trips. Note: (a) and (b) indicate times and months that were significantly different from other groups.

5.4.1.3. Sightings cues

Out of the 442 first encounters, over 80% of Hector's dolphin groups were sighted unassisted for both dolphin-watching and swimming trips (Fig. 5.8). In approximately 10% of monitored trips, the position of a group was given verbally by another vessel and a further 3% by the visual presence of another vessel. The known association of Hector's dolphins with white-fronted terns was used as a sighting cue, although only during 1% of the time. No significant difference was detected in the method used to locate dolphins between dolphin-watching and swimming trips (Pearson's χ^2 test: $\chi^2_2 = 2.769$, $p = 0.251$).

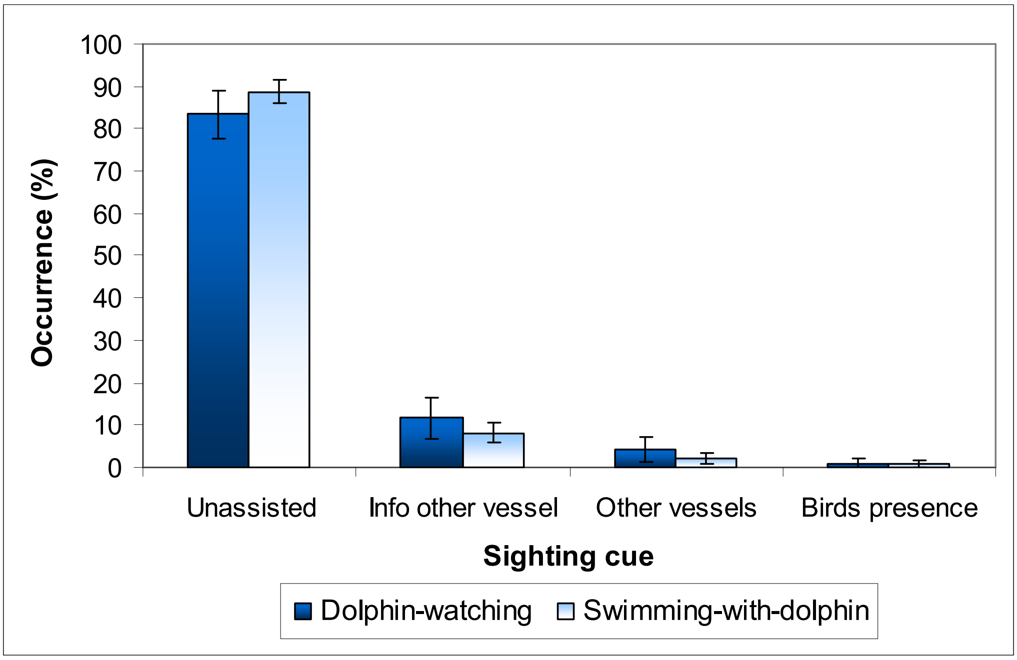


Fig. 5.8: Occurrence (percentage) of different sighting cues used to locate Hector's dolphin groups in Akaroa Harbour, New Zealand, by commercial dolphin-watching and swimming-with-dolphin trips. Bars represent the 95% confidence intervals.

5.4.1.4. Reason to end an encounter

As there were no statistical differences between field seasons for both swimming (Pearson's χ^2 test: $\chi^2_3 = 6.908$, $p = 0.075$) and dolphin-watching trips ($\chi^2_3 = 5.181$, $p = 0.159$), all data were pooled. In both tour types, approximately 45% of encounters ended because dolphins left the vicinity (Fig. 5.9). A further 23.8% (n = 207) of swim attempts were halted due to time constraints imposed by permit conditions (60 min until 2007, 45 min thereafter). Dolphin-watching tour skippers made the decision to leave the group during 34.8% of the time (n = 138) in order to continue the cruise and show other points of interests around Akaroa Harbour (refer to Fig. 3.25-1 in Chapter III for further details). Overall, the two types of tours differed significantly in how they were terminated ($\chi^2_3 = 31.855$, $p < 0.0001$; Fig. 5.9).

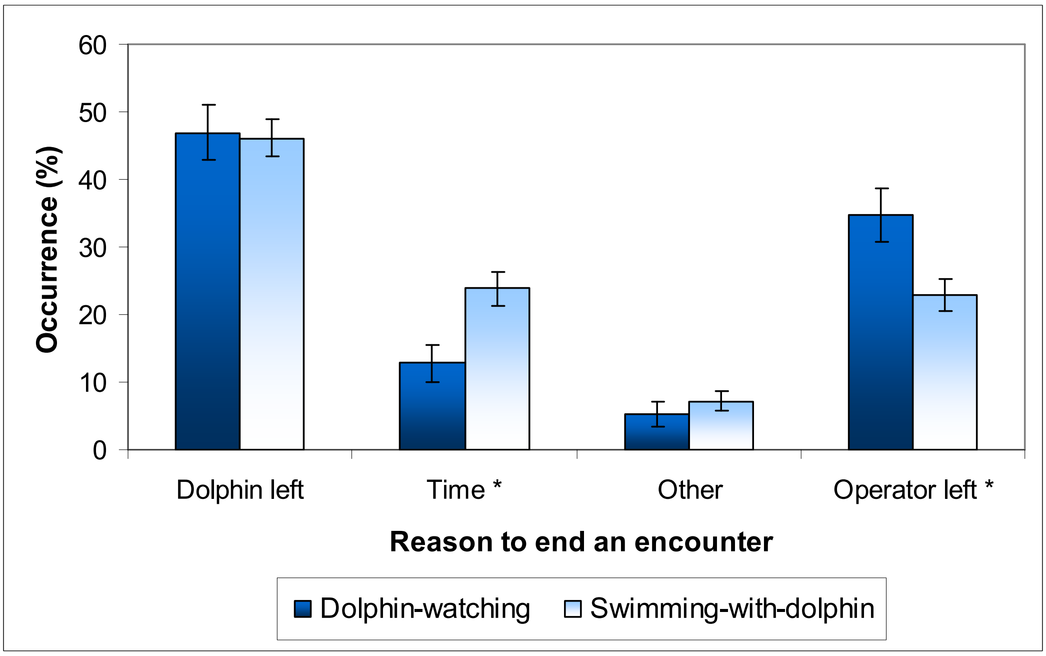


Fig. 5.9: Reasons for terminating a dolphin-watching or a swimming encounter in Akaroa Harbour, New Zealand. Bars represent the 95% confidence intervals. Note: * indicates categories that were significantly different between the two types of tours.

5.4.2. Responses of Hector's dolphins to encounters

5.4.2.1. Time dolphins spent in the presence of swimmers

The optimal GLZ for interaction time was as follows:

Interaction time ~ (Month, d.f. = 4) + (Behaviour, d.f. = 4) + (Group size, d.f. = 3).

Adding swimmers number, placement, and departure time did not improve the model ($p > 0.05$). Effects of month ($p < 0.001$), behaviour ($p < 0.0001$) and group size ($p < 0.001$) were all significant.

In the presence of large dolphin groups (6-10 individuals), interaction time increased significantly ($p = 0.015$) by 214.7% (range = 22 - 709%) compared to small groups (1-2 individuals). Behaviour also had a strong effect on encounters. Interaction time increased significantly ($p < 0.001$) with milling dolphin groups rising by 415.3% (range = 96 - 1,252%), 480.5% (range = 135 - 1,332%), 615.1% (range = 151 - 1,938%), and 702.2% (range = 230 - 1,848%) compared to bow riding, diving, socialising, and travelling groups, respectively. In the austral mid-summer (January and February) there was a significant ($p < 0.001$) decrease of 71.7% (range: 45 - 85%) in the amount of time dolphins engaged in the presence of swimmers compared to earlier austral summer months (November and December).

5.4.2.2. Swim encounter length according to the number of swim attempts with a same group

During the vast majority of swim-with-dolphin trips (91.6%; n = 285) in 2006/2007, commercial operators did not interact with the same group for the duration of a tour. From the 22 multiple swim attempts with a same group that were monitored, swim duration decreased after two attempts (Fig. 5.10).

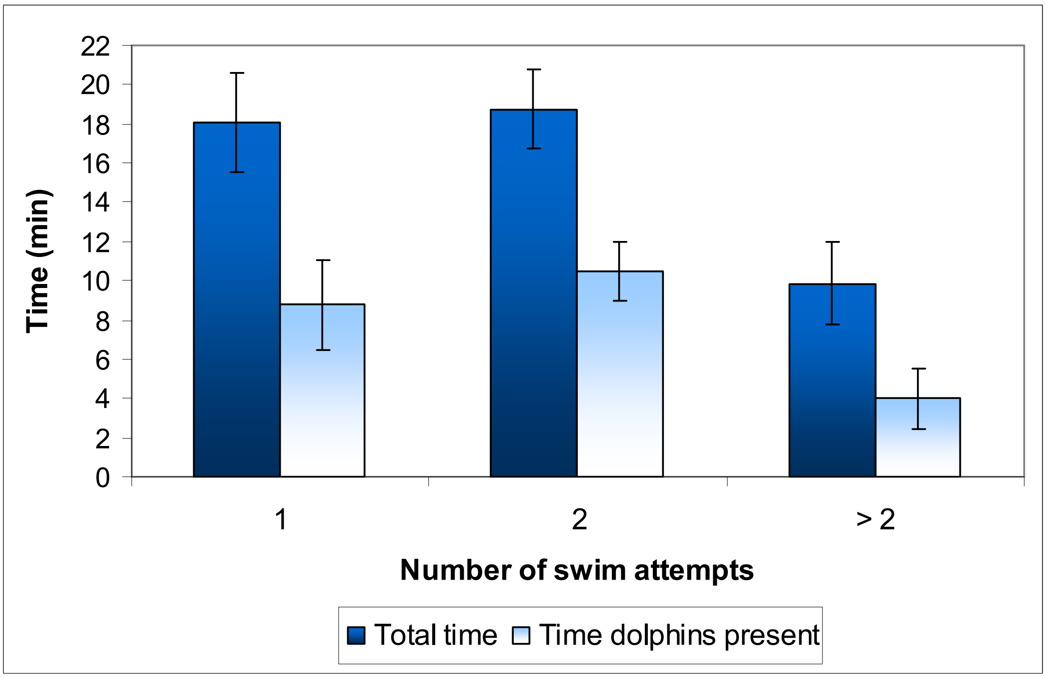


Fig 5.10: Encounter duration (min) of successive swim attempts with a same group of Hector's dolphins in Akaroa Harbour, New Zealand. Bars represent the standard error of the mean.

The second swim attempt was the longest with a mean of 18.8 min (S.E. = 2.046, range = 3 – 41 min). In contrast, by the third attempt, duration of swims lasted less than ten minutes (mean = 9.9 min, S.E. = 2.100, range = 3 – 19 min, n = 9), although this difference was not significant (ANOVA: $F_2 = 2.394$, $p = 0.102$). The same trend was apparent when taking into consideration the time that dolphins spent actively in the presence of swimmers (Fig. 5.10), which was significant (ANOVA: $F_2 = 3.552$, p = 0.036). A Bonferroni's *post-hoc* test indicated that two or more attempts were significantly shorter than a second swim attempt with a same group (p = 0.043).

5.4.2.3. Responses to approach type

Hector's dolphins initiated the approach in 38.5% of encounters (n = 1,132). For the remaining 61.5% of approaches, vessels came near a dolphin group predominantly from the side (or *line abreast*, 66.2%). *In path*, *drifting*, and *rear* approaches represented 18.0%, 10.6%, and 5.2% of approaches, respectively. Due to small sample size, *rear* and *in path* approaches were pooled as no significant difference was detected (*Z*-test of proportions: z = 1.000, p = 0.350) and both are considered as either within the *no approach* or *waiting zone* (Fig. A, Appendix 3.1).

Overall, the dolphins' initial behavioural state had a significant effect on any subsequent behavioural changes irrespective of the method of vessel approach (Pearson's χ^2 test: $\chi^2_3 = 33.853$, $p < 0.001$). Diving groups changed behaviour less often when approached (Freeman-Tukey deviates < -1) compared to socialising (Freeman-Tukey deviates > 1) or travelling groups (Freeman-Tukey deviates > 1). *In path-rear* approaches led to a higher proportion of behaviour change (Freeman-Tukey deviates > 1), although differences between approach types were marginally insignificant ($\chi^2_2 = 4.635$, $p = 0.099$).

Dolphin responses to the different vessel approaches also varied according to their initial behaviour when first sighted (Fig. 5.11). However, in all initial behavioural states, approach type had no significant effect on dolphin response ($p > 0.05$), with the exception of diving ($\chi^2_2 = 7.263$, $p = 0.026$). When diving, dolphins were less likely to switch behaviour when approached from the side or *line abreast* (Freeman-Tukey deviates < -1) and more likely to do so when a vessel was *drifting* (Freeman-Tukey deviates > 1).

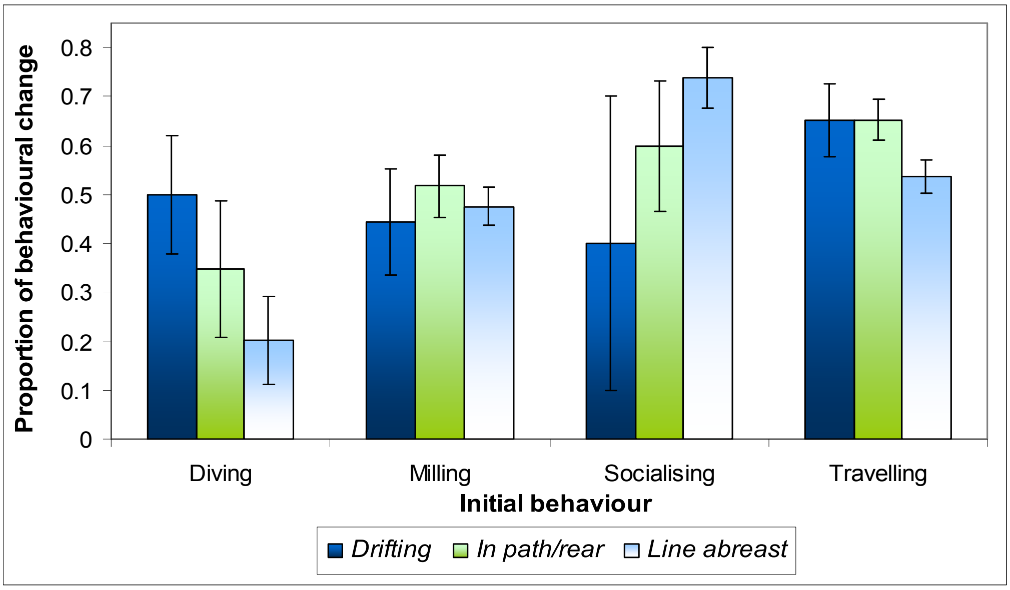


Fig. 5.11: Proportion of behavioural change in Hector's dolphin groups observed in relation to vessel approach type, when considering the initial behaviour of dolphins in Akaroa Harbour, New Zealand. Bars represent the standard error of the sample proportion.

5.4.2.4. Responses to swimmers placement

Dolphin responses to swim encounters varied significantly with swimmer placement (Pearson's χ^2 test: $\chi^2_4 = 19.775$, $p = 0.0006$). *Line abreast* placement resulted in a decrease in avoidance of swimmers (Freeman-Tukey deviates < -1). In contrast, when swimmers were placed *in path*, dolphins were more likely to avoid the swimmers or stay neutral rather than interact (Freeman-Tukey deviates > 1; Fig. 5.12).

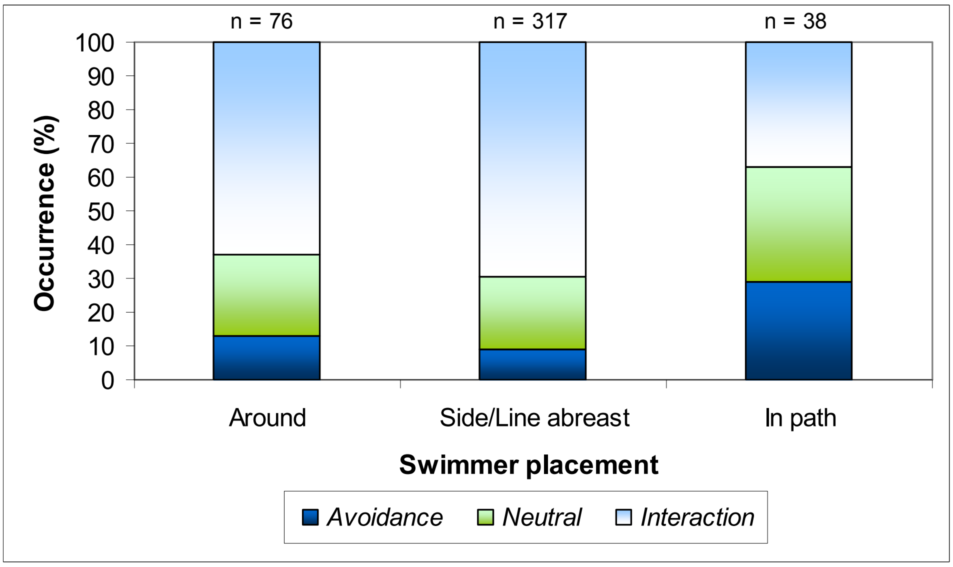


Fig. 5.12: Hector's dolphin responses to swimmers (percentage) as a function of swimmer placement in Akaroa Harbour, New Zealand.

Swimmer placement also significantly affected encounter duration between Hector's dolphins and swimmers (χ^2_4 = 19.775, p = 0.0015). An *in path* placement resulted in an increase (Freeman-Tukey deviates > 1) in the likelihood of a short swim encounter (less than five minutes) but an actual decrease in both medium and longer encounters (Freeman-Tukey deviates < -1; Fig. 5.13).

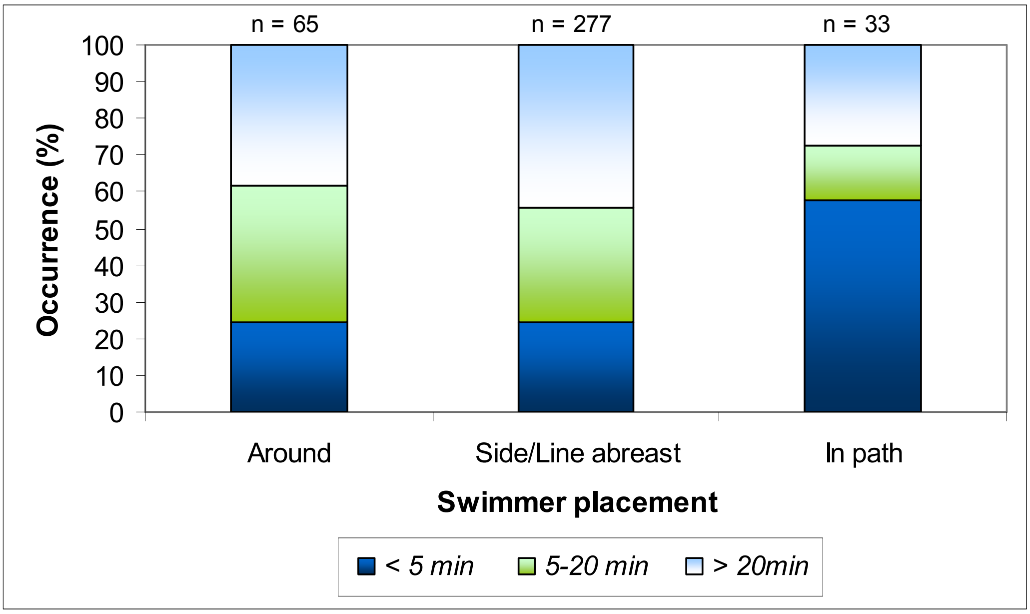


Fig. 5.13: Encounter duration between Hector's dolphins and swimmers (percentage) as a function of swimmer placement, in Akaroa Harbour, New Zealand.

5.4.2.5. Orientation of Hector's dolphins during an encounter

According to behaviour

As there were no statistical differences between dolphin-watching and swimming-with-dolphin vessel platforms (Pearson's χ^2 test: χ^2_2 = 3.699, p = 0.157), data were pooled to increase sample size. Dolphin movement in relation to swimmers and/or vessel(s) varied with the behavioural state of the dolphins (Table 5.6). Dolphin groups headed *away* from swimmers and/or a vessel more often when diving (25.0%) or travelling (23.6%) than during milling (2.8%; χ^2_6 = 77.125, p < 0.0001). When milling, dolphins were more likely to head *towards* swimmers (Freeman-Tukey deviates > 1) and were less likely to move *away* (Freeman-Tukey deviates < -1). In addition, dolphins had a significant tendency to remain *neutral* when diving (Freeman-Tukey deviates > 1), *i.e.* neither approaching not avoiding swimmers and/or vessel(s).

Table 5.6: Hector's dolphin headings (percentage) as *towards*, *neutral* and *away* from swimmers and/or vessel(s) in relation to their behavioural state during encounters in Akaroa Harbour, New Zealand.

Behaviour	Towards (%)	Neutral (%)	Away (%)	n
Milling	64.6	32.6	2.8	325
Diving	19.4	55.6	25.0	36
Socialising	45.5	42.4	12.1	33
Travelling	41.9	34.5	23.6	203

According to time into an encounter

Logistic regression

a) Towards

Responses of dolphin groups observed from 62 land-based encounters, regardless of their behaviour, and relative to time into an encounter, are presented in Table 5.7.

Table 5.7: Orientation of Hector's dolphins *towards* swimmers and/or vessel(s) relative to time into encounters (ten minute-intervals) in Akaroa Harbour, New Zealand.

Time into encounter (min)	Total number of orientations (n)	Total number *towards* orientations	Proportion *towards* orientations
0 - 10	204	123	0.603
11 - 20	132	58	0.439
21 - 30	103	57	0.553
31 - 40	65	35	0.538
41 - 50	32	18	0.563
> 50	35	11	0.314

The best fitting model was Model 4 (Table 5.8). The goodness-of-fit test of model 4 showed no evidence of lack of fit ($p < 0.05$), thereby confirming that this model was a good predictor of the probability of a group of dolphins heading *towards* swimmers and/or vessel(s) as a function of time into an encounter.

Table 5.8: Analysis of deviance for assessing goodness-of-fit of models performed using logistic regression to predict Hector's movement *towards* swimmers/vessels as a function of time into an encounter in Akaroa Harbour, New Zealand. Note: d.f. refers to statistical degrees of freedom.

Model	Deviance	d.f.	Deviance difference	d.f.	Estimates for fitted equation
Constant only	11.755	5			-0.917
Constant + T	8.719	4	3.036 (ns)	1	0.132
Constant + $T + T^2$	8.651	3	0.069 (ns)	1	-0.005
Constant + $T + T^2 + T^3$	2.617	2	6.034 (*)	1	5.4×10^{-5}

(ns) = not significant at $p < 0.05$. * = significant at $p < 0.05$.

Dolphin groups exhibited significant attraction *towards* swimmers and/or vessel(s) for the initial 50 min of an encounter (Fig. 5.14). However, after the initial 50 min, no orientation *towards* of swimmers and/or vessel was evident (Fig. 5.14). Consequently, the null hypothesis could not be discarded, *i.e.* dolphin group movement could, therefore, be entirely random after 50min into an encounter.

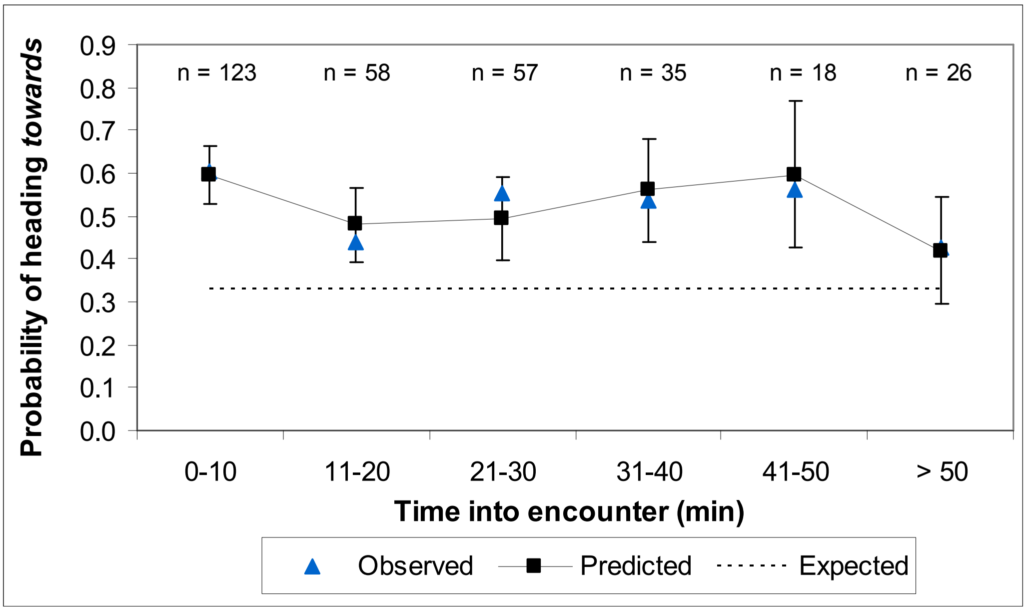


Fig. 5.14: Probability of a dolphin group heading *towards* swimmers and/or vessel(s) as a function of time into the encounter (min), as observed from land-platforms in Akaroa Harbour, New Zealand. Error bars indicate 95% confidence intervals of predicted probabilities. Note: n = number of observed group orientations in relation to a vessel in a given time interval.

b) Away

Responses of Hector's dolphin groups *away* from swimmers and/or vessel(s) are presented in Table 5.9.

Table 5.9: Orientation of Hector's dolphins *away* from swimmers and/or vessel(s) relative to time into encounters (ten minute-intervals) in Akaroa Harbour, New Zealand.

Time into encounter (min)	Total number of orientations (n)	Total number *away* orientations	Proportion *away* orientations
0 - 10	204	23	0.113
11 - 20	132	18	0.136
21 - 30	103	10	0.097
31 - 40	65	9	0.138
41 - 50	32	2	0.063
> 50	35	8	0.131

There was no statistical evidence that the addition of T, T^2, and/or T^3, further improved the fit (Table 5.10). As a result, model 1 (constant only) was selected. The goodness-of-fit test of model 1 showed no evidence of lack of fit ($p < 0.05$), thereby confirming that this model was a good predictor of the probability of a group of dolphins heading *away* from swimmers and/or vessel(s) as a function of time into an encounter.

Table 5.10: Analysis of deviance for assessing goodness-of-fit of models performed using logistic regression to predict Hector's movement *away* swimmers/vessels as a function of time into an encounter in Akaroa Harbour, New Zealand. Note: d.f. refers to statistical degrees of freedom; n/a = not applicable.

Model	Deviance	d.f.	Deviance difference	d.f.	Estimates for fitted equation
Constant only	2.3858	5			2.019
Constant + T	2.3857	4	0.0001 (ns)	1	n/a
Constant + T + T^2	2.3644	3	0.2122 (ns)	1	n/a
Constant + T + T^2 + T^3	1.8324	2	0.5320 (ns)	1	n/a

(ns) = not significant at $p < 0.05$.

Dolphin groups moved *away* from swimmers and/or vessel(s) significantly less often than expected for the duration of an encounter (Fig. 5.15). The predicted level of avoidance, while constant, remained low at 0.117 (Fig. 5.15).

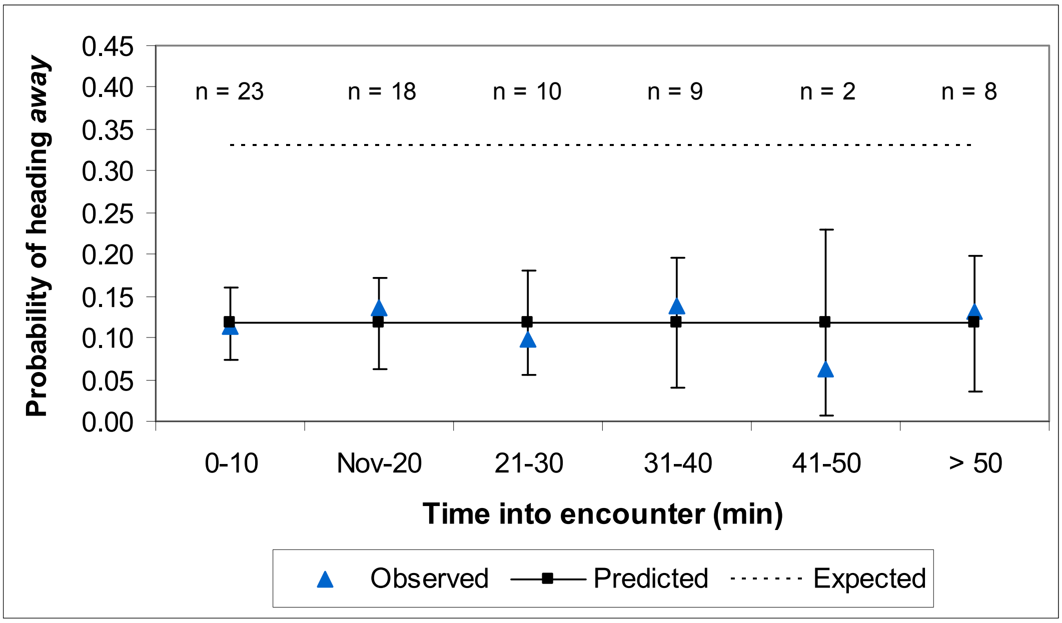


Fig. 5.15: Probability of a dolphin group heading *away* from swimmers and/or vessel(s) as a function of time into the encounter, as observed from land-platforms in Akaroa Harbour, New Zealand. Error bars indicate 95% confidence intervals of predicted probabilities. Note: n = number of observed group orientations in relation to a vessel in a given time interval.

5.4.2.6. Behavioural budget

All first-order transitions in behavioural state provided more information than the sole frequency distribution of the behavioural states (*i.e.* zero-order chain), except for those recorded in the presence of less than five swimmers (Table 5.11). No significant difference was detected between behavioural budgets calculated using zero- and first-order Markov chains for both vessel type and departure time (Z-test for proportions: $p > 0.05$). Consequently, it was assumed that although zero-order chains were used to analyse the effect of swimmer numbers, results would not have been significantly different from first-order chains, should assumptions had been met.

Table 5.11: Chain order selection using Bayes Information Criterion (BIC). A higher order chain provides more information than a lower chain order if $\Delta BIC > 2\log 100$ (= 9.2).

Chain	Chain order	BIC	ΔBIC
DW (1 vessel)	0	-4404.88	
	1	-3384.98	1019.898
SW (1 vessel)	0	-1552.42	
	1	-1149.84	402.582
SW (< 5)	0	-807.207	
	1	-832.714	-25.507
SW (> 5)	0	-2010.98	
	1	-1892.88	118.094
Discrete	0	-2119.93	
	1	-1677.73	442.204
Staggered	0	-2310.86	
	1	-1863.29	447.562

Effect of encounter type on the behavioural budget of Hector's dolphins

The behavioural budget of Hector's dolphins differed significantly between dolphin-watching and swimming encounters. Dolphins spent more time milling (Z-test of proportions: $z = 13.61$, $p < 0.0001$) in the presence of swim-with-dolphin vessels (Fig. 5.16a), but were less likely to be travelling ($z = -5.29$, $p < 0.0001$) or bow riding ($z = -13.9$, $p < 0.0001$). The amount of time dolphins engaged in diving and socialising did not differ between the two tour types (Z-tests, $p > 0.05$, Fig. 5.16a).

Effect of swimmer numbers on the behavioural budget of Hector's dolphins

In the presence of larger groups of swimmers, Hector's dolphins engaged significantly more in diving ($z = -3.1$, $p = 0.002$) and less in socialising ($z = 3.78$, $p = 0.0001$; Fig. 5.16b). The addition of more swimmers in the water did not affect the travelling (z = 0.09, p = 0.932) or milling (z = -0.92, p = 0.356) time budgets (p > 0.05, Fig. 5.16b).

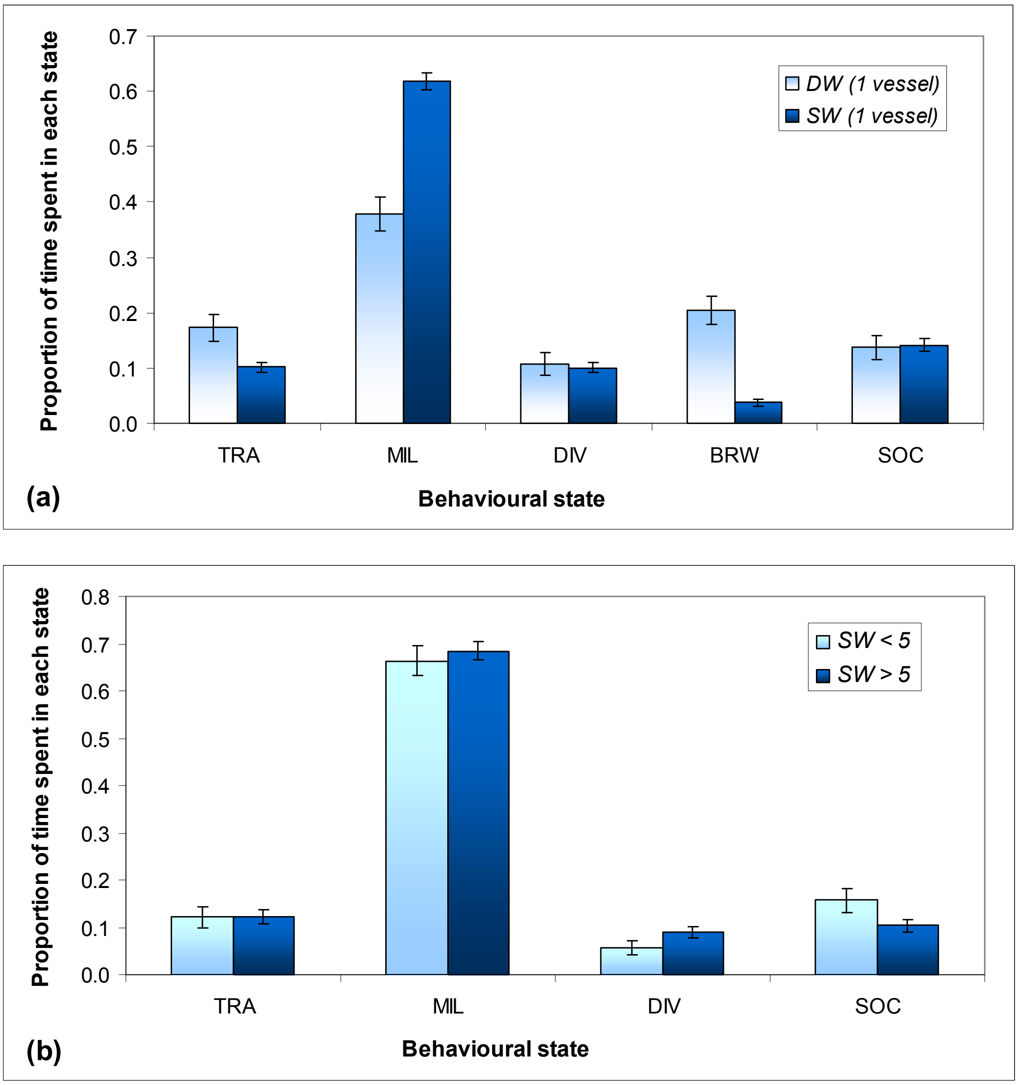


Fig. 5.16: Behavioural budget of Hector's dolphins in the presence of: a) one commercial vessel for viewing (DW) or swimming (SW) with dolphin; and b) small and large groups of swimmers (SW) (and vessel platform) in Akaroa Harbour, New Zealand. Values are proportion of time spent in each state. Error bars represent 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, BWR = bow-riding, and SOC = socialising.

Effect of staggered *vs*. discrete *departure times on the behavioural budget of Hector's dolphins*

In comparison with *discrete* departure times, *staggered* departures, occurring only in the afternoon, did not significantly affect the amount of time dolphins engaged in travelling, milling, and bow-riding (Z-tests, p > 0.05). However, a significant decrease in diving ($z = 3.219$, $p = 0.001$) and an increase in socialising were detected ($z = -2.69$, $p = 0.006$; Fig. 5.17).

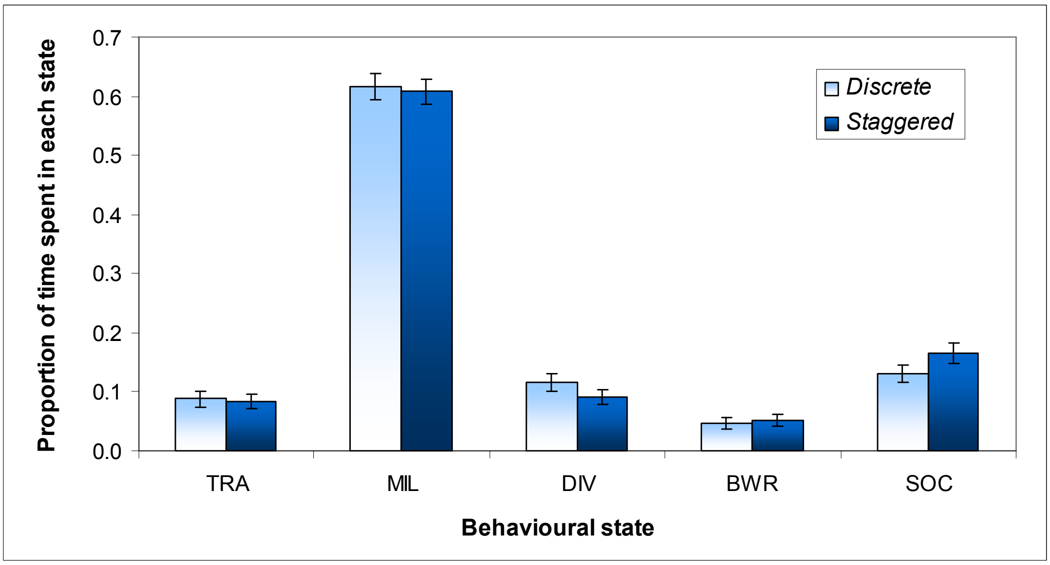


Fig. 5.17: Behavioural budget of Hector's dolphins in relation to *discrete* and *staggered* departure times of swim-with-dolphin trips in Akaroa Harbour, New Zealand. Values are proportion of time spent in each state. Error bars represent 95% confidence intervals. Note: TRA = travelling, MIL = milling, DIV = diving, BWR = bow-riding, and SOC = socialising.

5.5. Discussion

Under the Marine Mammals Protection Regulations (MMPR, 1992; Appendix 1.4), commercial tour operators must ensure that their operation has *no significant adverse effect* (sections 4c, 6c, and 12a) on the target population. Considering that even low-level tourism can have long-term effects (*e.g.* Bejder *et al*., 2006b), it is appropriate to question whether the current level of tourism in Akaroa Harbour is affecting the dolphins (including commercial swim-with-dolphin trips with Hector's dolphins, which are only permitted in Akaroa Harbour).

Characteristics of encounters

Hector's dolphins are an attractive target for dolphin tours as they are easily located within the permitted area of commercial tourism operation in Akaroa Harbour. In most cases (over 80%), skippers sighted a dolphin group unassisted and within 16 min of departure. Swim-with-dolphin trips lasted on average 1.75 hr, concurrent with 1.8 hr reported by Nichols *et al*. (2002). These trips were generally shorter than dolphin-watching tours, which also consisted of visiting points of interests within and around the harbour. As a result, no monthly variation was detected with dolphin-watching tours, whereas swimming trips varied in relation to the seasonal location of Hector's dolphins in the harbour. Tours were longer during early and late austral summer months when the majority of dolphins are typically located in the *outer* harbour (Chapter II), near the entrance, while groups were found more promptly in January and February when dolphins are further inside the harbour (Dawson, 1991b; Chapter II), reducing the distance travelled to locate them.

Compared to other species that support swim-with-dolphin tourism, Hector's dolphins are very receptive to contact with swimmers. This is shown in the high proportion of sustained and successful swim attempts (only 11.6% were *poor* encounters). The receptivity of this species is also evident in the low number of attempts needed to obtain a satisfactory swim encounter, in addition to the relatively long duration of each swim attempt (25.3 min). A swim was attempted during 93.8% of the trips monitored, with an average of 1.6 attempts per trip, which is less than with common dolphins observed in Mercury Bay (mean swim attempts = 2.6, Neumann and Orams, 2006) and dusky dolphins off Kaikoura (mean swim attempts = 4.0, Markowitz *et al.*, 2009c). In terms of duration, common dolphins appear to be the least receptive to swimmer contact as attempts last only three minutes on average in Mercury Bay (Neumann and Orams, 2006) and five minutes in the Bay of Islands (Constantine and Baker, 1997). Swim drops off Kaikoura with dusky dolphins were more prolonged with an average swim of nine minutes (Markowitz *et al.*, 2009c). The duration of swim encounters with delphinids outside New Zealand, appear to confirm this trend, appear to confirm this trend, with 12 and 14 min reported for rough-toothed dolphins (*Steno bredanensis*; Ritter, 2002) and short-finned pilot whales (*Globicephala macrorhynchus*; Scheer, Hofmann, & Behr, 2004), respectively in the Canary Islands.

Bejder *et al.* (1999) reported that 57% of recreational swim attempts from the shore with Hector's dolphins in Porpoise Bay lasted more than 5 min. In Akaroa Harbour, the mean duration of commercial swim encounters was 25 min, a three-minute increase over the five-year period since Nichols *et al.* (2002). As this change has not been tracked consistently (annually) across this time period, it may be that this increase is due solely to differences in methodologies between the studies. It may also suggest, however, that dolphin tolerance to swimmer presence may be slowly increasing over time, an indication of potential habituation. Tolerance is defined as "the intensity of disturbance that an individual tolerates without responding in a defined way" (Nisbet, 2000), while habituation is described as "the relative persistent waning of a response as a result of repeated stimulation, which is not followed by any kind of reinforcement" (Thorpe, 1963).

Bejder *et al*. (2009) clearly indicated that the inappropriate application of the term *habituation* could mislead managers to conclude that tourism activities have neutral, or even benign, consequences on dolphin populations when their effects are actually detrimental. Samuels *et al*. (2003) defined "habituated dolphins as a group in which many individuals have repeated and sustained interactions with human swimmers on a regular basis without pursuit by humans, without signs of disturbance in response to human actions, and without the incentive of food provisioning".

While a three minute increase in encounter duration may not indicate long-term increases in dolphin tolerance, associated changes in dolphin behavioural responses may lend evidence to the possibility of habituation. Stone and Yoshinaga (2000) provided anecdotal information on the changes in Hector's dolphin behaviour responses to swimmers that had taken place in Akaroa Harbour over the past 15 years, *i.e*. becoming less wary with time. According to these authors, until 1999, dolphins would typically "scatter when a diver entered the water, occasionally swimming within five or seven meters of the person and then swim away rapidly". The authors noted that starting in 1999, "the dolphins began remaining near the diver, sometimes swimming right up to him and the animals appeared less wary of the diver". In 2008, it was not uncommon to observe dolphins approaching very close to swimmers (within an arm length) and circling around them (Chapter VI). An increase in tolerance levels has also been demonstrated in other species. In Kaikoura, the duration of swim encounters with semi-resident dusky dolphins increased from 8.3 to 9.1 min between 1997-1999 and 2007-2009, (Markowitz *et al*., 2009c). Ransom (1998) reported a rise in encounter duration from 7 to 11 min with Atlantic spotted dolphins in the Bahamas over a six-year period. Sensitisation to swimmers over time has also been demonstrated in some species, like the bottlenose dolphins in the Bay of Islands, New Zealand (Constantine, 2001).

Dolphin-watching and swimming tours in Akaroa Harbour target wild and non-provisioned Hector's dolphins. It is, therefore, not surprising that almost half (45%) of encounters terminated because dolphins left the vicinity of the vessel or the swimmers. However, in nearly a quarter of swim attempts (23.8%), the operators had to end an encounter due to a legally imposed time limit. This implies that Hector's dolphins, if given the opportunity, could potentially interact with swimmers for prolonged durations, hence the importance of determining whether such activity may have any detrimental effects on the dolphins.

Responses of Hector's dolphins to encounters

Individual Hector's dolphins that use the Akaroa Harbour as part of their home range (Chapter VII) may have had the opportunity to become habituated over time as first suggested by Stone (1992). To determine whether Hector's dolphins in Akaroa met the criteria to be classified as habituated, it was first necessary to ascertain the proportion of time Hector's dolphins spent actively engaging with swimmers and the factors affecting it, as it gives a more precise measure of the affinity of dolphins for swimmers than the overall encounter duration (*i.e.* total time swimmers were in the water).

Unlike in Kaikoura, where approaching and dropping swimmers in front of a group of dusky dolphins decreased the duration of swim interactions (Markowitz *et al*., 2009c), both swimmer placement and the number of swimmers did not appear to be the primary factors affecting the time Hector's dolphins interacted with swimmers in Akaroa. However, other variables did affect this, with dolphins interacting significantly longer when in larger groups (six or more individuals) and when previously engaged in milling behaviour. The findings of chapter IV demonstrated that Hector's dolphins increased the proportion of time they engaged in milling, as well as socialising, when interacting with vessels and/or swimmers. Groups engaged in such behavioural states tend to be naturally larger than when diving or travelling (Chapter II). In other species in New Zealand waters, group size and dolphin behavioural activity also influence the swim duration or the success of swim attempts. When in larger groups, common dolphins were more tolerant of the swimmers in both the Hauraki Gulf (Leitenberger, 2001) and Mercury Bay (Neumann and Orams, 2006). Leitenberger (2001) suggested that the observed increase in avoidance rate in common dolphins in the Hauraki Gulf was a function of small group sizes, supporting the notion that dolphins find "safety in numbers". This could also be the case for Hector's dolphins given that they are the smallest marine delphinid (Dawson, 2002). Constantine (2001) also indicated that age-class might be a factor influencing the success of a swim, with juvenile bottlenose dolphins more likely to interact than adults. In terms of behaviour, common dolphin groups in Mercury Bay were also more interactive when the predominant group activity was socialising, and less so when travelling or milling (Neumann and Orams, 2006). Similar observations were made with dusky dolphin groups in Kaikoura (Markowitz *et al*., 2009c).

Interaction time was also shorter in mid austral summer (*i.e.* January and February) than in early austral summer (*i.e.* November and December). Although, departure time was marginally insignificant, it is still worth noting that encounters around midday (1200 and 1400 hr trips) were shorter than morning (0600 and 0900 hr) trips. Nichols *et al*. (2002) also reported that Hector's dolphins were more interactive during the mornings. It may be that the operators' tendency to head to the same area where they had a good previous encounter and/or to "hand-over" a receptive dolphin group is increasing the likelihood of repeatedly targeting the same group over the course of a day. An increased number of swim attempts made towards the same group was found to reduce the duration of swim encounters or dolphin affinity for swimmers in both Hector's and dusky dolphins (Markowitz *et al*., 2009c). Alternatively, differences in interaction time might be a reflection of diel behavioural patterns. In Kealakekua Bay (Hawaii), spinner dolphins were found to be more interactive in early mornings when few local people swam, yet avoided swimmers around midday, when many tourists and vessels were present (Green and Calvez, 1999). Spinner dolphins enter bays in early morning to socialise and rest before moving further offshore in the late afternoon or early evening to forage (Norris *et al*., 1994). Lammers (2004) indicated that time of day rather than location, appeared to be a greater influence on the activity level of spinner dolphins in Oahu, Hawaii. Although resting behaviour could occur at anytime during the day, it was observed more consistently during the midday and early afternoon periods. Spinner dolphins also entered into a period of rest after an early morning phase of social activity. The behaviour state and the manner in which spinner dolphins are approached in Hawaii also appear to be the main factors that determine how the dolphins will react to vessels and swimmers (Norris *et al.*, 1994;

Lammers, 2004). Socially active groups were often tolerant of a human presence unless actively pursued (Lammers, 2004). When resting, however, they usually avoided engaging with swimmers and sometimes left an area if forced to interact (Norris *et al.*, 1994).

Vessel traffic and tourism activities peaked around midday and in January (Chapter III). The generally lower tourism activity in the mornings and earlier in the austral summer could explain the tendency for dolphins to interact longer with swimmers during these time periods. Markowitz *et al*. (2009c) also recorded shorter swim durations with dusky dolphins in the austral summer, coinciding with a peak in tourism, potentially indicating some level of sensitisation to seasonally high levels of vessel interaction. In the Bay of Islands, New Zealand, resident bottlenose dolphins exhibited long-term sensitisation to swim-with-dolphin tourism as their avoidance response increased over a five-year period (Constantine, 2001). Although Hector's dolphins in Akaroa Harbour may have developed an increased tolerance to swimmers over time (as indicated by an increased interaction time over a five-year period), they appear to display a temporal shift in their receptivity to swimmers during the austral summer months. This is yet another example illustrating how tourism activities may affect species differently, and why management needs to focus at the species, and more importantly, at the local population level.

Responses to vessel approach

National and international research suggests the strategies employed to approach a group of dolphins affect the way the animals respond to a vessel, and presumably the level of disturbance to the group (*e.g.* Lusseau, 2006; Neumann and Orams, 2006). It has been suggested that dolphins are able to detect and localise incoming vessels and adapt their behaviour accordingly (Nowacek *et al*., 2001; Lemon *et al*., 2006). Invasive approaches (*e.g. in path*) leave dolphins two choices, interaction or avoidance (Constantine, 2001). This type of approach could be perceived by dolphins as threatening, and may be more likely to result in a behavioural change. For that reason, it is prohibited to intercept the path of a dolphin group in New Zealand under the MMPR (1992, section 18k). When vessels are driven in a manner which is consistent with the provisions of the MMPR, both common and bottlenose dolphins showed fewer behaviour changes (Lusseau, 2006; Neumann and Orams, 2006).

In the present study, Hector's dolphins also had a tendency to change their behavioural state more often when vessels used an *in path*/*rear* approach. Compliance with this regulation by commercial tour vessels in Akaroa Harbour was relatively high at 76.8% (Appendix 3.1). However, there is a particular concern about jetskis as they were two and six times more likely to breach the MMPR by manoeuvring their vessel improperly around dolphins (*e.g.* circling around a group) compared with other recreational and commercial operators, respectively. When vessels are driven in a manner, which is consistent with the provisions of the MMPR, common, bottlenose, and Hector's dolphins showed fewer behaviour changes (Lusseau, 2006; Neumann and Orams, 2006; this study).

Reactions to approaching vessels may also be related to the dolphin behavioural state. Hector's dolphins were more likely to change behaviour when engaged in social or travel states, and least likely to do so when diving, especially if approached from the side (a less invasive approach). This is consistent with other studies, although intra- and inter-species differences are apparent. In the Bay of Islands, socialising was the most likely disrupted behaviour for both common and bottlenose dolphins, while resting common and foraging bottlenose dolphins were less likely to change their behaviour (Constantine and Baker, 1997). In contrast, disruption was less likely to occur when Atlantic spotted dolphins in the Bahamas (Ransom, 1998) and bottlenose dolphins in Florida (Shane, 1990a) were socialising. A lower probability of a behavioural change occurring when diving (foraging) Hector's dolphins were initially approached, potentially denotes the importance of this behaviour in terms of energy intake for this species survival (Chapter IV). This further suggests that changes in socialising behavioural patterns might not be as biologically important. Furthermore, effects associated with tourism activities (Chapter IV) would be expected to be lessened if skippers of commercial and recreational vessels avoid approaching and interacting with a diving dolphin group that show no interest, as indicated by the absence of behaviour change.

Responses to swimmers placement

Previous research has demonstrated that swimmer placement can also affect dolphin response to swimmers (*e.g.* Constantine and Baker, 1997; Constantine, 2001; Markowitz *et al.*, 2009c). In Akaroa Harbour, operators have a high compliance level in terms of swimmer placement, as with vessel approach (Appendix 3.1). Swimmers entered the water to the side of the dolphin groups (*line abreast* placement) during 73.5% of the time and a further 17.6% of swim attempts were initiated when dolphins were milling around stationary vessels. *In path* placement was least observed, accounting for just 8.8% of approaches. Despite a low sample size, it is clear that an *in path* approach resulted in the highest rate of avoidance response and the shortest encounter times. This type of reaction is consistent with that observed for other species within New Zealand waters, namely common (Leitenberger, 2001; Constantine and Baker, 1997), dusky (Markowitz *et al*., 2009c) and bottlenose dolphins (Constantine, 2001). A *line abreast* placement offers dolphins the choice to approach swimmers or maintain their current behavioural activity. Conversely, with an *in path* approach, dolphins must choose to stay and interact or physically avoid the swimmers (Constantine, 2001). An *around vessel* placement resulted in a significant increase in avoidance response of bottlenose dolphins (Constantine, 2001). There is no evidence, however, to suggest that this is also the case for Hector's dolphins. Unlike bottlenose dolphins, Hector's dolphins that remain once a vessel approaches, appeared willing to interact with the vessel, as well as the swimmers. Some skippers and guides in Akaroa Harbour (usually those more experienced) tend to use that cue as an indicator of a group's receptivity prior to deploying swimmers (Nichols *et al*., 2002; pers. obs.).

Orientation of Hector's dolphins during an encounter

Hector's dolphins are neither vessel nor swimmer-phobic (*e.g.* Bejder *et al*., 1999). Indeed, previous research in Porpoise Bay, Southland, indicated that dolphins tended to approach the dolphin-watching vessel in the initial stages of the encounter (10 to 50 min after the vessel entered the bay), before decreasing their interest beyond 70 min (Bejder *et al*., 1999). As a consequence of these research findings, a 40 min-limit was legally imposed on the local operator. In a subsequent study, Green (2003) suggested that although Hector's dolphins were more likely to head *towards* vessels in concurrence with Bejder *et al*. (1999), the duration of an encounter had no longer significant effect on dolphin movement. On the other hand, Green (2003) reported that Hector's dolphins showed an increased attraction *towards* swimmers (entering the water from shore) for the initial 30 to 40 min of an encounter before subsequently decreasing. The different response of Hector's dolphins *towards* vessels and/or swimmers in Porpoise Bay may be due to an increase in the proportion of time dolphins spent with swimmers between the two studies (*i.e.* increased tolerance levels). Interaction levels with vessels, however, remained constant at that location (leading to potential habituation).

Although the methods used to assess the orientation of Hector's dolphins differed between Porpoise Bay (Bejder *et al*., 1999) and Akaroa Harbour (this study), a similar trend in dolphin heading was found between the sites. In the present study, dolphin groups typically approached vessel(s) and/or swimmers for the initial 40 to 50 min into an encounter. After this point, dolphins lost interest and their movements became random. This finding supports the decision by DOC in 2007 to reduce the legal time limit from 60 min down to 45 min for swim-with-dolphin permittees in Akaroa Harbour (Allum, pers. comm.).

Interestingly, after a marginal decline in *towards* dolphin headings within the first 20 min of a swim (which could be part of an initial response), these headings gradually increased until the legal swim time limit was reached. This concurs with Nichols *et al*. (2002), who reported an increase in the rate of approaches to swimmers as the swim time elapsed. This could be linked to a growing number of dolphins that participate in a swim over time as suggested by Nichols *et al*. (2002). During the course of this study, it was not unusual to observe additional dolphin groups approaching vessel(s) and/or swimmers over the course of an encounter (pers. obs). As such, it can be hypothesised that dolphin interactions with vessels and/or swimmers might be of benefit to the Hector's dolphins. Over time, they could have learnt to use the presence of vessels and/or swimmers as a cue to find conspecifics, given that there is evidence to suggest that small groups (< 5 individuals) show high degree of sex segregation (Webster *et al*., 2009).

Time into an encounter had no effect on the movement of Hector's dolphins *away* from a vessel and/or swimmers. However, dolphin avoidance was less than expected for the whole duration of an encounter, and are in contrast to findings by Martinez (2003). In Motunau, prior to the establishment of a commercial wildlife-tour operation, movement of Hector's dolphins in relation to vessels was random during the entire duration of an encounter (Martinez, 2003). Although no baseline data are available for Akaroa Harbour Hector's dolphins (prior 1985), these findings potentially support previous suggestions that Hector's dolphins in Akaroa Harbour could have become more tolerant of tourism activities over the years (Stone and Yoshinaga, 2000). Interactions with this species might, therefore, be dependent on the level of exposure to vessel traffic and tourism activities that a population has been subjected to over the years.

Hector's dolphin attraction, avoidance, or neutral responses to a vessel and/or swimmers were also influenced by the behavioural state of the group. Hector's dolphins engaged in diving and travelling activities were more likely to move *away* or to remain neutral in the case of diving, when compared to milling. This explains why milling was found to be the main behaviour affecting the duration of an interaction between dolphins and swimmers. The lack of significant movement *away* from vessels and/or swimmers during an encounter does not imply that tourism activities have no negative effects on the dolphins. Even in the case of a positive response (*i.e.* attraction), dolphins spending a significant proportion of their time interacting with humans could potentially detract from their normal daily activities. If behavioural budgets are subsequently disrupted, particularly in relation to critical behaviours such as foraging (Chapter IV), interactions may have important long-term population consequences (*e.g.* Williams *et al*., 2006).

Behavioural budget

The International Whaling Commission (IWC) Scientific Committee (2000) argued that the effects of swim-with-cetacean programmes in the wild should be assessed on a case by case basis because they can vary among species, populations and locations. In addition, vessel tour type, number of swimmers in the water, and *staggered* departure times can also potentially influence the delphinids response. In Akaroa Harbour, the behavioural budget of Hector's dolphins differed when interacting with viewing or swimming tours. Dolphins engaged more, for example, in milling in the presence of swimmers. The differences observed between the two encounter types (viewing *vs.* swimming) are likely to reflect the way these tours are operated. Swim-with-dolphin trips tend to be stationary when swimmers are in the water, encouraging dolphins to mill more, while decreasing opportunities to bow-ride or travel as opposed to dolphin-watching cruises.

In Kaikoura, Markowitz *et al*. (2009c) reported no direct relationship between the number of swimmers and dolphin behavioural changes. This suggests that vessel activity and the number of vessels, rather than swimmers, are the main factors influencing dusky dolphin behaviour. In Akaroa Harbour, the presence of swimmers in the water did affect diving and socialising behavioural activities, behaviours not influenced by dolphin-watching tours. When the number of swimmers was large (more than five), dolphins spent significantly less time socialising and more time diving. An increase in diving could indicate a vertical avoidance of an interaction with swimmers, a typical response in cetaceans used to elude predators (Weihs and Webb, 1984), or alternatively a method to come close to swimmers without being detected. As Hector's dolphins are the smallest marine dolphin (Dawson, 2002), it is possible that a large number of swimmers might appear intimidating to a diving dolphin group, especially if swimmers are in a tighter formation. Anecdotally, skippers and guides often inform swimmers to keep a minimum distance of one human body-length between them to not only encourage dolphins to swim among them but also to appear less daunting (pers. obs.). Swimmers are also encouraged to look underwater for the dolphins, rather than keep their head above the surface during an encounter.

In the Bay of Islands, Constantine *et al*. (2004) suggested that *staggered* departure times resulted in a further decrease in resting and foraging but an increase in milling and travelling behaviour of bottlenose dolphins. In Akaroa Harbour, Hector's dolphins were observed to dive less and socialise more in relation to *staggered* departures. A trend also observed as a result of the close presence of vessel activity (Chapter IV). *Staggered* departures between viewing and swimming tours can potentially increase the cumulative effects of tourism activities, especially when dolphin groups are "handed over" between operators. These departures also occur in the afternoon, which also coincides with a peak in vessel activity in the harbour (Chapter III). It is possible, therefore, that Hector's dolphins' ability to dive and forage could be affected by the underwater noise generated by vessels (*e.g.* Stocker, 2002; Au *et al*., 2007) and/or frequent encounters. As a result, dolphins may adjust their behavioural budget accordingly, *e.g.* dive more in the absence of vessels (Chapter IV). This reinforces concerns over the amount/duration of continuous pressure that tourism may be placing on Hector's dolphins in Akaroa Harbour, in addition to that of other human threats already identified (*e.g.* by-catch in fisheries; Dawson, 1991b; Secchi, 2006; Slooten, 2007).

5.6. Conclusion

There is a large market for swim-with-dolphin activities, which represent a long-standing desire to interact with delphinids based upon the perception of dolphins as charismatic mega-fauna and popular representations of dolphins in the media (Curtin and Wilkes, 2007). Dolphin-tourism has one of the greatest potentials for altering dolphin behaviour due to the extended time swimmers and tour vessels spend with the dolphins. This is particularly true for swim-with-dolphin encounters with Hector's dolphins, a species that appears very receptive to contact with vessels and swimmers, compared with other species targeted by this type of activity in New Zealand. The Hector's dolphin is also an attractive species to target, especially in Akaroa Harbour, where its seasonal preference means tourists can be interacting with dolphins within *ca.* 15 min of departure point, when dolphins tend to be found further inside the harbour (Dawson, 1991b; Chapter II). These characteristics provide patrons with as many as five different departure times throughout the day during the peak tourism season.

With up to 18 daily swim-with-dolphin trips between November and March alone (in addition to 14 dolphin-watching trips), pressure on Hector's dolphins is very high. Many individual dolphins can be subject to repeated swim attempts between November and March (Chapter VII), and to a lesser extent the rest of the year, in particular, individuals exhibiting a high degree of site fidelity. Over a five-year period, Hector's dolphins have become more tolerant to the presence of swimmers. However, within an austral summer season, some level of sensitisation to varying levels of tourism activities and vessel traffic is evident. Hector's dolphins are, therefore, not yet habituated (as defined by Samuels *et al*., 2003). This study also confirms that adherence to the MMPR and code of conducts is imperative to minimise the effects of tourism activities on a targeted species.

It is important not to dwell on the statistical significance of the results but to determine whether such changes are "biologically" meaningful (Orams, 2004; Richter *et al.*, 2006). There is a common misconception that because dolphins "choose" to approach and interact, there are no detrimental consequences. Even apparently positive interactions could, however, have long-term effects on populations by detracting from important behaviour such as foraging or resting. Tourism activities in Akaroa Harbour, whether commercial or recreational, are disrupting Hector's dolphin behavioural budgets (Chapter IV). There is further evidence that *staggered* departure times affect further the dolphin diving behaviour. An increased tolerance of human interactions linked with a disruption of diving, which is important in terms of energy uptake, could potentially have major consequences for this population, already vulnerable to other human activities (*e.g.* Slooten, 2007; Stockin *et al.*, 2010b).

This study provides sufficient evidence to support the main recommendations that: a) no further swim-with-dolphin permits within Akaroa Harbour should be granted; and b) a reduction in the level of exposure of Hector's dolphins to tourism activities should be considered. In addition, adhesion to the MMPR and enforcement of regulations should both be improved. This is essential if the MMPR requirement of *no significant adverse effect* on this endemic and endangered species is to be upheld.

CHAPTER VI

The use of auditory stimulants during swim encounters with the South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) in Akaroa Harbour, Banks Peninsula

Photo: A.R.E.V.A. Project © 2007

Chapter VI draws on the manuscript:
Martinez, E.; Orams, M.B.; Pawley, M.D.M.; Stockin, K.A. (in press). The use of auditory stimulants during swim encounters with Hector's dolphins (*Cephalorhynchus hectori hectori*) in Akaroa Harbour, New Zealand. *Marine Mammal Science*.

6.1. Introduction

Marine mammal tourism is a large industry worth an approximated US$2.1 billion in total expenditures (O'Connor *et al.*, 2009). On a global scale, the industry has grown at an average rate of 3.7% per annum between 1998 and 2008 (O'Connor *et al.*, 2009). However, there is a growing body of evidence, both worldwide and within New Zealand, to suggest that both cetacean-watching and -swimming activities are not benign, disturbing targeted animals in the short-term (*e.g.* Baker and Herman, 1989; Janik and Thompson, 1996; Bejder *et al.*, 1999; Constantine, 2001; Nowacek *et al.*, 2001; Samuels *et al.*, 2003; Lusseau, 2003a; Constantine *et al.*, 2004; Ribeiro *et al.*, 2005; Bejder *et al.*, 2006a; Richter *et al.*, 2006; Stockin *et al.*, 2008a; Williams *et al.*, 2009). Recently, research has linked short-term effects of tourism with long-term biological consequences on the viability and fitness of targeted species (*e.g.* Bejder *et al.*, 2006b).

While tourism impact studies within New Zealand have focused heavily on bottlenose dolphin (*Tursiops truncatus*; Constantine, 2001; Lusseau, 2003a; Constantine *et al.*, 2004; Lusseau *et al.* 2006), common dolphin (*Delphinus* sp.; Neumann and Orams, 2006; Stockin *et al.*, 2008a), dusky dolphin (*Lagenorhynchus obscurus*; Barr and Slooten, 1999; Lundquist and Markowitz, 2009), and sperm whale (*Physeter macrocephalus*; Richter *et al.*, 2006), considerably less emphasis has been placed on the South Island Hector's dolphin (*Cephalorhynchus hectori hectori*, herein referred to as Hector's dolphin), with the exception of Bejder *et al.* (1999) and Nichols *et al.* (2001). This is particularly the case off Banks Peninsula (Nichols *et al.*, 2001) on the eastern coast of South Island, New Zealand. This area has been identified as the main 'hotspot' for this sub-population (Clement, 2005), with Hector's dolphins exhibiting high site fidelity (*e.g.* Bräger *et al.*, 2002; Stone *et al.*, 2005; Rayment *et al.*, 2009). Akaroa Harbour (Akaroa 43.81° S, 172.97° E) is an important part of the home range for a large number of individual Hector's dolphin found around Banks Peninsula (Bräger *et al.*, 2002; Rayment *et al.*, 2009), particularly during the summer season. This coastal distribution (*e.g.* Baker, 1983; Dawson and Slooten, 1988; Bräger *et al.*, 2002; Clement, 2005; Rayment *et al.*, 2009, 2010) and vessel tactic response of Hector's dolphins (Baker, 1983; Dawson and Slooten, 1988; Dawson *et al.*, 2000) make this species attractive and potentially vulnerable to commercial tourism operations. An endemic and endangered species (Reeves *et al.*, 2008) that already faces serious pressures from human activities, mainly by-catch in fisheries (*e.g.* Dawson, 1991b; Martien *et al.*, 1999; Secchi, 2006; Slooten, 2007).

Currently within Akaroa Harbour, seven commercial marine mammal tourism permits allow a maximum of 32 trips per day to interact with Hector's dolphins, including 18 daily swim-with-dolphin trips. Both dolphin-watching and swim-with dolphin tourism occur year round, although most tourism activities coincide with the austral summer season (November to March). During this period, trips operate throughout the day, with the majority of tours occurring between 0900 and 1600 hours (hr). Since 2003, commercial swim-with-dolphin operators in Akaroa Harbour have been encouraging their patrons to use auditory stimulants, in particular stones (brought together under the water to create sounds), to entice dolphins to approach and sustain interaction with swimmers. Other techniques used include, but are not limited to, bubble blowing, singing, tapping on objects, and hitting the surface of the water with hands. The implications of such activities remain unknown and are poorly described within the published literature, although there is a widespread concern about the potential effects of man-made noise on marine mammals and marine ecosystems (see Richardson *et al.*, 1995; Nowacek *et al.*, 2007 for reviews). Furthermore, the deliberate use of such techniques to create sound underwater in the proximity of dolphins could contravene section 4 of the Marine Mammals Protection Act (MMPA, 1974; Appendix 1.3), which stipulates that no "person shall take any marine mammal" and where "take" is considered to include "to take, catch, kill, injure, **attract**, poison, tranquilize, herd, harass, disturb, or possess". The increasing prevalence of such activities and any potential effects on Hector's dolphins has not, until now, been examined.

The New Zealand Marine Mammals Protection Regulations (MMPR, 1992; Appendix, 1.4) do not provide many specific guidelines on swim-with-dolphin activities *per se*. However, section 18(i) states that "no person shall disturb or harass any marine mammal", where "harass" is defined under section 2 as "any act that disrupts significantly or is likely to disrupt significantly the normal behaviour patterns of any marine mammal". Moreover, section 20(d) also states that "no person shall make any loud or disturbing noises near dolphins". These sections of the regulations do, therefore, raise the issue about whether enticing and maintaining Hector's dolphin interactions with stones (or any other deliberate creation of sound) may cause disruption to a sufficient level such as to be considered detrimental.

6.2. Objectives

This chapter aims to:

1) Examine whether the use of human-made noise affects swim interactions with Hector's dolphins.
2) Assess in particular whether: a) banging stones under the water increases the frequency of Hector's dolphins approaching swimmers; b) the amount of time that dolphins spent interacting with people is affected by the use of stones.
3) Consider whether any potential changes in dolphin behaviour related to the use of sound by swimmers could further disrupt dolphin activity patterns and be of detriment to Hector's dolphins in Akaroa Harbour.

6.3. Materials and methods

6.3.1. Data collection

Opportunistic observations were conducted in Akaroa Harbour, Banks Peninsula, South Island New Zealand (Fig. 6.1) between 10 November and 7 December 2008. This time period corresponds to the start of the austral summer tourism season and was chosen to: a) reduce any potential effect of increasing vessel traffic throughout the season on the swim experiences since Hector's dolphins show signs of sensitization to interaction between January and February (Chapter V); and b) ensure opportunities were maximized to record data from as many trips as possible. Weather permitting (Beaufort Sea State - BSS- ≤ 3), data were collected daily during trips commencing at 0900, 1200, 1400 and 1600 hr. Observations were primarily conducted from onboard the swim-with-dolphin vessel, *Cat2*. This purpose-built 12.5 metre (m) long catamaran was powered by twin powered jet units (2 x Yanmar 350 hp) and could carry a maximum of 30 passengers, including ten permitted swimmers.

Fig. 6.1: Map showing Banks Peninsula and Akaroa Harbour, New Zealand.

6.3.2. Sampling protocol

An independent sampling session started when a dolphin group had been sighted. An encounter, which typically consisted of several interactions (Table 6.1), was judged to have commenced when the first swimmer entered the water and ended when the last swimmer climbed back onboard the vessel. This typically occurred either because the dolphins had left the vicinity, or the weather conditions deteriorated and were judged unsafe for the swimmers, or because the maximum time allowed with the dolphins had been reached (45 minutes - min- under the current permit conditions).

Table 6.1: Definitions of sampling protocol terms used in the present study in Akaroa Harbour, New Zealand.

Term	Definition
Swim attempt or encounter	Total time swimmers present in the water irrespective of the presence of dolphins. A trip could consist of several swim attempts.
Interaction	From the time one or several dolphins swim within less than two dolphin body lengths of any swimmer until they all are further away than two dolphin body lengths of any swimmer. During that time, a swimmer might not necessarily be approached (see definition below) by one or several dolphins. A typical swim attempt consists of several interactions unevenly spaced out and of varying duration.
Approach	One or several dolphins swimming past a swimmer and within less than one dolphin body length of a swimmer. Underwater approaches were not taken into account due to low visibility.
First approach	Time when one or several dolphins first swim towards the group of swimmers at a distance of less one dolphin body length.
Sustained approach	When a dolphin is swimming around a swimmer but without forming a complete circle.
Circle approach	When a dolphin is swimming around a swimmer and forming one or more complete circles. This type of approach is sustained and can also be categorised as a close approach (see definition above).
Tail slap	When a dolphin raises its fluke out of the water and then slaps it on the surface of the water, producing a clearly audible sound.

Once a group of Hector's dolphins was located, swimmers entered the water and were asked to form a circle keeping a distance of two or three meters between them so that dolphins could swim between and among them. Swimmers were also encouraged to let the dolphins approach them and not swim after them. The skipper or guide gave two stones to a swimmer and asked that person to be positioned in the middle of the circle or group of swimmers. This swimmer was encouraged to bang the stones both when dolphins were already present around the vessel and also when dolphins were not in close proximity. For example, when the dolphins had not approached the group of swimmers for a few minutes, the skipper encouraged the person with the stones to use them, with no particular instructions regarding the rhythm. Other swimmers were free to float, be active, and could also be encouraged to create noise to make their presence known to the dolphins. The stones were often swapped between swimmers during the course of a swim encounter (especially to a swimmer that had not had the chance to see the dolphins at close range).

At the start of an encounter, the number of individual dolphins within the group (refer to Chapter II, section 2.3.2.1. for definition of a group), time of initial sighting, BSS, and the number of swimmers were recorded. In addition, the predominant dolphin group behaviour was also determined and recorded after an instantaneous focal group sampling (Altmann, 1974; Mann, 1999). The initial predominant behaviour was defined as the behavioural state in which 50% or more of the animals were simultaneously engaged. Widely accepted categories of behavioural state were adopted (Table 6.2). Discrete behavioural events (*e.g.* aerial, sexual) previously described for Hector's dolphin (Slooten, 1994) were also incorporated in the behavioural state definitions used within the present study. "Wave riding", although a behavioural event, was included for analytical purposes. Resting, on the other hand, was not observed during the study and, therefore, not included in the analysis.

Table 6.2: Definitions of behavioural state categories used in the present study in Akaroa Harbour, New Zealand (derived from Shane, 1990a; Slooten, 1994).

Term	Definition
Travelling	Dolphins engaged in persistent, directional movement, swimming with short, relatively constant dive intervals. Group spacing varies.
Wave surfing (boat included)	Dolphins engaged in riding surf of waves, including those created by boats (either bow, stern wake, or wakes from other vessels in the vicinity), resulting in a net movement in the direction of the wave. Group spacing varies.
Milling	Dolphins exhibited non-directional movement, with frequent changes in heading. No net movement. Group spacing and dive interval vary but are less than 1 min for the latter.
Diving	Dolphins' direction of movement varies. Groups dive for long intervals (> 1 min) often arching their backs at the surface to increase speed of descent. Group spacing varies. The presence of birds diving close to a group is also indicative of diving behaviour. Note - this represents the "feeding/foraging" category in other studies.
Socialising	Dolphins observed chasing and/or engaged in any other physical contact with other individuals in the group. Aerial, sexual, and aggressive behaviours are frequently observed. Group is often split into small subgroups spread over a large area. Dive intervals vary. No obvious forward movement.
Resting (RES)	Dolphins engaged in slow movements (*i.e.* less than 1.5 km/hr) in a constant direction, with little evidence of forward propulsion. Dolphins were occasionally stationary. Dive intervals were short, relatively constant, and synchronous. Group spacing is tight (*i.e.* less than one body length between individuals). Resting lacked the active components of the other behaviours described.

After the initial observations were recorded, continuous focal-group follows (Altman, 1974) were subsequently used for the duration of each dolphin interaction (Table 6.3) with swimmers. Although focal individual follows offer clear advantages (Mann, 1999; Mann, 2000), this sampling technique was neither feasible nor appropriate for this study, because Hector's dolphins have very few identifying scars (Slooten *et al.*, 1992), needed to allow accurate individual follow protocols to be used successfully. Furthermore, focal groups were sampled to determine the effect of human-made noise on the behaviour of dolphins at the group rather than individual level. For the purpose of this study, an interacting group was defined as any number of dolphins surrounding swimmers within two adult dolphin body-lengths from the closest swimmer. This typically equated to a three meter distance.

Table 6.3: Definition of the different types of swimmers' activity used in the present study in Akaroa Harbour, New Zealand.

Term	Definition
Floating swimmer	A swimmer not engaged in any activity and simply floating at the surface (either in a horizontal or vertical position). Limited movement.
Music swimmer	A swimmer engaged in making any underwater sound, except using stones, using the vocal area of their body. This includes singing, squealing, bubble blowing, etc.
Tapping swimmer	A swimmer engaged in making sound by tapping an object against another (*e.g.* ring on mask) or winding underwater camera.
Swimmer with stones	A swimmer engaged in bringing stones together under the water to create sounds (clicks, bangs and rhythms)
Active swimmer	A swimmer engaged in active swimming, including duck diving or swimming in circles.

The duration of each interaction was measured to determine the proportion of time dolphins were present in the proximity of swimmers during an encounter. The number of dolphin approaches was also recorded using an all-occurrences protocol (Martin and Bateson, 1993), taking into account both the type of approach and the activity of a swimmer at the time of the approach (Table 6.1, Fig. 6.2). The different types of swimmers' activity were defined to be mutually exclusive and cumulatively inclusive (Table 6.3). If one dolphin approached and swam between two swimmers at a similar distance, that particular individual was recorded as approaching both swimmers. Stones were given by the skipper and/or guide to only one swimmer at any given time. As a result, it was possible to keep track of the characteristics and behaviour of that specific swimmer. The total time that stones were used by that same swimmer and the number of approaches dolphins made towards that swimmer were also recorded. In addition, dolphin approaches made towards the remaining swimmers, who did not have stones, was also noted. Given that the skipper and/or guide decided which swimmer should use the stones, the selection was considered random.

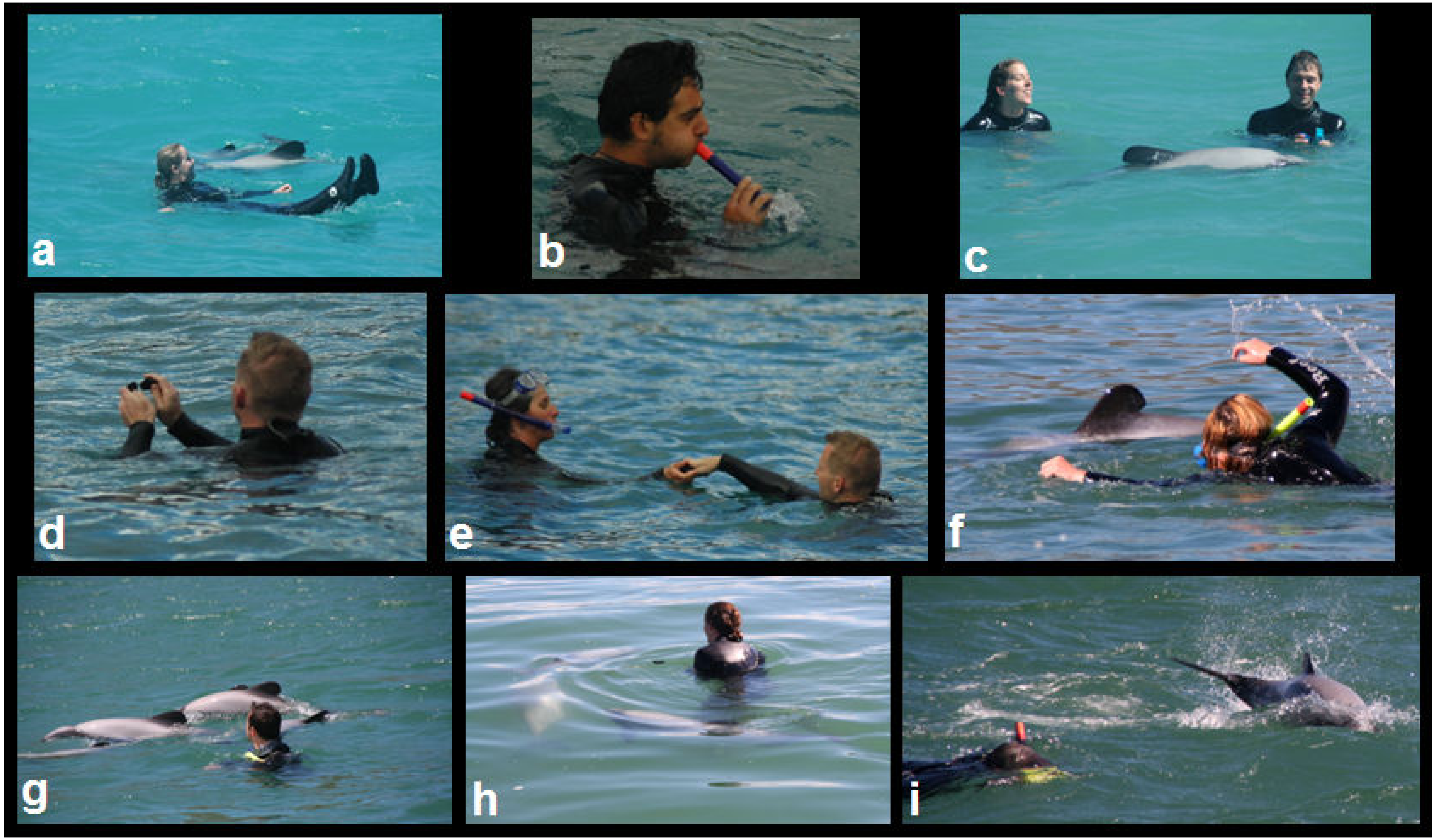


Fig. 6.2: Photos showing a) a swimmer floating; b) a swimmer blowing bubbles underwater using his snorkel; c) a swimmer using his underwater camera to make noise; d) a swimmer using stones; e) swimmers exchanging the stones; f) an active swimmer; g) a close approach; h) a sustained approach, here circling; i) a dolphin tail slapping near a swimmer. All photos © A.R.E.V.A. Project.

Swimmers have anecdotally reported that when they used the stones, dolphins had a tendency to approach more frequently and closely, circling them. The validity of these claims was investigated by recording the number of close approaches, defined as dolphin(s) swimming within an arm length of a swimmer (typically less than one meter), taking into consideration swimmers' activity. Finally, the occurrence of specific behavioural events, tail slaps and bubble blowing, was also recorded. As bubble blowing could not always be observed accurately (due to distance or water visibility), this behavioural event was excluded from subsequent analysis.

6.3.3. Data analysis

Data recorded for each interaction within an encounter were potentially auto-correlated as they were collected sequentially from the same focal dolphin group and the same swimmers. To reduce the effect of dependence between interactions, the mean number of dolphin approaches was calculated for each encounter in order to examine if the use of stones had any effect on the dolphin behavioural responses. Each encounter or swim attempt was, therefore, considered as a single sampling unit ($n = 62$). Data were further standardised per minute, per dolphin, and per swimmer. This was deemed necessary to account for variations in: a) the duration of interactions; b) the number of individual dolphins during each interaction; and c) the number of swimmers in the water during a given interaction and engaged in a particular activity. The frequency of close approaches and occurrence of tail-slaps near swimmers were also calculated for each type of swimmers' activity.

Stones were given to only one swimmer at a time. Consequently, it was possible to determine whether the use of stones had an effect on the number of approaches towards that particular swimmer. Subsequently, these data were also used to test whether swimmer gender affected the number of dolphin approaches. No significant differences were detected between genders (Welch's ANOVA tests: $p > 0.05$), so data were pooled for analyses.

Data were heteroscedastic. As a result, Welch's analysis of variance (ANOVA; Welch, 1951) and Welch t-tests were performed using R version 2.10.0 (R Development Core Team, 2009) to test differences between group means (Zar, 1996).

Multiple comparison *post hoc* tests and 95% confidence intervals (C.I.) used Bonferroni correction to maintain a family-wise error rate of alpha = 5% (Miller, 1981; Zar, 1996).

6.4. Results

6.4.1. Field effort

Fifty four independent trips resulting in 62 observed swim attempts were recorded and analysed during the present study. The number of swimmers participating in a swim-with-dolphin trip ranged between four and ten (mean = 8.4, S.E. = 0.233, n = 54). Each swim attempt lasted between five and 48 minutes (mean = 33.1, S.E. = 1.624, n = 62), with dolphins interacting 35.1% (S.E. = 2.266, range = 4.8 – 83.1, n = 62) of the duration of swim attempts.

6.4.2. Effect of swimmers' activity on the number of dolphin approaches

There was strong evidence that the mean dolphin approach rate (min^{-1} $dolphin^{-1}$ $swimmer^{-1}$) differed, depending on swimmers' activity (Fig. 6.3; Welch's ANOVA: $F_3 = 10.34$, $p < 0.001$). The mean approach rate when swimmers used stones was higher at between 0.08 and 0.59 more approaches (95% C.I.) than when swimmers made music and between 0.13 and 0.59 more approaches than when swimmers floated. Likewise, the mean approach rate for active swimmers was from 0.06 to 0.51 and between 0.1 and 0.51 approaches higher (95% C.I.) than when making music and floating, respectively (Fig. 6.3).

The mean sustained approach rate was also strongly dependent on swimmers' activity (Fig. 6.4; $F_3 = 20.3$, $p < 0.001$). For active swimmers, the mean sustained approach rate (min^{-1} $dolphin^{-1}$ $swimmer^{-1}$) was 0.09 to 0.31 approaches higher (95% C.I.) than swimmers making music and 0.1 to 0.3 approaches higher than floating swimmers. Similarly, swimmers using stones averaged between 0.05 and 0.15 more sustained approaches (95% C.I.) than swimmers making music and from 0.06 to 0.16 more sustained approaches than floating swimmers.

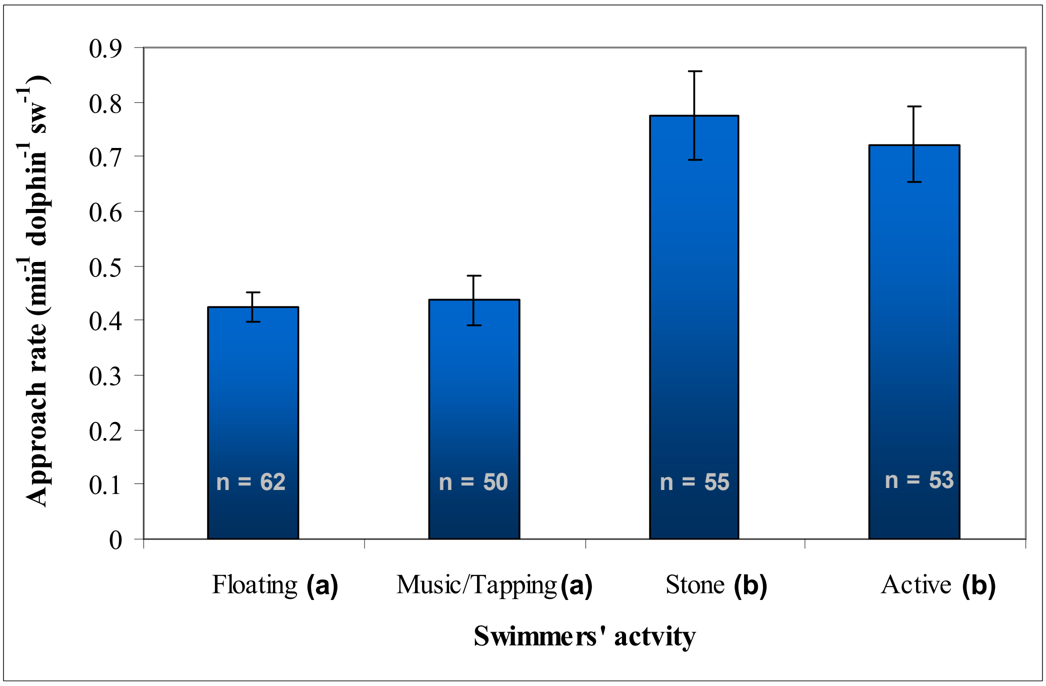


Fig. 6.3: Mean approach rate (min^{-1} dolphin^{-1} swimmer^{-1}) according to swimmers' activity. Lines represent the standard error of the mean. Sample sizes are listed for each category as n. Note: Not all swimmers' activity categories were recorded for each of the 62 swim attempts. (a) and (b) indicate swimmer activities that were significantly different to other groups.

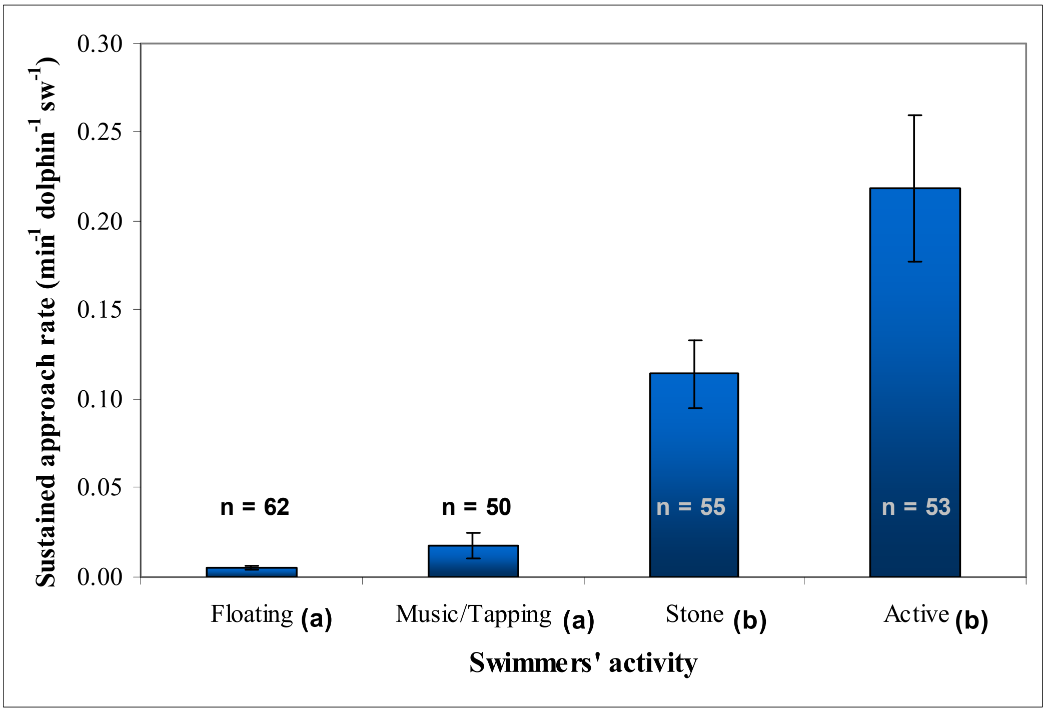


Fig. 6.4: Mean sustained approach rate (min^{-1} dolphin^{-1} swimmer^{-1}) according to swimmers' activity. Lines represent the standard error of the mean. Sample sizes are listed for each category as n. Note: Not all swimmers' activity categories were recorded for each of the 62 swim attempts. (a) and (b) indicate swimmer activities that were significantly different to other groups.

There was also strong evidence that the mean frequency of close approaches varied significantly with the type of activities swimmers engaged in when dolphins were around (F_3 = 19.4, p < 0.001). The mean frequency of close approaches for active swimmers was from 0.17 to 0.43, 0.15 to 0.40, and up to 0.28 higher (95% C.I.) than for swimmers making music, floating, and using stones, respectively. The mean frequency of close approaches for swimmers using stones was between 0.04 and 0.15 higher (95% C.I.) than swimmers making music and from 0.06 to 0.16 higher than floating swimmers (Fig. 6.5).

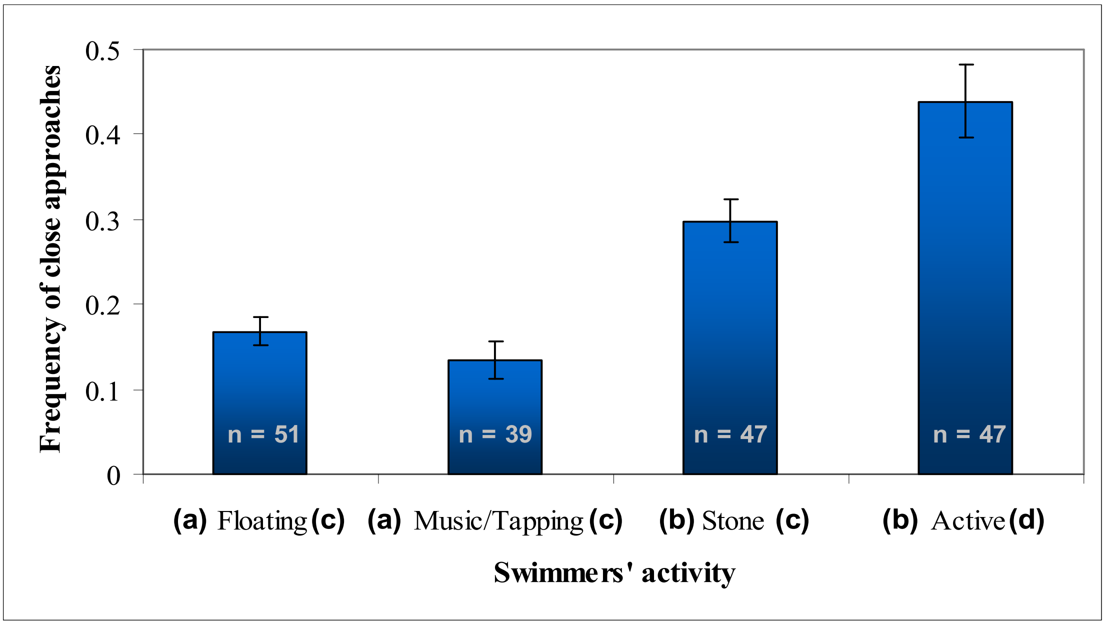


Fig. 6.5: Mean frequency of close approaches (per total approaches) according to swimmers' activity. Lines represent the standard error of the mean. Sample sizes are listed for each category as n. Note: Not all swimmers' activity categories were recorded for each of the 62 swim attempts. (a) (b) and (c) (d) indicate swimmer activities that were significantly different to other groups.

6.4.3. Comparison of number of approaches towards an individual swimmer while using stones and after transferring them to another swimmer

There was strong evidence that individual swimmer's activity affected both the approach rate (Welch's ANOVA: F_3 = 24.4, p < 0.001) and sustained approach rate (F_3 = 19.7, p < 0.001). When an individual swimmer used stones during a swim encounter, that individual averaged 0.78 to 1.72, 0.8 to 1.77, and 0.57 to 1.60 more approaches (min^{-1} $dolphin^{-1}$) (95% C.I.) than when the same swimmer was active, making music or floating, respectively (Fig. 6.6). The use of stones also increased the frequency of sustained approaches towards an individual by between 8.6 and 23.3% more (95% C.I.) than when the same individual was making music and between 11 to 24.3% more than when floating (Fig. 6.7).

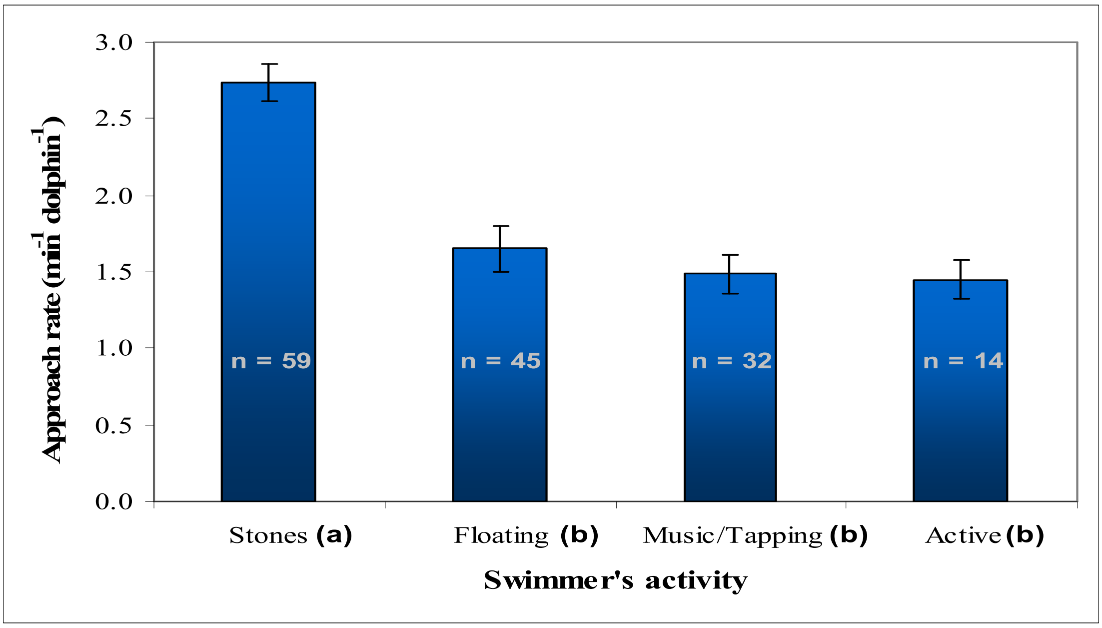


Fig. 6.6: Mean approach rate (min^{-1} dolphin^{-1}) while a swimmer had stone and after having given them over to another swimmer. Lines represent the standard error of the mean. Sample sizes are listed for each category as n. Note: Not all swimmers' activity categories were recorded for each of the 62 swim attempts. (a) and (b) indicate swimmer activities that were significantly different to other groups.

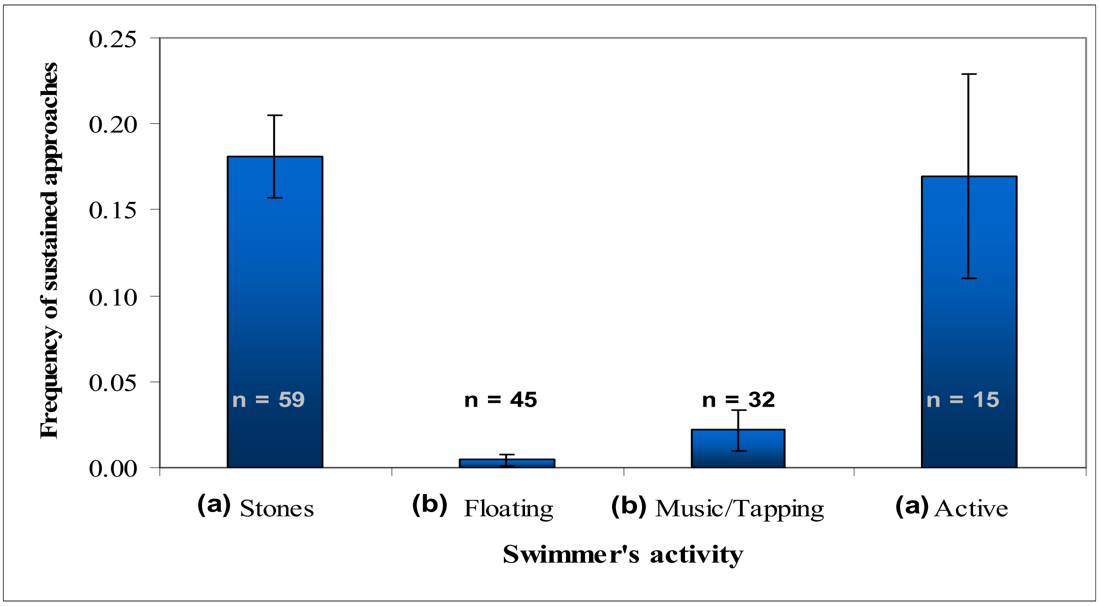


Fig. 6.7: Mean frequency of sustained approaches (per total approaches) according to a swimmer's activity. Lines represent the standard error of the mean. Sample sizes are listed for each category as n. Note: Not all swimmers' activity categories were recorded for each of the 62 swim attempts. (a) and (b) indicate swimmer activities that were significantly different to other groups.

6.4.4. Influence of the initial dolphin behaviour on their interactions with swimmers during a whole encounter

The initial dolphin behaviour did not affect the mean time to first interaction (Fig. 6.8a; Welch's ANOVA: $F_4 = 1.9$, $p = 0.152$) or the mean interaction time (Fig. 6.8c; $F_4 = 2.53$, $p = 0.07$). However, interaction rate (min^{-1} $dolphin^{-1}$ $swimmer^{-1}$) during an encounter depended upon initial dolphin behaviour (Fig. 6.8b, $F_4 = 5.26$, $p = 0.004$). The interaction rate for milling and travelling dolphins was higher than socialising dolphins by up to 0.22 and 0.10 interactions, respectively. There was also evidence that the percentage of time dolphins present in the proximity of swimmers was influenced by the initial dolphin behaviour (Fig. 6.8d; $F_4 = 3.59$, $p = 0.02$). When socialising, dolphins were observed between 2.9 and 52.3% more (95% C.I.) in the presence of swimmers than when dolphins were diving.

6.4.5. Occurrence of tail-slaps

Although, tail-slaps did not occur during all swim attempts, the mean frequency of tail-slaps (per total approaches) near swimmers differed according to swimmers' activity (Fig. 6.9, Welch's ANOVA: $F_3 = 7.31$, $p < 0.001$). The occurrence of tail-slaps near (*i.e.* within 3m) using stones was up to 0.04 slaps higher than those making music or floating.

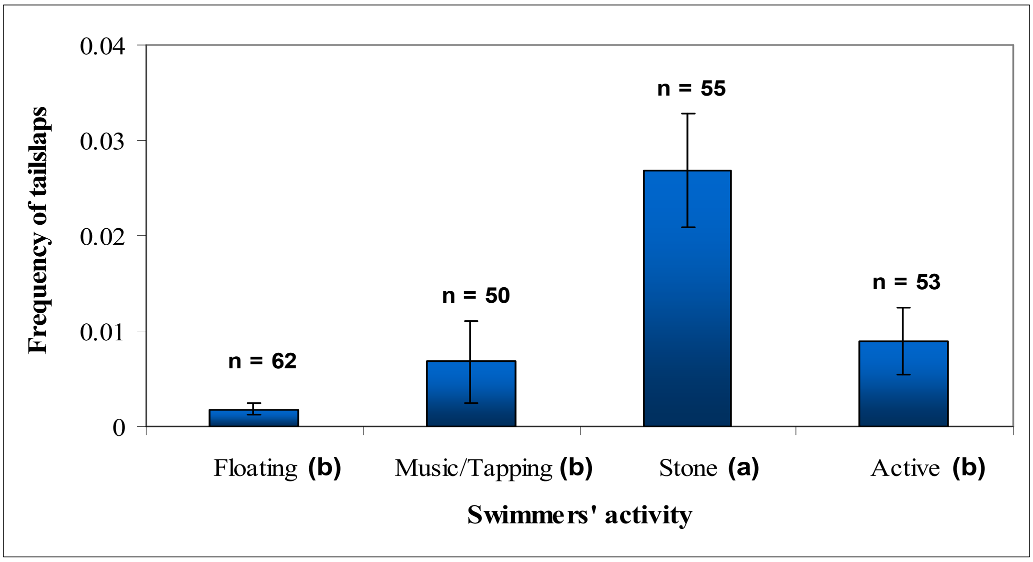


Fig. 6.9: Mean frequency of tail-slaps (per total approaches) according to swimmers' activity. Lines represent the standard error of the mean. Sample sizes are listed for each category as n. Note: Not all swimmers' activity categories were recorded for each of the 62 swim attempts. (a) and (b) indicate swimmer activities that were significantly different to other groups.

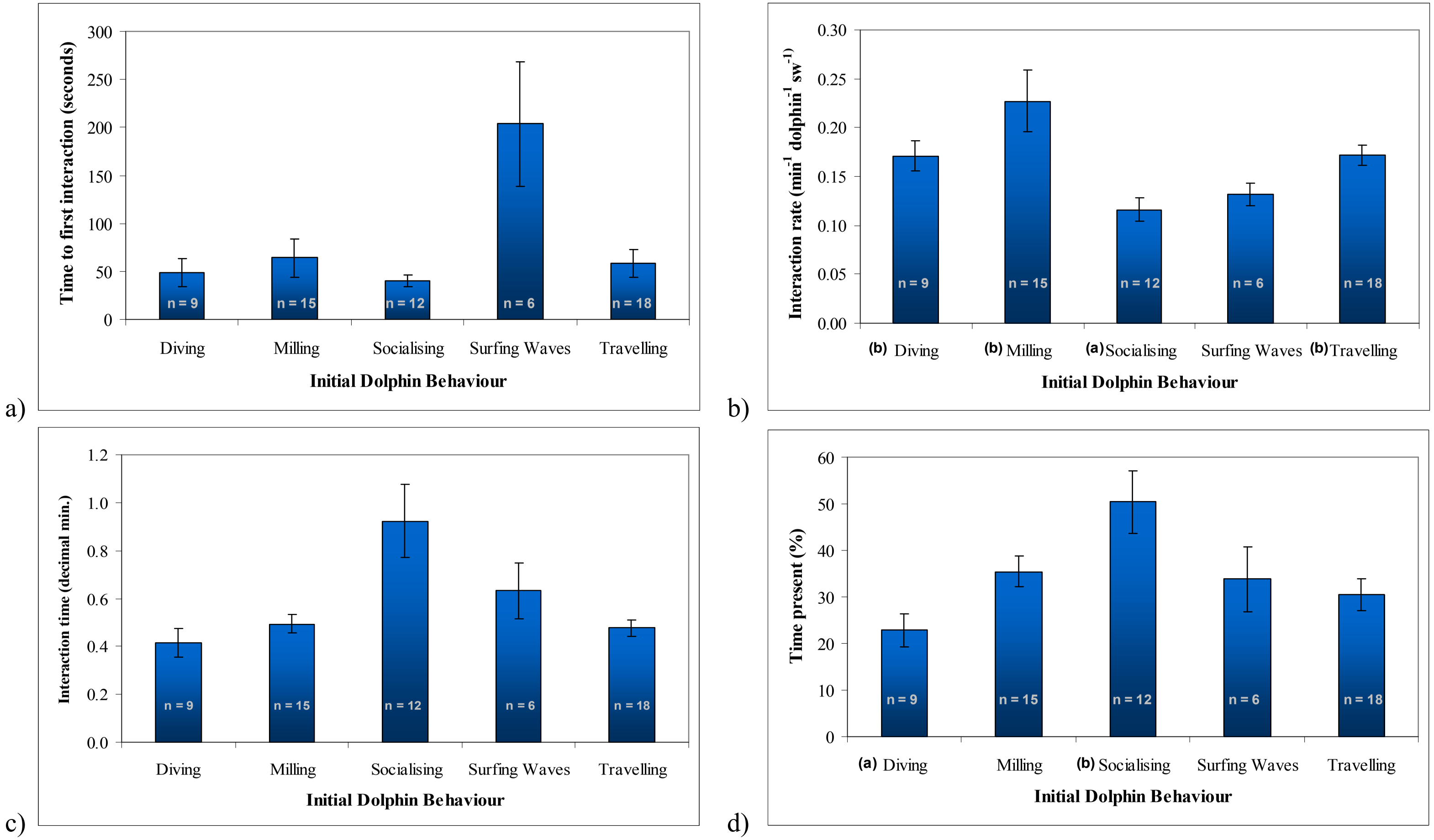


Fig. 6.8: Mean a) time to first interaction; b) interaction rate (min^{-1} $dolphin^{-1}$ $swimmer^{-1}$); c) interaction time (min); d) percentage of time dolphins present; according to the initial behaviour of the dolphins. Lines represent the standard error of the mean. Sample sizes are listed for each behaviour as n. Note: The behaviour of the focal dolphin group at the start of an encounter was unknown on two occasions. (a) and (b) indicate swimmer activities that were significantly different to other groups.

6.5. Discussion

The use of stones as auditory stimulants

The use of sound to facilitate interactions between tourists and Hector's dolphins in Akaroa Harbour occurs within a wider context of marine mammal tourism. Findings presented here support anecdotal reports that the use of stones can sustain and result in closer interactions between Hector's dolphins and swimmers in that particular location. Overall, the use of stones as an auditory stimulant had a significant effect on the movement and proximity of dolphins to swimmers. More specifically, swimmers with stones had a greater probability of close approaches by dolphins than those singing or simply floating on the surface of the water. The number of close and sustained approaches was also significantly higher for swimmers banging stones underwater. The same observations were made for active swimmers. Additionally, dolphins were found to significantly focus more on the stone bearer, when focussing on an individual level. As such, an individual swimmer was significantly more likely to be approached, experience longer interaction times, and have dolphins in closer proximity when they used stone rather than when they did not. Furthermore, the number of approaches from dolphins decreased once the stones were passed to another swimmer. Therefore, it was the use of stones and not the individual swimmer that was the influential variable.

There was no evidence, overall, to suggest that a singing swimmer had greater probability of interaction with dolphins than a swimmer simply floating at the surface. However, being active (*e.g.* duck diving and spinning around) did significantly increase the number of dolphin approaches, including close, and sustained approaches, towards swimmers. Both noise and movement (also likely to produce sound underwater) appear to entice dolphins to approach and interact with swimmers, supporting earlier anecdotal reports from commercial tour operators, guides, and swimmers (Edwards, pers. comm.). Neumann and Orams (2006) also noted that swimmers had more successful encounters with New Zealand common dolphins (*Delphinus* sp.) when duck diving.

When socialising, Hector's dolphin groups had a tendency to have longer interactions and overall encounters. Approaches were standardized by dolphin group size as preliminary analyses found larger dolphin groups (five or more individuals) interacted longer with swimmers. Based on these results, commercial operators were more likely to have prolonged encounters with Hector's dolphins if they interacted with a group engaged in socialising activities, had a swimmer banging stones, and encouraged other swimmers to be active when dolphins were present.

Understanding why the use of stones had an effect on interactions between Hector's dolphins and swimmers as well as on the proximity of dolphins to swimmers was beyond the scope of this study. Future research on acoustic and individual dolphin monitoring would help determine: a) how similar the sound created by stones is to echolocation and communication clicks: and b) whether it is the same animals that consistently approach swimmers with stones.

Implications for the use of stones during swim-with-dolphin trips

Until now, the use of auditory stimulants (particularly stones) has not been empirically investigated. Their effect on the targeted animals' behaviour, biology, and physiology is, therefore, unknown. This is surprising given: a) the routine practice of tour operators encouraging tourists to participate in such activities; b) the increasing concerns reported in the literature regarding both noise pollution on cetaceans, including from tour vessels (*e.g.* Richardson *et al.*, 1995; Nowacek *et al.*, 2007; Martinez and Orams, in press); and c) the increasing evidence demonstrating that swim-with activities also disturb the targeted animals in the short-term (*e.g.* Bejder *et al*. 1999; Constantine 2001; Samuels *et al*. 2003; Courbis 2004). According to Nowacek *et al*. (2007), cetaceans responses to man-made noise fall into the following three categories: behavioural (*e.g*. changes in heading patterns), acoustic (*e.g*. changes in vocalisation), and physiological (*e.g*. auditory threshold shifts). Research focusing specifically on quantifying sound produced by tour vessels and their effects on targeted species is, at this time, still limited (*e.g*. Erbe, 2002; Williams *et al*., 2002b; Buckstaff, 2004). Furthermore, the MMPA and associated regulations clearly prohibit actions that attract, disturb or alter natural behavioural patterns of marine mammals. Perhaps the production of such sounds by tourists is deemed to be relatively minor, intermittent and/or of low priority compared with the potential effects resulting from cetacean-watching itself or other human pressures (*e.g*. by-catch). Nonetheless, caution should be exercised when making such assumptions.

In most studies, it remains difficult to differentiate between the effects of dolphin swimming *versus* the effects of dolphin viewing, especially when swimmers in the water are accompanied by a vessel, as is the case in Akaroa Harbour. The only previous study to measure the effects of swimmer presence on Hector's dolphin behaviour in the absence of vessels showed that the majority of swim-with-dolphin attempts caused only weak, non-significant effects compared to their reactions towards vessels (Bejder *et al.*, 1999). However, this study assessed the effects of small number of swimmers who entered the water from shore, not from a vessel. The swim-with-dolphins encounters in Akaroa Harbour only occur from vessels. Consequently, the effect of swimming cannot be disassociated from the potential reaction of the dolphins towards the vessel. Similarly, the use of auditory stimulants cannot be totally separated from the potential behavioural responses of dolphins to the presence of both the tour vessel and other vessel traffic in the harbour.

In comparison to most other marine mammal tourism locations around New Zealand, Akaroa Harbour has the highest level of permitted commercial tourism operations. Land-based research has reported that vessels/swimmers were absent over the austral summer months (November to March) less than 15% of daylight hours Hector's dolphins were found inside the harbour (Martinez, 2010). In Porpoise Bay (46.65° S, 169.1° E), 440 km south-west of Akaroa, vessels/swimmers were present 23% of the time Hector's dolphins were found in the bay over the same time period (Green, 2003). However, even relatively low-level tourism such as this has been shown to have short-term effects on group dispersion, length of encounters with vessels, and behavioural budget of targeted species (*e.g.* Bejder *et al.*, 1999, 2006b; Stockin *et al.*, 2008a), negating the presumption that any cetacean-based tourism is benign.

Data presented here suggest there is a trend for dolphin groups to be present longer during encounters when stones were used as auditory stimulants and, in some cases, when swimmers were active. It also indicated that when encountering a group of dolphins engaged in diving, interaction rate and total encounter lengths were shorter compared to socialising groups. In other species in New Zealand waters, dolphin behavioural activity also influences swim encounter duration or the success of swim attempts. In Mercury Bay, common dolphins were more interactive when the predominant group behaviour was socialising (Neumann and Orams, 2006). Similar observations were made with dusky dolphins in Kaikoura (Markowitz *et al*., 2009).

Studies examining behavioural changes in relation to the presence of vessels report a decrease in the amount of time dolphins forage (*e.g.* Allen and Read, 2000; Lusseau, 2003a; Williams *et al.*, 2006; Carrera *et al.*, 2008; Dans *et al.*, 2008; Stockin *et al.*, 2008a; Lusseau *et al.*, 2009). Disturbance or disruption of foraging and subsequent feeding can have major biological consequences for dolphins (Williams *et al.*, 2006). Changes in the duration of diving and other critical aspects of dolphin activity budgets, as a consequence of interactions with vessels, have been shown to have long-term biological consequences at both individual and population levels (*e.g.* Bejder *et al.*, 2006b; Lusseau *et al.*, 2006a; Williams *et al.*, 2006). In Akaroa Harbour, the current level of tourism activities is significantly altering the behaviour budget of Hector's dolphins (Chapter IV). The additional use of auditory stimulants that increase interaction time between dolphins and swimmers could potentially contribute and exacerbate behavioural changes caused by the presence of vessels.

Finally, the significantly higher occurrence of tail-slaps, near swimmers using stones, is also worthy of consideration. Within the literature, mouthing, chasing, and tail-slaps are generally considered to be indicators of aggression in at least some cetacean species, although they can also be classified as play aggression (Shane, 1990a,b; Slooten, 1994; Mann and Smuts, 1999; Ritter and Brederlau, 1999). Slooten (1994) suggested that tail-slaps were not only associated with aggressive and sexual behaviours but also with aerial behaviours (leaps) and bubble-blowing. For Hector's dolphins, tail-slapping appears to indicate a high level of motivation and sometimes, but not always, aggression (Slooten, 1994). It is possible, therefore, that sustained approaches with swimmers act as stimuli to which dolphins respond with a higher frequency of tail-slaps in the proximity of active swimmer and those using stones. Aggravation of this motivational state could be a cause of concern for both animals and swimmers, an opinion also expressed by Nichols *et al.* (2001).

Management recommendations

The wording contained within Section 4 of MMPA (1978) appears to make the use of auditory stimulants, including stones, unlawful if the intent is to "attract" the dolphins.

Tour operators at Akaroa are aware of this stipulation and, possibly as a consequence, argue that stones are used only to "sustain" the attention of the dolphins. Observations made from swim-with-dolphin vessel platforms during the course of this study, however, indicate that operators do encourage swimmers to use the stones (and other techniques) prior to the first interaction between dolphins and swimmers or when dolphins left their vicinity. In this case, stones are clearly being used with the intent of "attracting" the dolphins. Furthermore, this study indicates such actions are successful in doing so.

The use of artificial auditory stimulants during swim-with-dolphin activities can be problematic for the reason that intuitively most tourists (and indeed many operators) assume that because it is the dolphins choosing to approach and interact rather than move away, it implies that there are no detrimental consequences (Martinez and Orams, in press). The absence of an avoidance response, however, does not necessarily mean there is no effect. Empirical evidence is clear with regard to vessel and swimmer approaches. Even if cetaceans do not avoid interactions with vessels and/or swimmers, they can still be detrimentally affected in terms of behavioural budget allocations and/or energy expenditure (*e.g.* Williams *et al.*, 2006; 2009). In Akaroa Harbour, the current level of tourism activities is significantly altering the normal daily behavioural patterns of the dolphins (Chapter IV). By using stones underwater to create sounds to either entice dolphins or sustain their interaction with swimmers, the amount of time dolphins interact with humans is increased and could, therefore, potentially contribute to the breach of the MMPA, in particular section 18(i), by exacerbating this situation.

Any additional impact to Akaroa Hector's dolphins is of particular concern given this endemic and endangered species already faces significant anthropogenic pressures, especially from fisheries by-catch (*e.g.* Dawson, 1991b; Martien *et al.*, 1999; Pichler *et al.*, 2003; Secchi, 2006; Slooten, 2007). This, in conjunction with a low migration rate and high site-fidelity, further add to their vulnerability. Currently, it is difficult to determine whether the use of stones as auditory stimulants has quantifiable long-term detrimental effects on Hector's dolphins in Akaroa Harbour. However, this study demonstrates there are short-term behavioural responses that warrant concern.

CHAPTER VII

Photo-identification of the South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) associating with commercial tour vessels in Akaroa Harbour, Banks Peninsula

Photo: A.R.E.V.A. Project © 2005.

Chapter VII draws on material that also appears in:
Martinez, E.; Orams, M.B.; Stockin, K.A. (2009). Estimation of the exposure levels of Hector's dolphins (*Cephalorhynchus hectori hectori*) to commercial tourism vessels in Akaroa Harbour using photo-identification. Unpublished report to the Department of Conservation, Canterbury, New Zealand. 57p.

7.1. Introduction

It is widely accepted that understanding and managing the potential effects of human activities, such as cetacean-watching, is critical to the long-term conservation of any targeted species. Although whale-watching (here defined as any commercial tour interacting with free-ranging cetaceans) is often promoted as a viable, sustainable eco-friendly activity (IFAW *et al*., 1995), research on a diverse range of species in a wide range of locations clearly identifies that this type of activity is not as benign (*e.g*. Lusseau and Bejder, 2007), with a wide range of short-term responses reported within the scientific literature (refer to Parsons *et al*., 2006a,b; Scarpaci *et al*., 2008, 2009, 2010 for reviews). Recently, a number of studies have shown potential long-term detrimental consequences for the targeted population, including displacement and a decline in reproduction success (*e.g*. Bain, 2002; Bejder *et al*., 2006b; Lusseau *et al*., 2006a; Williams *et al*., 2006; Lusseau and Bejder, 2007).

To develop effective population conservation and/or management plans that can promote the sustainability of tourism activities, knowledge on the targeted population, particularly demographics and spatio-temporal distribution, is critical (Evans and Hammond, 2004). Specifically, the potential level of exposure of targeted individuals to tourism activities is fundamentally crucial. For example, research off Kaikoura (New Zealand) has shown that an individual sperm whale (*Physeter macrocephalus*) will be accompanied by at least one whale-watching vessel for approximately 50% of its daylight surfacings, a level twice that recommended by the International Fund for Animal Welfare (IFAW, 1996).

Banks Peninsula, on the east coast of the New Zealand South Island, is an important habitat for the small, coastal, and endemic South Island Hector's dolphin (*Cephalorhynchus hectori hectori*; Hector's dolphin hereafter). This dolphin is categorised and listed as an endangered species by both the International Union for Conservation of Nature and the New Zealand Department of Conservation (Hitchmough *et al*., 2007; Reeves *et al*., 2008), with fisheries by-catch being the primary threat for this species (*e.g*. Dawson, 1991b; Martien *et al*., 1999; Secchi, 2006; Slooten, 2007). The Banks Peninsula population is estimated at approximately

1,119 (C.V. = 0.21; Gormley *et al*., 2005). Despite occurring all around the peninsula, *Cephalorhynchus* distribution is described as "patchy" and they have been found to exhibit a high degree of site fidelity (Bräger *et al*., 2002; Clement, 2005; Rayment *et al*., 2009).

The Banks Peninsula Hector's dolphin population has been extensively studied since the mid 1980s. In addition, dolphins using Akaroa Harbour (as part of their home range) have also been the target of commercial tourism operation since 1985 (refer to Chapter I, section 1.1.3.2., for further details). Hector's dolphin tourism at Akaroa Harbour is a well developed industry providing both commercial dolphin-watching and swim-with-dolphin tours. Until 2007, only four companies were permitted to operate (Allum, 2009). Since then, a further three permits to view Hector's dolphins have been granted by the Department of Conservation (DOC).

The expansion of the tourism industry in Akaroa Harbour over the past 25 years has occurred with little scientific oversight. Since 1985, only a couple of studies have examined the responses of Hector's dolphins to tourism activities (Nichols *et al*., 2001, 2002). Consequently, our understanding of the effects of the industry, and vessel traffic in general, on Hector's dolphins using the harbour is limited. In 2000, DOC issued a moratorium in Akaroa Harbour on any additional permits until the effects, if any, of the existing tourism activities were determined (Allum, 2009). This decision was based on growing concerns regarding the potential impacts resulting from the growth of the industry (Constantine, 1999). Due to an increasing demand in the number of permits to view and swim with this species in the area, it is important to determine, based on scientific fact, whether the moratorium should remain in place or be lifted.

7.2. Objectives

For management to be able to make decisions that are effective in promoting the sustainability of the industry and protecting Hector's dolphins, concurrent information on the dolphin biology and ecology is needed. More specifically, it is critical to have an understanding of the abundance, site fidelity and movement patterns. This type of data already exists for this species (*e.g.* Slooten, 1991; Slooten *et al*., 1992; Bräger *et al*., 2002; DuFresne, 2005; Gormley *et al.*, 2005; Slooten *et al*., 2006a; Rayment *et al*., 2009). Knowledge of the level(s) of tourist-related interactions to which individual dolphins are potentially subjected to is also of importance but still unknown.

The main aims of this chapter were, therefore, to:

1) Construct a photo-ID catalogue of Hector's dolphins observed during encounters with tour operators in Akaroa Harbour during the austral summer (from November to March) between 2006 and 2008.
2) Compare the photo-ID catalogue with the Banks Peninsula Hector's Dolphin Photo-ID catalogue from the University of Otago, New Zealand (hereafter BPHDP). Use available data to determine whether certain classes of individuals (age and sex) are more likely to interact with vessels.
3) Investigate site fidelity through the analysis of re-sighting rates.
4) Estimate the number of identifiable individuals that are present in the harbour from November to March.
5) Assess the level of vessel traffic identifiable individuals are exposed to from November to March.

7.3. Materials and methods

7.3.1. Study area

Photo-identification (Photo-ID) research surveys were conducted primarily in Akaroa Harbour or within the permitted swimming and viewing area of operation for the commercial tour operators based in Akaroa (43.81º S, 172.97 º E) (Fig. 7.1). Akaroa Harbour is situated on the southern side of Banks Peninsula, on the east coast of the South Island, and is approximately 17 kilometres (km) long with a predominantly north-south orientation (Heuf *et al.*, 2005). Further details of the study area are provided in Chapter II (section 2.3.1.1.)

7.3.2. Survey platforms, effort and survey protocol

7.3.2.1. Survey platforms

Commercial dolphin-watching and swim-with-dolphin tour vessels were primarily used as platforms to conduct photo-ID surveys. Except for Akaroa Dolphin Ltd., which only offers dolphin-watching trips, all other vessels were used for swim-with-dolphin trips and belonged to two different companies (Black Cat Group Ltd. and Dolphin Experience Ltd.; refer to Chapter III, section 3.3.2.1., for further details). In 2007, the Black Cat Group Ltd. acquired Dolphin Experience Ltd. and by the end of 2008 had replaced all the Dolphin Experience fleet.

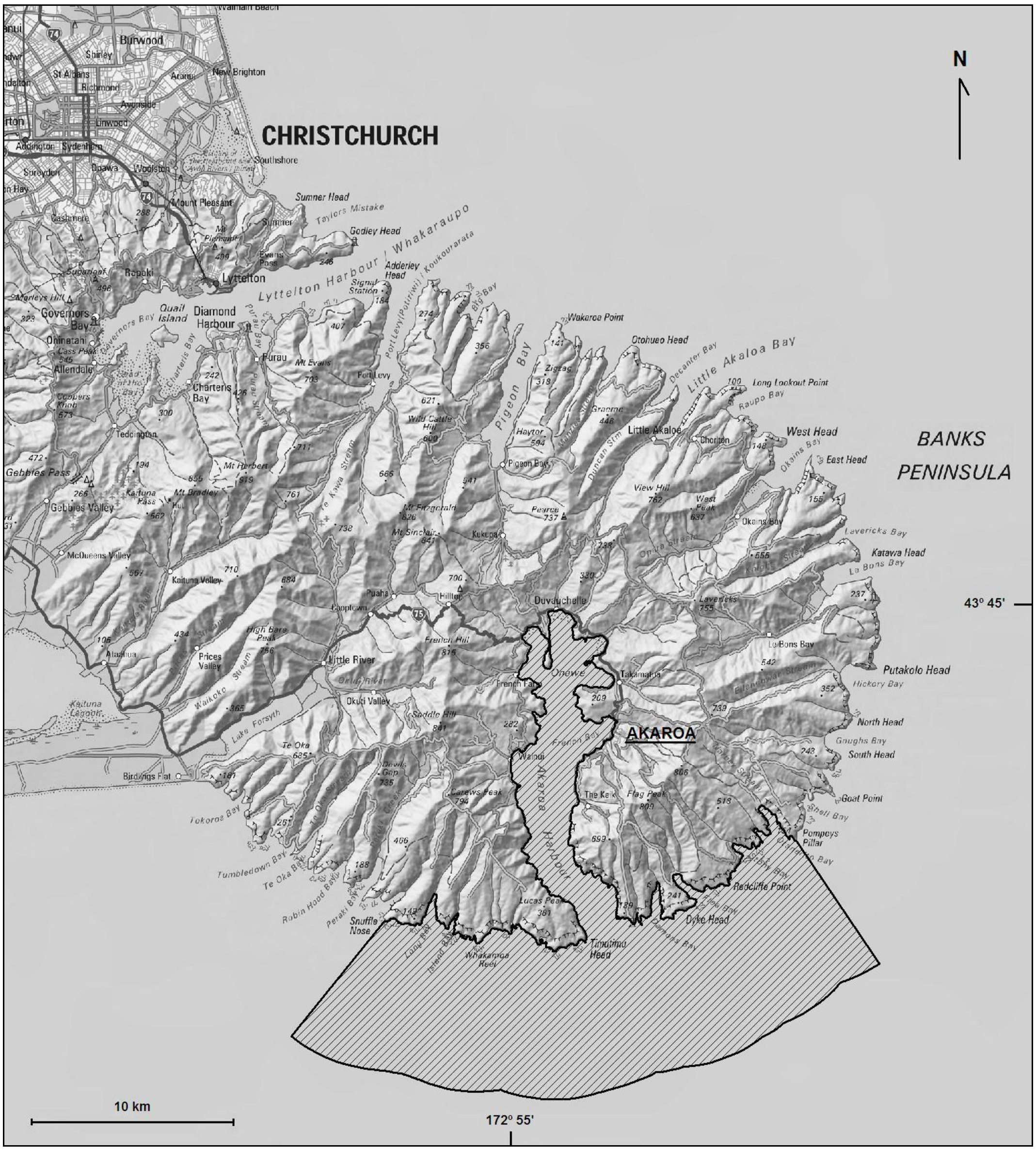


Fig. 7.1: Permitted area of operation for commercial tour operators based in Akaroa, New Zealand (Source: Department of Conservation, Canterbury).

7.3.2.2. Survey effort

Opportunistic photo-ID surveys were initiated in November 2006 and conducted over two consecutive five-month field seasons (November to March 2007 and 2008). During this sampling period, Hector's dolphins are found closer to the shore than at other times of the year (Dawson, 1991b; Chapter II).

The number of daily permitted swim-with-dolphin trips from the two main tour companies was 16 (Table 1.3; departure times 0600 hr, 0900 hr, 1200 hr, 1400 hr, and 1600 hr), with an additional three dolphin-watching trips at 1045 hr, 1215 hr, and 1515 hr provided by the third company. Commercial operators, therefore, provided a good daily coverage of the harbour. An attempt was made to undertake equal sampling effort between the different departure times, so as to cover most of the commercial daily activities.

The primary focus of vessel-based surveys was the collection of behavioural data throughout the duration of an encounter (Chapters IV and V). Photo-ID was, therefore, only undertaken opportunistically between behavioural samplings. The ability to perform useable photo-ID from the different vessels was preliminary investigated during the austral summer 2005/2006 and found feasible. Photo-ID surveys conducted that year were excluded from subsequent analyses.

Over the 2006/2007 and 2007/2008 seasons, photo-ID surveys were conducted opportunistically due to space availability on board of commercial vessels. Survey route was not predetermined; rather it was largely based on the skipper's discretion and, therefore, influenced by prevailing weather conditions and previous sightings (refer to Chapter III, section 3.3.2.3., for further details). More than one vessel was typically searching the area, providing an extensive coverage of the harbour, even though effort was unequal.

The opportunity to conduct photo-ID was also highly dependent on:

a) Weather and sighting conditions. Beaufort Sea State (BSS) of greater than two (equivalent to wind speeds of more than ten knots-kts) and bad visibility precluded taking photo-ID. Obstruction by passengers during a sighting also limited photo-ID opportunities.

b) How the vessel was manoeuvred around the dolphins (in most cases engines were put in neutral during encounters or in idle or "no wake" speed, *i.e.* less than five kts).

c) The length of an encounter, *i.e.* how much time was spent in close proximity to the animals (within 15 body lengths or 20 m). Photo-ID sessions typically ended when dolphins moved away from a vessel, when a skipper ended an encounter, or when weather conditions deteriorated precluding further photo-ID opportunities.

d) The behaviour of the dolphins. Hector's dolphins typically exhibit boat-positive behaviour (Dawson and Slooten, 1988), therefore, facilitating photo-ID. However, in some cases, dolphins could also actively avoid the vessel. Under their current permit conditions, operators must refrain from approaching a group of dolphins more than three times.

Only surveys conducted in BSS two or less, with good visibility, and a sighting duration of a minimum of ten minutes, were considered for analysis to ensure that all dolphins in the group were photographed. Here a sighting is defined as any period of time spent with the same group (Slooten *et al.*, 1993; Chapter III).

7.3.2.3. Survey protocol

At the start of each survey, date, vessel name and departure time, number of passengers onboard, as well as weather conditions (BSS, cloud cover, swell height and wind direction) were recorded on a standardised datasheet. Upon encountering a focal group (Altmann, 1974; within 10 m of a group) further data including time of sighting, vessel position (recorded with a hand held Global Positioning System - GPS unit: Garmin GPS 60), group size/composition, and initial behaviour were recorded.

A focal group was defined as individuals located in close proximity (less than five body lengths or approximately less than 10 m) from one another (Smolker *et al.*, 1992). Here, groups sighted further than 15 dolphin body-lengths away (*ca.* 20 m) were deemed independent from the focal group. Calves were identified by their small body size and the consistent close association with an adult, presumed to be the mother (Smolker *et al.*, 1992; Slooten and Dawson, 1994).

Photo-ID of individuals within a group was conducted, when possible, in between three-minute behavioural samples (Chapters IV and V). When several groups were sighted during a single survey, a "spacer" shot was taken between sightings to exclude the chance of mixing photographs between the different groups. The time at which a sighting terminated was also recorded to determine its duration.

Photo-ID was performed following methods described in Würsig and Jefferson (1990). For each sighting, an attempt was made to "capture" (photograph) all individuals present irrespective of their level of marking (Bearzi, 1994). Where possible, images were taken of both sides. Features on flanks and/or any other areas of the body, *e.g.* scars and lesions, were also recorded (Wilson *et al.*, 1999).

All photographs were taken using one of two digital SLR cameras fitted with an auto-focus zoom lens up to 300 mm; Nikon D70/D70s or Canon EOS 350D. All cameras achieved a high-resolution above five mega-pixels. Digital photographs were predominantly taken using a virtual film speed of 400ASA at highest quality resolution. Shutter speed was typically set at 1/1000 s or faster, depending on weather conditions.

7.3.3. Photo-ID catalogue

7.3.3.1. Mark quality and photograph grading

It is well recognised that the potential for identification error due to false positive or negative errors can cause bias in mark-recapture analysis, especially for abundance estimation (Stevick *et al.*, 2001). As such, data selection criteria based on mark quality (*e.g.* Whitehead and Waters, 1990; Langtimm and Beck, 2003), photo quality (*e.g.* Wilson *et al.*, 1999; Clapham *et al.*, 2003), or a combination of both (*e.g.* Slooten *et al.*, 1992; Childerhouse *et al.*, 1995; Bräger *et al.*, 2002; DuFresne, 2005) were taken into consideration during the present study.

Mark quality

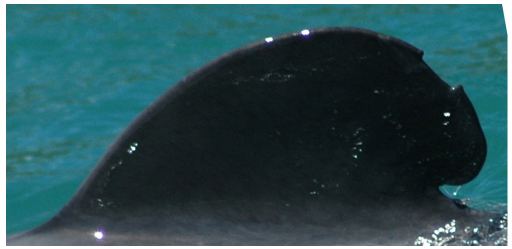
Following Slooten *et al.* (1992), each individual was sorted and categorised by mark quality (how distinctive its marks are), based on the presence of one or more notches/nicks on the dorsal fin or immediately anterior or posterior of the dorsal fin (which could be detected from either left-or right-side angles), and/or scars on the fin or on the body (Table 7.1). Lesions, tooth-rakings, and/or blemishes on the dorsal fin were not used to identify unique individuals. These marks are considered unreliable due to their potential instability over time, resulting in mark loss (Lockyer and Morris, 1990; Wilson *et al.*, 1999). Additionally, no calves were photographed during the course of this study because these animals remain generally unmarked (Slooten *et al.*, 1992; pers. obs.).

The permanency of marks can become an issue when considering that the trailing edge of the dorsal fin can be damaged relatively easily (Würsig and Jefferson, 1990). Although scars and fin nicks can be permanent, they can change with time via the addition of new marks. The use of high quality images, however, only allows such changes to be usually detected. Misidentification due to new marks obscuring former marks (or mark loss) is more likely to occur with category III individuals that have minor marks. The exclusion of category III individuals combined with the use of photo-quality criteria should minimise cases of mark changes going unnoticed (DuFresne, 2005). In this study, photo-ID was carried out over two austral summer seasons, further reducing the likelihood of identification error.

Photo-quality

Protocols for cataloguing Hector's dolphins have been well established (Slooten *et al.*, 1992; Bräger, 1998a; DuFresne, 2005). The same criteria were, therefore, followed in the present study for both left- and right-sided images. The main criteria necessary to ensure that all identifiable Hector's dolphin had an equal opportunity of being identified is the overall quality of the photographs. Photo-quality criteria were based on several attributes: focus or sharpness, exposure, size, and angle of the body relative to the photographic frame (Table 7.2). Images were subsequently rated as poor, fair, good, or excellent (Table 7.3).

Table 7.1: Definition of categories used in the photo-ID catalogue following Slooten *et al*. (1992).

Category	**Definition**	**Examples**
Category I	Individuals have such distinctive marks that they are very unlikely to have been missed in the field, and have an excellent chance of being identified from photographs after each encounter.	
Category II	Individuals have obvious identifying marks that are unlikely to be misidentified from good photographs. However, they are more likely either to go unnoticed in the field, or are more difficult to identify from photographs taken at less than ideal angles.	
Category III	Individuals have more subtle marks, which are useful for distinguishing individuals while observing behaviour or group interactions, but may be easily missed in the field and/or are difficult to identify positively from photographs.	

Heterogeneity of capture is a potential important bias in all capture-recapture studies (Clapham *et al*., 2003; Stevick *et al.*, 2003; Friday *et al*., 2008). Consequently, only good- and excellent-quality photographs of well-marked animals (Category I and II) were used in subsequent analyses to minimise any risk of misidentification. This is consistent with the approach of previous studies done using the BPHDPC database (*e.g.* DuFresne, 2005; Gormley *et al*., 2005).

Table 7.2: Description of attribute criteria used to judge the quality of dorsal fin photographs.

Attribute		**Description**
Focus	a)	Blurred
	b)	Partially blurred: outline of fin visible
	c)	In focus
Exposure	a)	Poor: dorsal fin over or under-exposed, only outline is visible
	b)	Medium: some over or under exposure but details and outline are visible
	c)	Good exposure: all details are visible
Size	a)	Too small: dorsal fin occupies < 25% of the frame
	b)	Fair size: dorsal fin occupies 25-50% of the frame
	c)	Good size: dorsal fin occupies > 50% of the frame
Angle	a)	Bad angle: dorsal fin is perpendicular or > 45º
	b)	Fair angle: dorsal fin is about 45º
	c)	Good angle: dorsal fin is parallel

Table 7.3: Scale of photo-quality and attributes (Table 7.2) used for the catalogue and database.

Grade of photographs	**Attributes**
Poor	Three or more attributes failed to comply, or one or more attributes was significantly affecting nick/notch visualisation. Information content is, therefore, compromised by poor photographic quality.
Fair	Two attributes failed to comply. However, information content is not compromised by photographic quality.
Good	One attribute failed to comply. Information content is retained.
Excellent	All attributes complied.

7.3.3.2. Matching and Hector's dolphin catalogue

Identification and matching was done by eye by the primary researcher and cross checked by an independent researcher (M. Mariani, Oceanomare-Delphis Onlus, Italy). Prior to confirming a new individual, images were checked and cross-matched to reduce the likelihood of any false-negative (when previously photographed individuals are not recognized) and false-positive errors (when different individuals are incorrectly identified as the same individual; Hammond, 1986).

The Akaroa Harbour Hector's Dolphin Catalogue

The Akaroa Harbour Hector's Dolphin (AHHD) catalogue refers to a collection of individually identified Hector's dolphins (categories I and II only) in a single reconciled database. Individuals were classified with information on primary as well as secondary marks, damaged section of the dorsal fin, and position of body marks (Appendix 7.1), to assist with the matching process.

Each newly identified individual in the catalogue was given a unique reference number (*e.g.* SIHD001, South Island Hector Dolphin - first individual identified) and occasionally named. Other information in the catalogue included sex (if known) and date of sighting(s) (Appendix 7.2). Gender determination was opportunistically performed from photographs of the genital area during bow-riding, aerial behaviours or upside-down lobtails (Smolker *et al*., 1992). Adult individuals consistently accompanied by a calf were assumed to be female, although for this study, this assumption was not always verified via visualisation of the genital region.

Here a "sighting" refers to an individual identification photograph obtained during an encounter with a uniquely marked dolphin (with an ID) and the associated data collected during such an encounter (*e.g.* GPS position). The complete sighting record of each identified individual constitutes the encounter history of that particular individual (Tezanos-Pinto, 2009).

For each individual with an ID number, the best image in terms of quality was selected for the catalogue, with, if possible, a photograph of both sides of a dorsal fin and/or body (Appendix 7.2). If an individual was matched to another already present in the catalogue, new photographs were included in the catalogue if: a) the new photograph was of superior quality; and b) if the animal was taken from a different perspective (*i.e.* left or right side).

***Catalogue created using* Finscan**

Finscan (Araabi *et al.*, 2000; Hillman *et al.*, 2003) is a computer assisted dolphin photo-ID matching program. This software matches images based on a mathematical algorithm of the irregularities in the trailing edge of the dorsal fin (Araabi *et al.*, 2000; Hillman *et al.*, 2003). It employs string and curved-based matching methods to present most likely identification matches in order (Hillman *et al.*, 2003). When the highest ranked probable matches are displayed, dorsal fins can then compared manually to make a confirmation of identification.

Finscan performed very well with several delphinid species including bottlenose (*Tursiops truncatus*), dusky (*Lagenorhynchus obscurus*), and spinner dolphins (*Stenella longirostris*; Hillman *et al.*, 2003). However, with species like pilot whales (*Globicephala melas*), the system was less efficient (Hillman *et al.*, 2003). This study presented an opportunity to test the possibility to use the software on a species with a different dorsal fin shape, which could later facilitate the matching process of a large catalogue, such as that held by the University of Otago.

Following photographic sorting for suitability, dorsal fin images of marked individuals were digitally catalogued using *Finscan* 1.5.4 (Araabi *et al.*, 2000; Hillman *et al.*, 2003), creating a second digitalised catalogue. The matching process was then completed by eye as per Markowitz *et al.* (2003), and cross-checked by another experienced and independent cetacean researcher (M. Merriman, Massey University). This process not only increased the speed of the matching process (several photographs can be viewed at once), but also further reduced potential matching error due to false-positive and false-negative matches.

7.3.4. Analysis of photo-ID data

Several independent analyses were conducted using the dataset: a) matching of individuals between the AHHD and BPHDP (Otago University) catalogues; b) calculation of parameters for the sub-sample of the main population using Akaroa Harbour, such as age-class, sex-ratio, and mark rate; c) investigation of site fidelity (*i.e.*

whether individuals sighted were *frequent* or *infrequent* users of the Harbour) through analyses of re-sighting rates; and d) assessment of whether data collected opportunistically from commercial tour vessels can be used to estimate the abundance of identifiable dolphins using the Harbour each month during between November and March.

7.3.4.1. Matching between catalogues

Except for a couple of years (1998 and 1999 due to involvement in line-transect surveys, Dawson *et al.,* 2004), photo-ID surveys have been conducted continuously since 1985 by several researchers from the University of Otago (*e.g.* Bräger, 1998a; Smith, 1992; DuFresne, 2005; Rayment, 2008; Webster, 2008). Matching between the AHHD and BPHDP catalogues was done by eye and cross-checked by another experienced researcher (T. Webster, University of Otago). This helped determine the number of new individuals and those previously sighted around Banks Peninsula. Historical information on each individual that was matched (sex and year when first sighted) was then extracted from the BPHDP database and later used for subsequent analyses.

7.3.4.2. Parameters of the sub-sampled population using Akaroa Harbour

Sex ratio

The number of known male, female, and unknown individuals observed around commercial tour vessels was compared using a Pearson's χ^2 test (Zar, 1996) with the overall ratio of individuals in the BPHDP catalogue to assess for any sex bias during encounters.

Age-class

To estimate the age-class of identifiable individuals, it was assumed that an individual was at least one year old when first sighted. The minimum age for each individual was, therefore, equal to the number of years that the individual was known to be alive within the BPHDP catalogue or the AHHDC catalogue for new individuals. These estimates represent only minimum ages. For example, a female dolphin first sighted in 2003 would be at least four years old when last sighted in 2006 and would be recorded as being "4+". However, as she was sighted with a calf in 2006, she would be a mature female and, therefore, be at least seven years old because female Hector's dolphin become sexually mature between the age of seven and nine years (Slooten *et al*., 1992).

Mark rate or proportion of identifiable individuals

Capture-recapture analysis procedures produce an estimate of the number of identifiable individuals in the population of interest, but no estimation on the number of total individuals is provided. The proportion of marked to unmarked individuals or mark rate (Jolly, 1965) can, however, be used to extrapolate the total population size by multiplying the abundance obtained by the mark rate (Williams *et al*., 1993).

In order to ensure an accurate assessment of mark rate, only those surveys in which every individual in a sighting group was photographed were used in mark analyses. Surveys in which: a) less than four times as many photographs as the number of individuals within the focal group were taken (Würsig and Jefferson, 1990); and b) only bad quality photographs of identifiable individuals were obtained, were discarded.

Mark rate (Q) was then obtained by the following equation:

$$Q = \frac{I}{P}$$

where *I* is the number of photographs containing identifiable individuals and *P* the total number of good- and excellent-quality photographs taken.

As mark rate was assumed to be binomially distributed (*i.e.* animals could only be marked or unmarked), a binomial confidence with 95% limit was also estimated. Mark rate was finally compared with previous studies (*e.g.* Gormley *et al*., 2005; Webster and Rayment, 2006) and other species (*e.g.* Constantine, 2002; Neumann *et al.*, 2002; Markowitz, 2004; Tezanos-Pinto, 2009).

7.3.4.3. Site fidelity

Re-sighting rate

The number of occasions an individual was "captured" within a sampling period (re-sighting-rate) was calculated according to months (a total of ten months across the two field seasons) and number of days.

Site fidelity was assessed within both field seasons, in terms of number of days between sightings and between first and last encounters. The frequency of the number of days (pooled weekly) between re-sightings was also determined.

Frequent *and* infrequent *users*

To determine the number of *frequent* and *infrequent* users of Akaroa Harbour, a Poisson distribution was calculated to test the null hypothesis that individuals were sighted randomly (Zar, 1996), following previous methods applied to New Zealand *Tursiops* (Constantine, 2002; Merriman *et al*., 2009; Tezanos-Pinto, 2009). This particular distribution was selected given that it expresses the probability of a number of sightings occurring in a time period with a known average rate. A two-week time period was selected, taking into account the data set (10 months), to reduce pseudo-replication (Hurlbert, 1984) that could result from individuals photo-identified on several consecutive days and then not being sighted again for several months. Consequently, only one sighting per sampling period was used in the analysis (a total of 21 two-week periods; 10 in the 2006/2007 season and 11 in the 2007/2008 season).

Frequent users were demarcated at the point where the frequency of observed sightings exceeded the expected frequency of the Poisson distribution. *Occasional* visitors were defined as those individuals that were observed more than once (*i.e.* not *infrequent* users) but were not *frequent* users.

7.3.4.4. Estimated abundance of identifiable individuals using Akaroa Harbour

Discovery curve

The photo-ID dataset was used to create a discovery curve (Darling and Morowitz, 1986) of individually identifiable dolphins to determine the number of marked dolphins with time. The cumulative number of new identifiable individuals was plotted against the number of individuals captured within each monthly sampling period. The shape of the curve was then used to assess the likelihood of the population being closed or open. A closed population assumes both geographic and demographic closure, *i.e.* animals do not move in and out of the study area and the size of the population is constant over the study period, with no recruitment (natality, immigration) or losses (mortality, emigration). An open population, on the other hand, allows for natality, mortality, and movements in and out of the study area during the study period (Chao and Huggins, 2005).

Mark-recapture methods

Before attempting to use mark-recapture methods and models, it is important to define what constitutes the "population" under study. Here, a "population" is defined as Hector's dolphins that represent a sub-sample of the Banks Peninsula population that use Akaroa Harbour and its close vicinity (*i.e.* within the permitted area of operation for commercial tour operators, Fig 7.1). Directed photo-ID surveys were not conducted during the course of this study and the entire home range of individuals was not encompassed. As a result, an estimate of population abundance *per se* was not intended here, especially given that this has already been covered by previous research (*e.g.* DuFresne *et al*., 2001; Gormley *et al*., 2005). Instead, an estimation of the number of individuals that frequent the harbour each month was of greater interest. Such data can be used to better understand the potential exposure of individual dolphins to tour vessels between November and March.

Once a "population" has been defined, a model must be chosen. There is a wide array of models available for mark-recapture analysis, resulting in the difficult question of which are the most suitable for the population of interest (Burnham *et al*., 1995). Selecting a particular model depends on matching characteristics of the data to the inherent assumptions made by each model (refer to Amstrup *et al*., 2005 for a review). Mark-recapture models are also subject to restrictive assumptions which must be met to ensure accuracy (Manly *et al*., 2005). These are as follows:

a) *Mark recognition*: all marked individuals must be uniquely identifiable with no loss of marks during the study period;
b) *Behavioural response*: marking/sampling procedure should not affect the chances of capture of individuals;
c) *Heterogeneity of capture*: the probability of capture of both marked and unmarked individuals should be equal; and
d) *Geographic and demographic closure*: there are boundaries which limit the individuals spatially and there is no net change in population size during the sampling period.

Possible violations of these assumptions should be carefully evaluated to avoid introducing unnecessary bias (Begon, 1983).

Assumptions

a) *Mark recognition*:

Studies have shown that most nicks on the trailing edge of bottlenose dolphins are permanent features (Wilson *et al*., 1999) and usually remain stable over several years (Tezanos-Pinto, 2009). The same can be assumed for Hector's dolphins (Rayment, 2008). The catalogue was also cross-matched by three independent researchers further reducing the likelihood of false-positive, false-negatives and/or mark loss errors. Finally, the survey period ranged over only two sampling periods. Consequently, the possibility of mark loss was minimal.

b) *Behavioural response*:

Markings on the dorsal fin of Hector's dolphins are naturally occurring and, therefore, photographing them should not cause a capture response or trap-dependence (trap-shyness or trap-happiness). Nonetheless, to evaluate whether there was a behavioural response to capture or survey methods a test (Test 2.CT) was implemented in the software U-CARE[1] version 2.02 (Choquet *et al*., 2005), which runs a stand-alone programme.

c) *Heterogeneity of capture*:

The assumption of heterogeneity of capture is often difficult to meet when studying dolphin populations as heterogeneity in capture probability can occur among individuals, groups, populations, and sampling periods (Pollock, 1982; Hammond, 1986). Although Hector's dolphins exhibit strong site fidelity, no dolphin was observed exclusively in Akaroa Harbour (Bräger *et al*., 2002). This would result in variation in individual heterogeneity, with some dolphins having a higher capture probability than others. Using U-CARE, a test (Test 3.SR) was implemented to detect whether there was an excess of individuals only sighted once (*i.e.* transient individuals).

[1] http://www.cefe.cnrs.fr/BIOM/en/softwares.htm

d) *Geographic and demographic closure*:

Mark-recapture models can be dichotomized into open and closed models. Violation of the closure assumption results in over-estimation of population estimates (Pollock *et al.*, 1990). Individuals using Akaroa Harbour are part of the larger Banks Peninsula population (Bräger *et al.*, 2002; Rayment *et al.*, 2009). In addition, births occurred during the course of this study. As such, it is assumed that the population is open. A closure test in CAPTURE (Rexstad and Burnham, 1992) was implemented to confirm this assumption using data pooled monthly. It should also be noted that this test can provide a false rejection of closure if behaviour is having an influence on capture probabilities (assumption b).

Cormack-Jolly-Seber models

Given the characteristics of the individuals using Akaroa Harbour, *i.e.* they cannot be described as resident within the harbour (Bräger *et al.*, 2002), four classical open models were deemed more appropriate to estimate the number of identifiable dolphins using the harbour each month and to predict trends. Cormack-Jolly-Seber (CJS) models were, therefore, tested using the programme MARK[2] v 4.3 (White and Burnham, 1999). CJS models allow for more than one capture event, immigration, permanent emigration, and heterogeneity in capture probabilities over time. These models provide estimates of survival and capture probabilities but not of abundance. Prior to running any model, data were pooled by month across the seasons 2006/2007 and 2007/2008, and time intervals were set, taking into account a seven month gap between sampling seasons.

The four CJS models that were run included:

- {φ(.)p(.)}, where both survival (φ) and recapture (p) probabilities are invariant;
- {φ(t)p(.)}, where recapture probability is invariant and survival time-dependent (t);
- {φ(.)p(t)}, where recapture probability is time-dependent and survival invariant; and
- {φ(t)p(t)}, where both recapture and survival probabilities are time-dependent.

[2] http://welcome.warnercnr.colostate.edu/~gwhite/mark/mark.htm

Model selection

Choosing the best model consisted of two main steps. First was the assessment of how well models fit the data, *i.e.* how well they explained the variation in the capture history. Goodness of fit (GOF) were used for this process (Lebreton *et al.*, 1992) using U-CARE (Choquet *et al.*, 2005). Assessing the GOF of the most general model, here {φ(t)p(t)}, to the data was crucial due to the subsequent reliance on using Akaike's Information Criterion (AIC) to choose between this model and reduced parameters models.

The programme U-CARE provided several GOF components for multi-state analyses. These included a test (Test 2.CL) to examine the variation in the time between re-encounters for captured and un-captured individuals among sampling occasions (Choquet *et al.*, 2005), and a test (Test 3.SM) exploring the effect of capture on "apparent" survival. In CJS models, birth and immigration are confounded (as are permanent emigration and mortality) and termed 'apparent survival". "Apparent" (or local) survival is, therefore, the probability that an individual will survive and return to the sampling area, *i.e.* the survival estimated with a given data set. "Apparent" survival may be influenced by confounding variables such as migration and may, therefore, represent an under- or over-estimate of "true" survival (Cooch and White, 2007). Variations in "apparent" survival are actually variations in either natality/immigration or mortality/emigration.

When a model was found to fit the data, it was subsequently determined whether a simpler model also fitted the data. AIC corrected for small sample bias or AICc (Hurvich and Tsai, 1989) was used to discriminate among potential models. The selection procedure consists of choosing the model in the programme MARK with the smallest AICc score, considered to be the "best-fit model". Effectively this provides a compromise between fit and complexity, *i.e.* a measure of model fit penalised by the number of parameters (Manly *et al.*, 2005). A model with fewer parameters will have less variance at the cost of increased bias, while a fully parameterised model will have reduced bias at the cost of increased variance (Burnham and Anderson, 1992). Generally, an AICc difference of two or less gives support to both models. In contrast, a difference greater than two gives considerably less support to the next best model (Burhnam and Anderson, 2004).

7.3.4.5. Potential exposure to vessel traffic

Percentage change

To have a better understanding of the potential level of vessel traffic that Hector's dolphins can be exposed to when using Akaroa Harbour, the percentage change in the monthly estimated abundance of identifiable individuals and in the number of vessels per hour (refer to Chapter III for actual numbers) were plotted and compared. Percentage change could only be calculated across the whole season in 2007/2008. Consequently, season 2006/2007 was excluded from this analysis.

***Baker's formulae* (2004)**

Baker (2004) suggested simple formulae be used in the absence of research. The aim was to guide management decisions regarding the appropriate number of tours that should be permitted to interact with dolphins in New Zealand. These formulae state that the number of trips should not exceed the total number of independent dolphin groups in a particular locality on any one day. Data on permitted numbers of trips and on groups of Hector's dolphins in Akaroa Harbour are available. As a result, these formulae have been recently applied (Allum, 2009). Such formulae were subsequently applied for Akaroa Harbour with data collected in this study. They were also used for other species targeted by commercial tour operations within New Zealand, where sufficient data are available.

Extrapolation from commercial operators' effort

The commercial dolphin-watching and swim-with-dolphin operators' on water effort for the ten-month period of this study was estimated using data provided by DOC. Under their permit system, each commercial tour operator must provide DOC with a monthly activity report, including effort (*i.e.* number of trips undertaken during a given period: day, month, and year). The number of trips a Hector's dolphin is typically exposed to between November and March was subsequently determined by extrapolating the re-sight rate calculated per trip from surveys to the total effort during that time period. Following Constantine (2001), the median (± interquartile range) was used to give a more conservative estimate of exposure.

7.4. Results

7.4.1. Survey effort

A total of 114 (2006/2007) and 110 (2007/2008) days were spent in the field, resulting in 227 and 216 surveys conducted from commercial tour operator vessels. Photo-ID was attempted in 89.9% (n = 204) and 82.4% (n = 178) of the surveys and Hector's dolphins were photo-identified in 45.9% (n = 304) and 41.2% (n = 293) encounters over the two sampling periods, respectively (Tables 7.4 and 7.5). While photo-ID was attempted on a collective total of 86.2% (n = 382) of the surveys, only 57.3% (n = 254) were retained for analysis purposes (Tables 7.4 and 7.5), *i.e.* surveys with good visibility and a duration of a minimum of ten minutes (refer to section 7.3.2.2). Even though surveys were conducted from commercial operator vessels, photo-ID was conducted in most parts of Akaroa Harbour, south of Akaroa township (Fig. 7.2).

Table 7.4: Summary of effort conducted in Akaroa Harbour, New Zealand, in the season 2006/2007.

	Nov-06	**Dec-06**	**Jan-07**	**Feb-07**	**Mar-07**	***Total***
Vessel surveys	45	51	51	40	40	*227*
Number of sightings	99	172	152	110	130	*663*
Surveys photo-ID attempted	36	46	44	39	39	*204*
Number of sightings with Photo-ID undertaken	40	65	73	57	69	*304*
Used photo-ID surveys	15	17	32	29	29	*122*
Number of sightings	16	44	45	53	52	*210*
Total number of good- and excellent photographs taken	*122*	*163*	*352*	*263*	*263*	***1163***

Table 7.5: Summary of effort conducted in Akaroa Harbour, New Zealand, in the season 2007/2008.

	Nov-07	**Dec-07**	**Jan-08**	**Feb-08**	**Mar-08**	***Total***
Vessel surveys	45	49	47	43	32	*216*
Number of sightings	136	151	155	133	137	*712*
Surveys photo-ID attempted	39	42	43	31	23	*178*
Number of sightings with Photo-ID undertaken	60	65	75	51	42	*293*
Used photo-ID surveys	25	32	33	25	17	*132*
Number of sightings	34	33	39	34	24	*164*
Total number of good- and excellent photographs taken	*245*	*183*	*183*	*186*	*78*	***875***

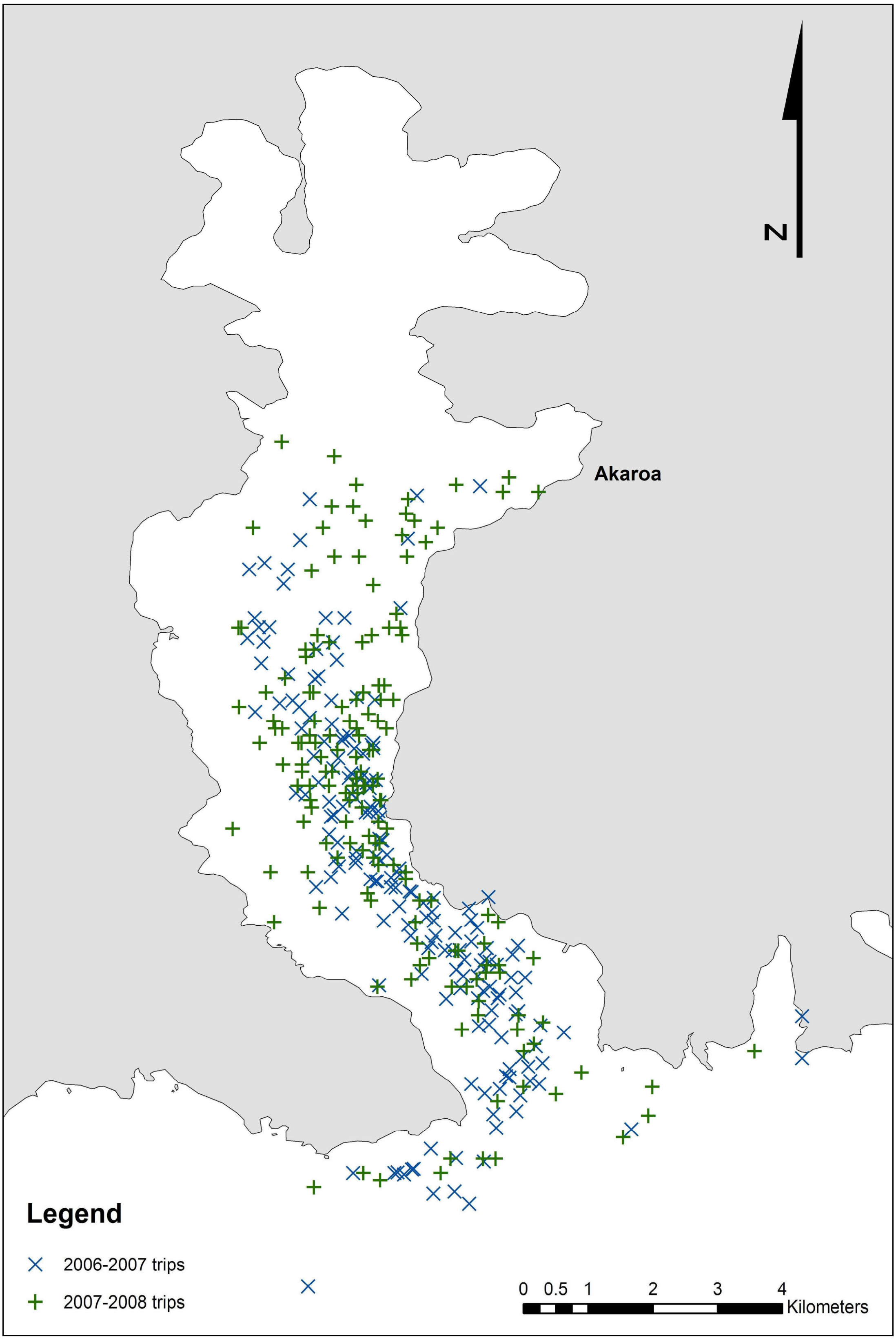


Fig. 7.2: Map showing the positions of each surveys where photo-ID was conducted in Akaroa Harbour, New Zealand. Positions were plotted using ArcGIS v. 9.1 (ESRI, Redlands, CA, USA).

7.4.2. Analysis of photo-ID dataset

Across the entire study period, a total of 2,038 photographs of good and excellent quality were taken of Hector's dolphins observed during encounters with tour operators in Akaroa Harbour. From these, 290 were of marked individuals of category III, 107 of category II, and 79 of category I. The remaining good and excellent quality photographs were of unmarked individuals.

7.4.2.1. Comparison between AHHD and BPHDP catalogues

The final catalogue contained a total of 50 unique dorsal fins from both category I and II. Upon completion of field work and data processing, a photo-ID catalogue was compiled and a copy submitted to DOC, Canterbury. In 2008, a smaller catalogue containing the most obviously marked individuals using Akaroa Harbour was also specially created for the local commercial tour operators for educational purposes (*i.e.* staff training and customers; Appendix 7.3).

Of the 50 individual dorsal fins identified here, 88% (n = 44) had been seen previously around Banks Peninsula (BPHDP catalogue) and the remaining 12% (n = 6) were new individuals.

7.4.2.2. Parameters of the sub-sampled population using Akaroa Harbour

Sex ratio

From the 890 individuals currently in the BPHDP catalogue, 24.7% (n = 220) were of known sex. Of these 75.9% (n = 167) were known to be females and 24.1% (n = 53) males, representing a sex ratio of 3.2:1. In the AHHD catalogue, of the 44 individuals matched with the BPHDP catalogue, 59.1% (n = 26) were of unknown sex. From the remaining 40.9% (n = 18), 72.2% (n = 13) comprised females and 27.8% (n = 5) males, representing a sex ratio of 2.6:1. No significant difference in the frequency distribution of females and males between both catalogues was detected (Pearson's χ^2 test: χ^2_1 = 0.645, p = 0.422).

Age-class

Minimum age identifiable individuals ranged between one and 22 years with a mean of 4.8 (median = 4, S.E. = 0.6, n = 50). The majority (54%, n = 27) were at least between three and six years of age (Fig. 7.3). While some of these individuals may represent sub-adults, others were likely older and, therefore, sexually mature adults. Individuals that were at least seven years of age could be assumed to be sexually mature and represented 22% (n = 11) of the identifiable individuals. Of these, nine dolphins were at least between seven and ten years of age. A significant gap in the dataset between the ages of 10+ and 20+ was detected (Fig. 7.3), with the two eldest individuals (> 22 years old: SIHD042 and SIHD050), both being female.

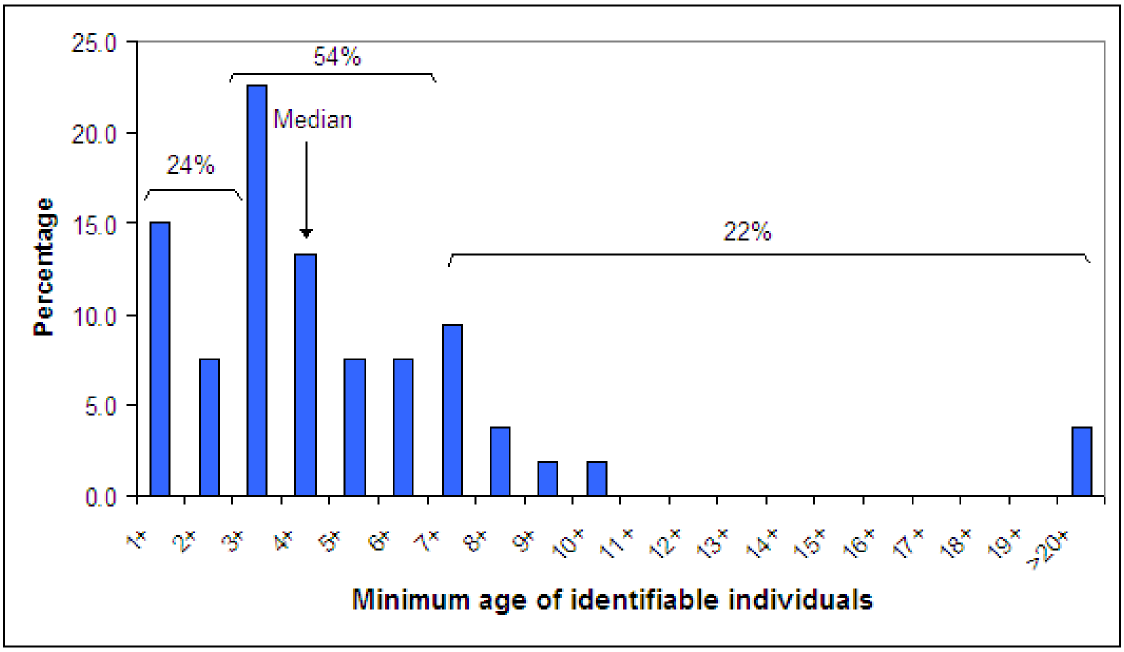


Fig. 7.3: Distribution (percentage) of the minimum age of identifiable individuals in Akaroa Harbour, New Zealand.

Sightings of mother and calf pairs

Over the two distinct sampling periods, two different marked individuals were sighted with a calf and, therefore, assumed to be female. Both were already in the BPHDP catalogue and confirmed as females. Minimum age was six and twenty-two years. Both were sighted in late December and/or January. Individual SIHD047 was sighted twice in 2006/2007, with both sightings occurring within one week.

Mark rate

The proportion of individuals with identifiable marks varied widely between trips, ranging from 0 to 50%. The mark rate was estimated from a total of 797 good- and excellent-quality photographs obtained during 45 surveys (Appendix 7.4). Of these, 86 photographs were taken of identifiable individuals of categories I and II (including multiple photographs of the same individual). The mark rate was, therefore, estimated to be 0.108 or 10.8% (95% binomial C.I. = 8.7 - 13.2%). Mean mark rate per trip was 0.092 or 9.2% (95% C.I. = 5.4 - 13.0%).

Mark rate in Hector's dolphins found in Akaroa Harbour was very low compared to other species within New Zealand waters. However, the mark rate estimated in this study is comparable to previous studies carried out around Banks Peninsula and Akaroa Harbour on Hector's dolphins (Table 7.6).

Table 7.6: Comparison of mark rates between different species found in New Zealand waters.

Species	**Area**	**Mark Rate**	**Reference**
Bottlenose dolphin	*Marlborough Sounds*	87.2%	Merriman (2007)
(*Tursiops truncatus*)	*Bay of Islands*	81.5%	Constantine (2002)
	Bay of Islands	75.0%	Tezanos-Pinto (2009)
	Doubtful Sound	73-84%	Gormley (2002)
Dusky dolphin	*Admiralty Bay*	76.0%	Markowitz (2004)
(*Lagenorhynchus obscurus*)	*Kaikoura*	38.0%	Markowitz (2004)
Common dolphin	*Hauraki Gulf*	28.0%	Stockin (Unpubl. data)
(*Delphinus delphis*)	*Bay of Plenty*	10.0%	Neumann *et al*. (2002)
Hector's dolphin	*Porpoise Bay*	46.8%	Green (2003)
(*Cephalorhynchus hectori hectori*)	*Porpoise Bay*	36.9%	Bejder and Dawson (2001)
	Akaroa Harbour	12.5%	Slooten *et al*. (1992)
	Akaroa Harbour	10.8%	This study
	Akaroa Harbour	10.5%	Gormley *et al*. (2005)
	Akaroa Harbour	10.5%	Webster and Rayment (2006)

7.4.2.3. Site fidelity

Re-sightings rates

Re-sighting rates were relatively low, 64% (n = 32) of identifiable individuals were observed over one season only. When considering months as an independent sampling period, 52% (n = 26) of these individuals were sighted only in one month out of a ten-month study period (November to March in 2006/2007 and 2007/2008), and only 12% (n = 6) were sighted over more than four different months (Fig. 7.4).

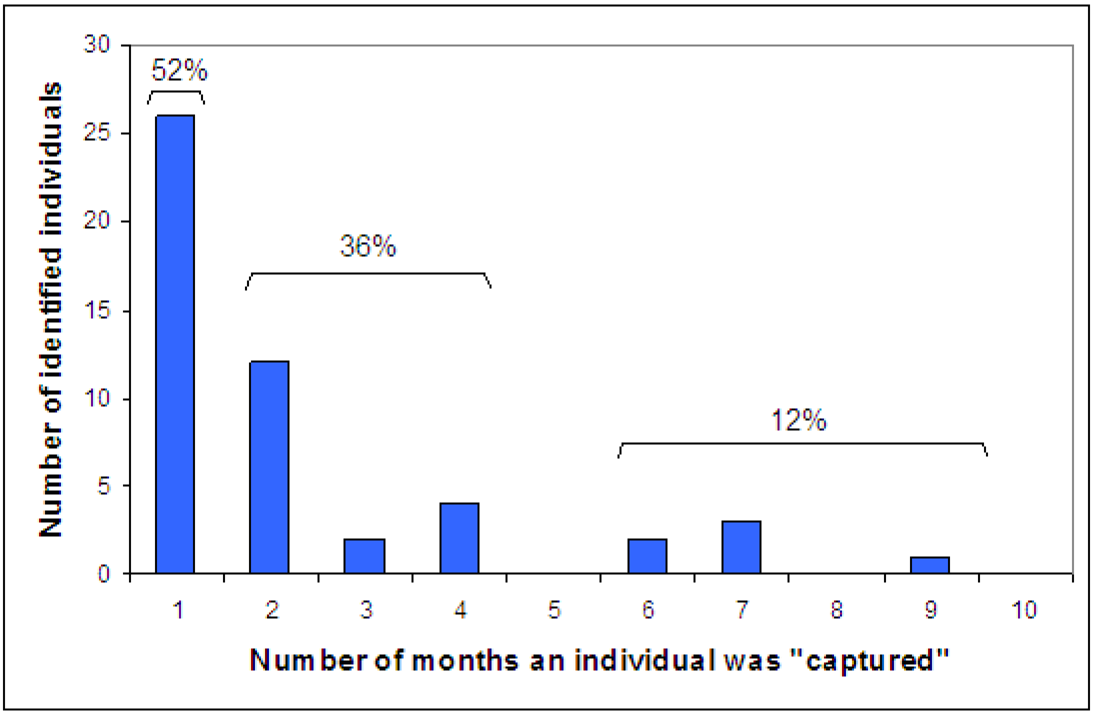


Fig. 7.4: Distribution of the number of months an individual was "captured" in Akaroa Harbour, New Zealand, during the two distinct sampling periods of 2006/2007 and 2007/2008.

Identifiable individuals (n = 50) were also sighted between one and 17 days over the same ten-month study period (mean = 3.6, S.E. = 0.579). Of these, 8% (n = 4) were observed over ten or more separate occasions (Fig. 7.5).

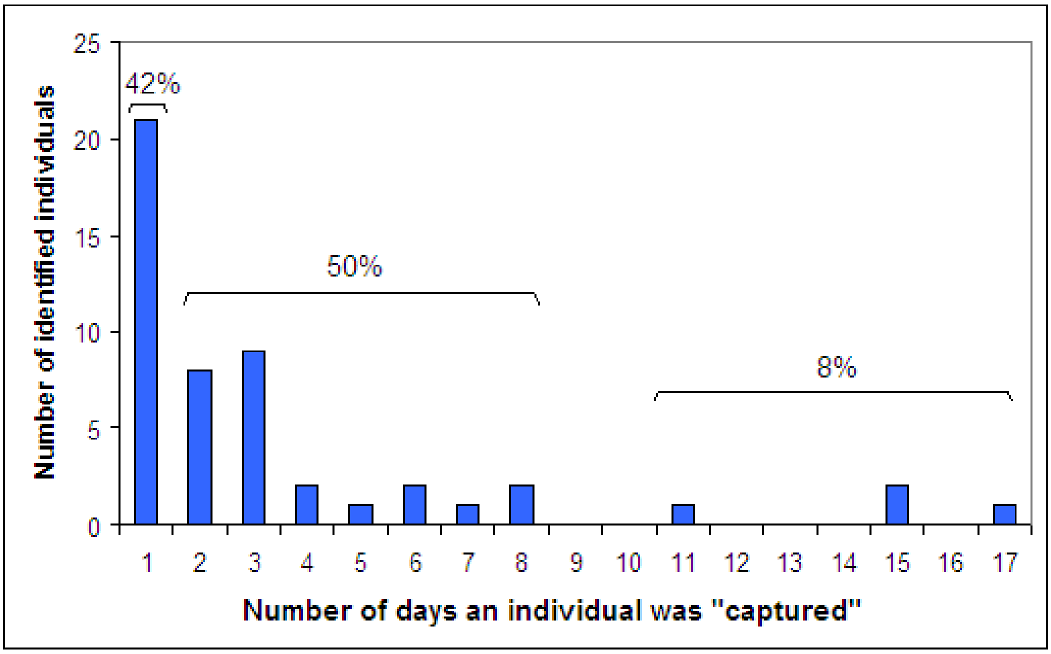


Fig. 7.5: Distribution of the number of days an individual was "captured" in Akaroa Harbour, New Zealand, during the two distinct sampling periods of 2006/2007 and 2007/2008.

For the 28 identifiable individuals observed more than once within the same field season, intervals between sightings ranged from one to 100 days (mean = 21.6, S.E. = 2.3, median = 12, n = 97). The time elapsed between the first and last sighting of an individual within the same field season ranged two to 139 days (mean = 65.5, S.E. = 8.3, median = 74.5, n = 32).

When investigating the number of days that elapsed between re-sightings of identifiable individuals within both field seasons, 75.5% (n = 74) of the re-sightings occurred within the first four weeks or first month (Fig. 7.6). Of these, 40.5% (n = 30) took place within a week or less. A further 17.4% (n = 17) occurred within eight weeks or two months, 5.1% (n = 5) within twelve weeks or three months, and only 2% (n = 2) were more than three months apart (Fig. 7.6).

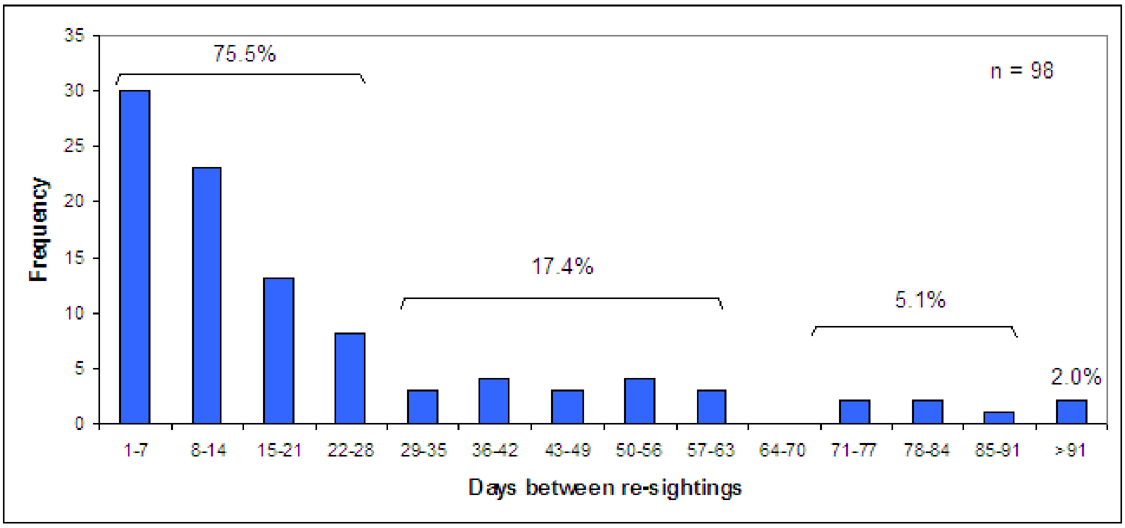


Fig 7.6: Frequency of the number of days (clumped in weekly period) between re-sightings of Hector's dolphins in Akaroa Harbour, New Zealand, during the two distinct sampling periods of 2006/2007 and 2007/2008. Percentages of re-sightings within monthly periods are indicated above bars.

Frequent *and* infrequent *users*

Frequent users were demarcated as those individuals that were sighted over at least eight two-week periods over the ten month-study period, at which point the frequency of observed sighting exceeded the expected frequency of the Poisson distribution (Fig. 7.7).

Individuals were typically sighted over a minimum of two independent fortnight periods (mean = 2.7, S.E. = 0.344, median = 2, n = 50). Observations made in Akaroa Harbour showed that a large number of individuals were only identified once (46%, n = 23) and, therefore, classified as *infrequent* users. *Frequent* users represented only 10% (n = 5) of the total identifiable individuals, the remaining being *occasional* users (Fig. 7.7).

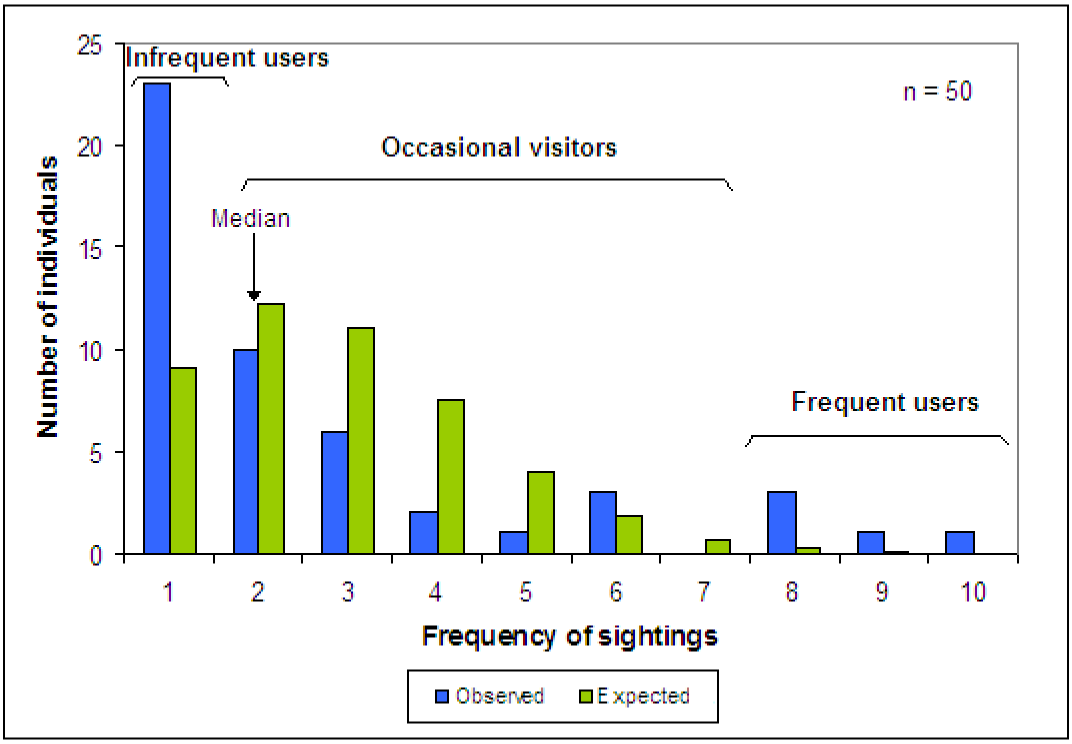


Fig. 7.7: Site fidelity of Hector's dolphins in Akaroa Harbour, New Zealand. Observed frequencies of sightings per two-week period (in blue) and expected (in green) after a Poisson distribution for data collected over a 21 effective two-week periods over the austral summer seasons of 2006/2007 and 2007/2008. *Infrequent* users, *occasional* visitors and *frequent* users are indicated in the figure. Note: The median is shown with a black arrow.

When examining site fidelity, it was again apparent that only a few individuals qualify as *frequent* users (Fig. 7.8). Individuals that were sighted the most (SIHD001 and SIHD003) were both females of minimum age of four years. Individual SIHD037 was the only other animal of known sex and was a male, also of minimum age of four years when last captured in 2008. The remaining two individuals (SIHD006 and SIHD062) had a minimum age ranging between three and seven years in 2008.

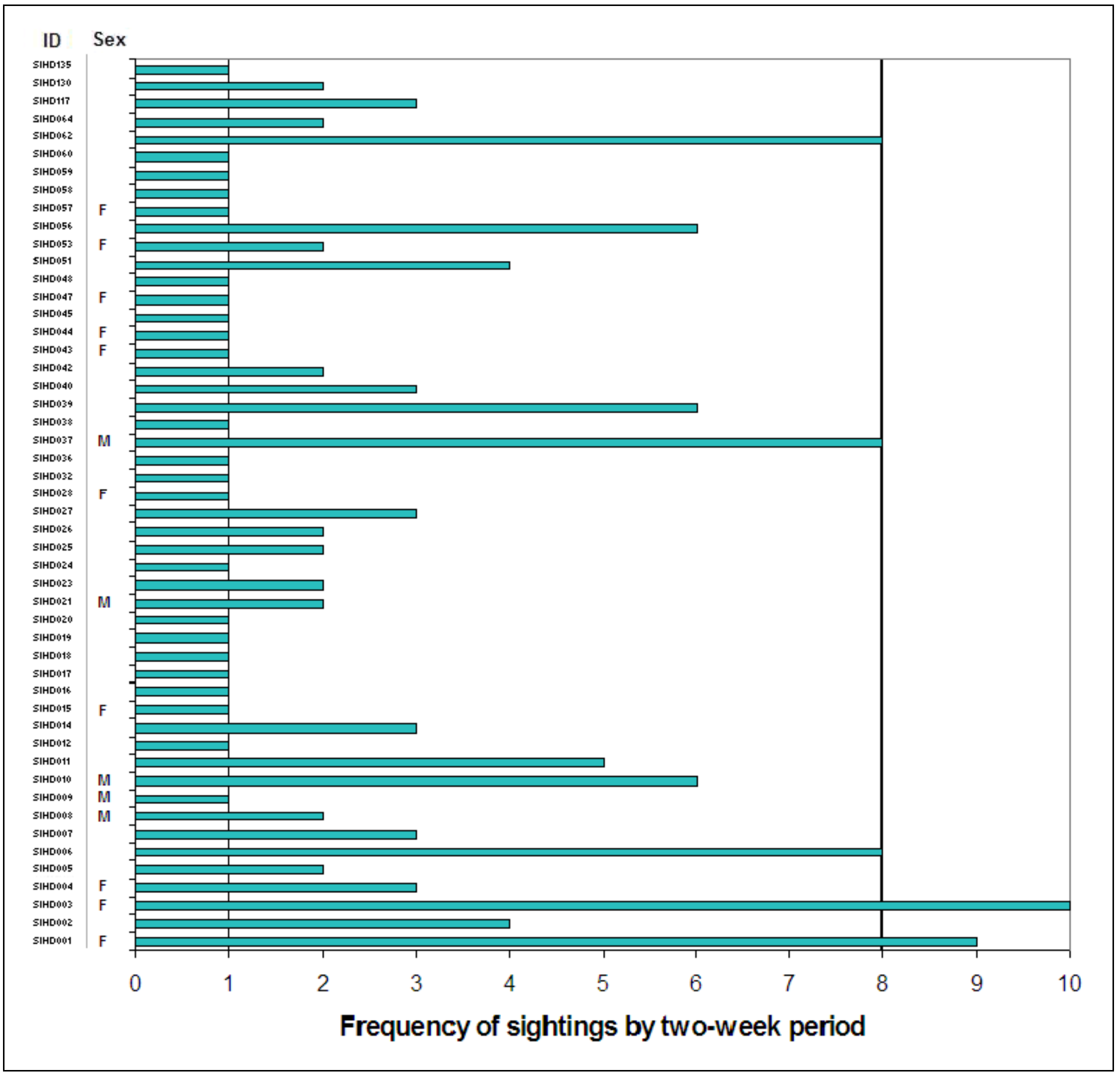


Fig. 7.8: Identified individual dolphins found to be *infrequent* users (1 sighting per two-week period), *occasional* visitors (2-7 sightings per two-week period), and *frequent* users (8 or more sightings per two week period) in Akaroa Harbour, New Zealand, in 2006/2007 and 2007/2008. Sex identification is shown, where available.

Frequent users all displayed similar site fidelity to Akaroa Harbour across the two field seasons. All sightings of *frequent* users made in 2007/2008 for all individuals were also made over the same period in 2006/2007 (Table 7.6).

Although sightings in 2007/2008 were made over the same period as in 2006/2007, individuals were not sighted as often as in the previous season (median = 3 in 2007/2008 and median = 5 in 2006/2007), except for individual SIHD037. Although effort was relatively uniform between the two field seasons, 122 in 2006/2007 and 132 in 2007/2008, the number of photographs used for analyses was higher in 2006/2007, with a total of 1,163 compared to 875 the next season.

Table 7.7: Sightings of the eight *frequent* users per month during each field season in Akaroa Harbour, New Zealand. Sightings made in 2007/2008 that were also made over the same month in 2006/2007 are indicated in green.

ID	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Total
SIHD001						5
SIHD003						4
SIHD006						5
SIHD037						3
SIHD062						5

ID	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Total
SIHD001						4
SIHD003						3
SIHD006						2
SIHD037						3
SIHD062						2

During the study period, 60% (n = 3) of *frequent* users were sighted during two different commercial trips, each on two independent occasions. In addition, another 60% (n = 3) were also identified from commercial vessel platforms on two consecutive days once. SIHD001 was also observed on three consecutive days (14-16 December 2006).

Maps of sightings of the* frequent *users

Frequent users typically used the entire harbour (south of Akaroa township), although there were two areas where sightings tended to be clustered. One of these was just off *9 Fathom* and the other centred within the first four kilometres from Akaroa Harbour entrance (Fig. 7.9).

When considering sightings made over consecutive days, up to a maximum of two days apart, some individuals were observed within very close proximity of previous sighting(s) (Fig. 7.10). For example, individual SIHD001 was observed within less than two kilometres away from a previous sighting on three separate occasions.

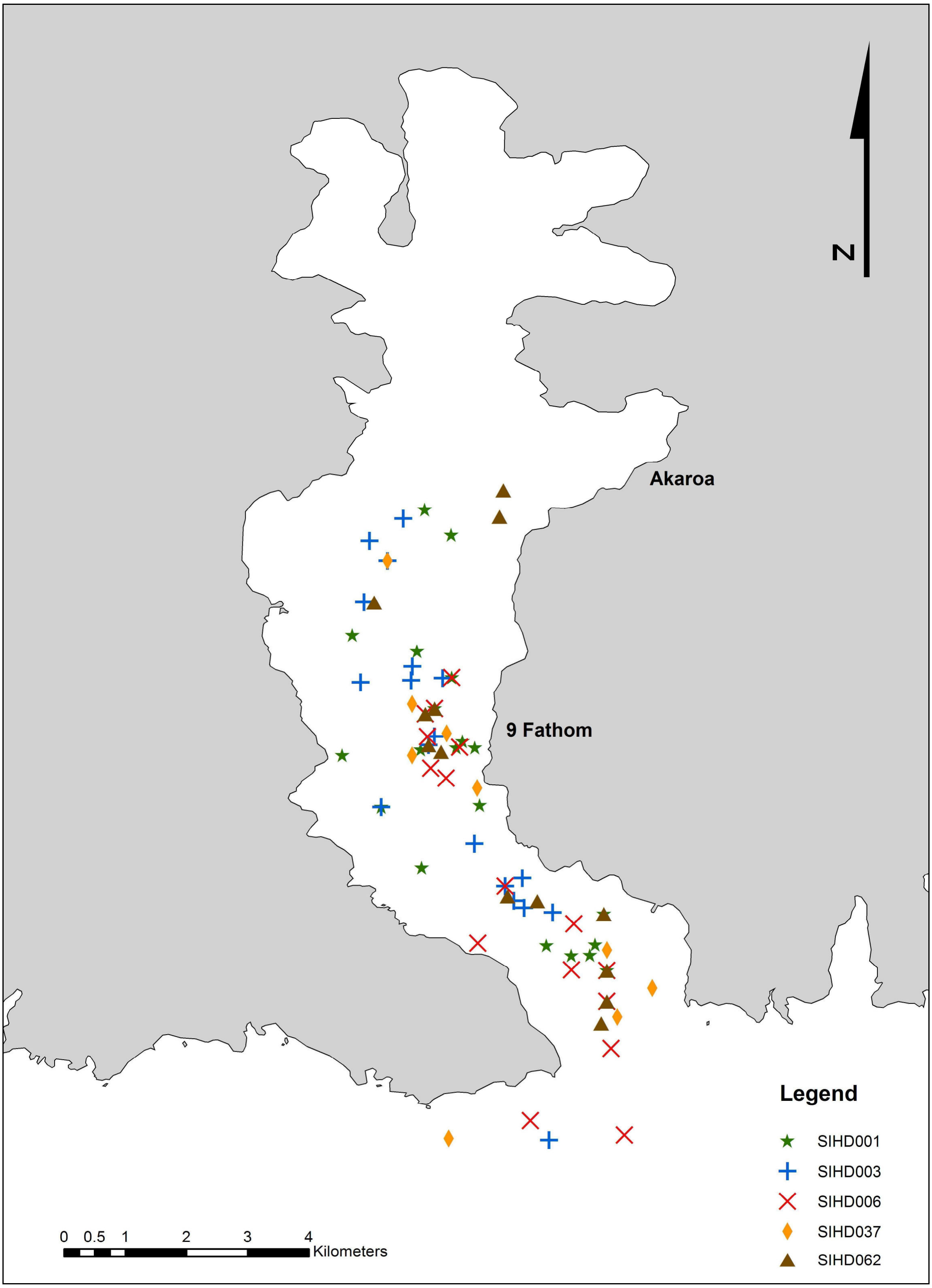


Fig. 7.9: Map showing the positions of sightings of the five most *frequent* users observed within Akaroa Harbour, New Zealand.

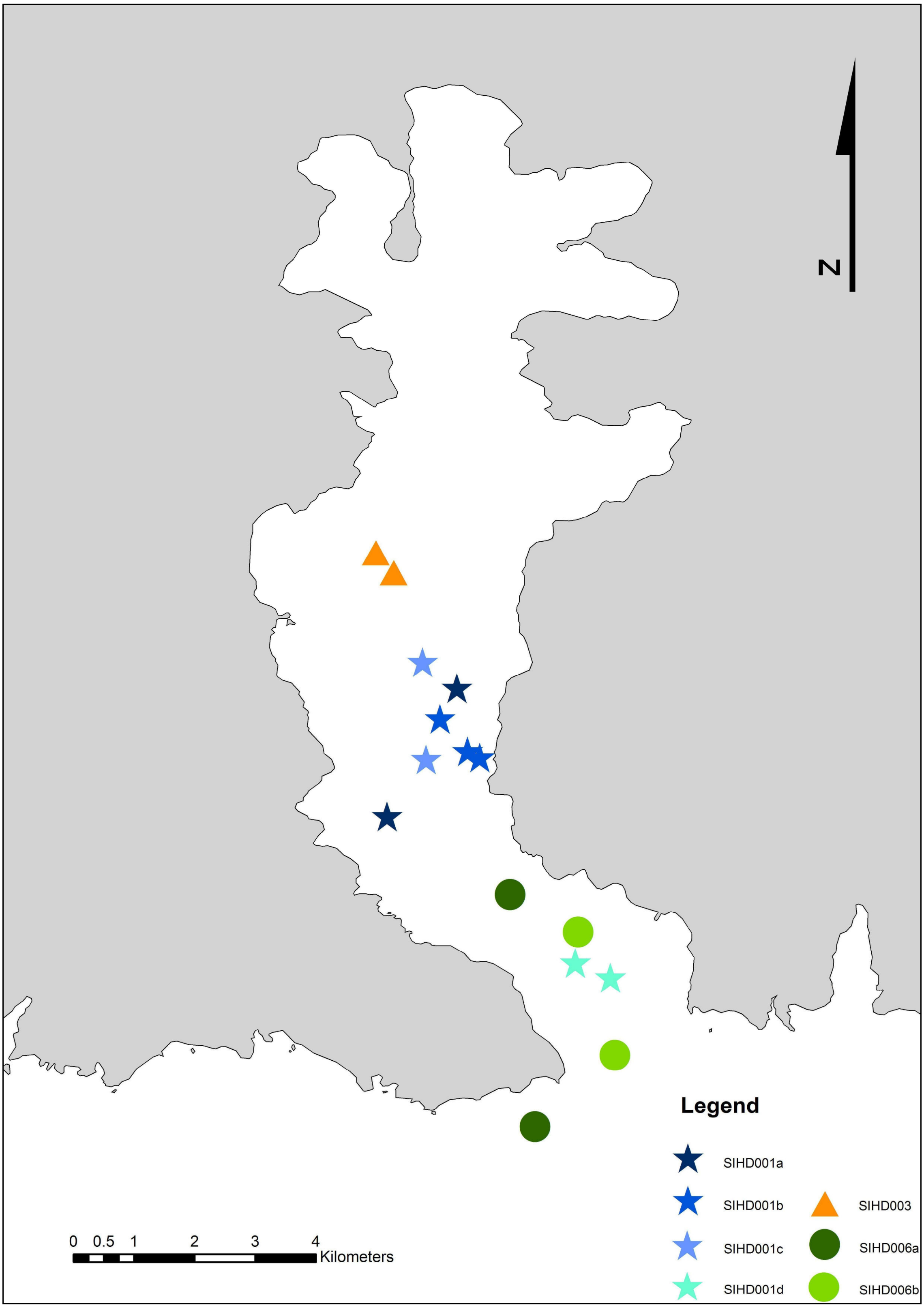


Fig. 7.10: Map showing the positions of sightings of three *frequent* users within Akaroa Harbour, New Zealand, made over consecutive days or with a maximum of two days apart. Note: Each *frequent* user is represented by a different symbol. Individuals that were sighted on separate occasions are symbolised by a different colour.

7.4.2.4. Estimated number of identifiable individuals using Akaroa Harbour between November and March

Discovery curve

The discovery curve indicates an increasing number of identifiable individuals over the study period (Fig. 7.11). The discovery rate of marked individuals was high during the first season in 2006/2007, with 82% (n = 41) of identifiable dolphins "captured" during that five-month period (Fig. 7.11). After the initial increase in the number of newly identified dolphins between November 2006 and January 2007, the curve suggests a slow but steady increase in the number of individuals being recruited. There is no plateau in the discovery curve, indicating that the sub-sample population is likely to be open or that the level of effort was not enough to capture all identifiable individuals. No account of emigration or mortality was made here (*i.e.* no individual was subtracted) because no case of death was confirmed).

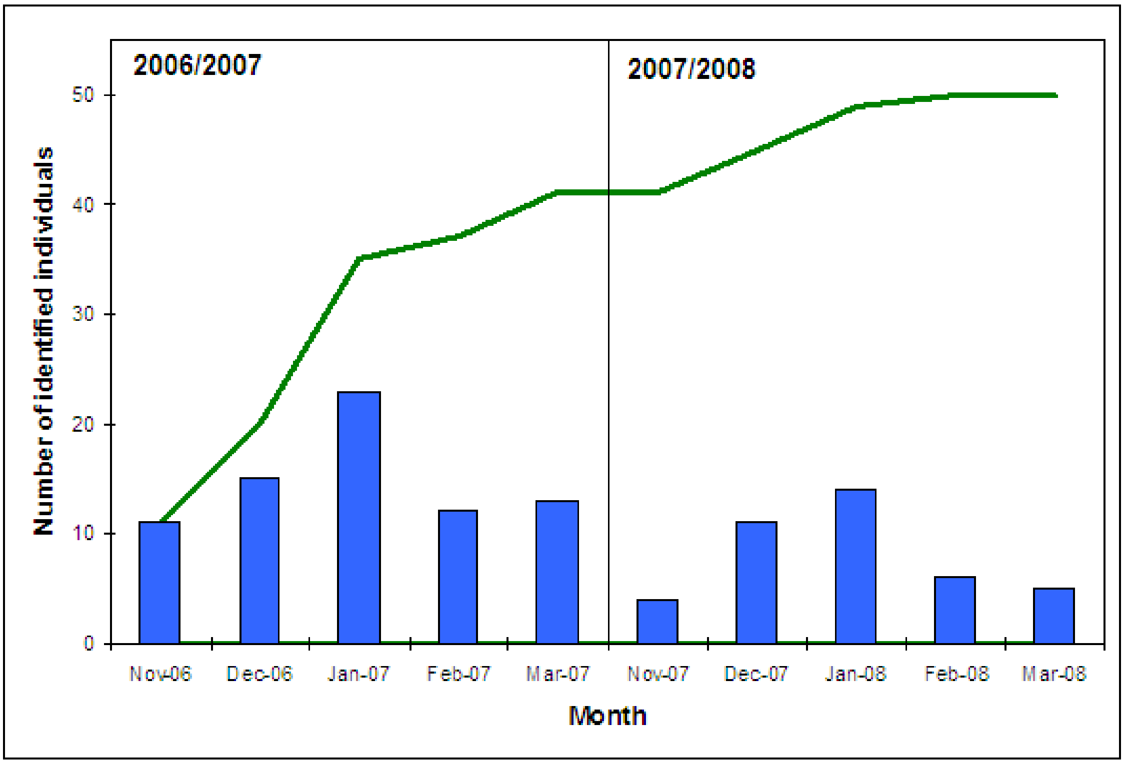


Fig. 7.11: Number of individuals captured during each sampling period and discovery curve for Hector's dolphins in Akaroa Harbour, New Zealand.

Assessing mark-recapture assumptions

a) Mark recognition

Out of 2,038 good- or excellent quality photographs, 3.9% (n = 79) were ranked as category I, 5. 3% (n = 107) as category II, and a further 14.2% (n = 290) as category III.

Mark loss

Apart from one dolphin (SIDH023; Fig. 7.12), none of the identifiable individuals presented changes to their nicks. SIDH023 was first encountered in 2006/2007 and subsequently not recaptured in 2007/2008. Consequently, as it acquired a new mark usable for photo-ID, it could not be counted as a mark loss or false-negative. The mark recognition and mark loss assumptions were, therefore, not violated.

Fig. 7.12: Photograph showing tissue damage and excessive loss along the trailing edge of the dorsal fin of individual SIDH023. This was probably caused by a shark attack. (Photo A.R.E.V.A. Project © 2007).

b) Behavioural response

Test 2.CT in U-CARE (behavioural effect to capture) revealed that there was no difference in the probability of being re-encountered at *i*+1 between individuals encountered (*i.e.* photo-identified) and not encountered (*i.e.* not photo-identified) at occasion *i*, conditional on presence at both occasions (two-sided, p = 0.138). This suggested that individuals were neither "trap-happy" nor "trap-shy". As such, the behavioural response assumption was not violated.

c) Heterogeneity of capture

Conversely, results from test 3.SR in U-CARE revealed that there was a significant difference in the probability of being re-encountered between the "new" and "old" individuals (two-sided p = 0.004). This implied that there was a transience effect in capture probabilities, with an excess of individuals sighted only once. The assumption of heterogeneity of capture was, therefore, violated and needed to be taken into account when running CJS models.

d) Geographic and demographic closure

Results from the closure test in CAPTURE confirmed that the sub-sample population was open with significant evidence of non-closure ($z = -6.545$, $p < 0.0001$).

Goodness of fit

Test 2.CL in U-CARE (*i.e.* time variation between re-encounters for captured and un-captured individuals) indicated that there was no difference in the expected time of next re-encounter between the individuals captured and un-captured at occasion *i* conditional on presence at both occasions *i* and *i*+2 (p = 0.617).

Results from test 3.SM in U-CARE (capture on survival) showed that there was again no difference in the expected time of first re-encounter between the "new" and "old" individuals encountered at occasion *i* and seen again at least once (p = 0.110). This suggested that there was no capture effect on survival over subsequent recaptures.

Best model selection

The best open model for the dataset with monthly pooling {φ(t)p(.)-Trans} (AICc = 298.727) took into account transiency, while capture probability remained constant over time (Table 7.8).

Monthly estimated abundance of marked animals from the CJS-transience model {φ(t)p(.)-Trans} indicated an increase in numbers until a peak was reached in January, followed by a decline (Table 7.9). This trend occurred over both seasons, although abundance estimates in general were lower in 2007/2008.

Table 7.8: AIC estimates from different CJS models when pooling data monthly. The best model is shown is bold, where φ = survival, p = probability of capture, t = variation in time, (.) = constant, and # para. = number of parameters. Note: Trans = transiency.

Model	AICc	Delta AICc	AICc Weights	Model likelihood	# para.	Deviation
{φ(t)p(.)-Trans month}	**298.727**	**0**	**0.758**	**1**	**5**	**166.286**
{φ(t)p(.)-Trans}	301.038	2.311	0.239	0.315	3	172.951
{φ(t)p(.)}	310.395	11.668	0.002	0.003	6	175.713
{φ(.)p(.)}	312.646	13.919	0.001	0.001	2	186.674
{φ(.)p(t)}	319.283	20.556	0.00003	0	10	175.180
{φ(t)p(t)}	320.989	22.262	0.00001	0	13	169.299

Table 7.9: Monthly estimates of abundance of marked Hector's dolphins in Akaroa Harbour, New Zealand, using a CJS-transience model. Note: $\hat{N}$ = estimated abundance, C.V. = coefficient of variation, Cap. p = probability of capture, S.E. = standard error of the mean, and C.I. = confidence interval.

Period	$\hat{N}$ (CV)	Cap. p	S.E.	95% CI
November 2006	n/a	n/a	n/a	n/a
December 2006	40 (0.207)	0.375	8.261	24 - 56
January 2007	61 (0.168)	0.375	10.230	41 - 81
February 2007	32 (0.231)	0.375	7.390	18 - 46
March 2007	35 (0.220)	0.375	7.691	20 - 50
November 2007	11 (0.388)	0.375	4.266	2 - 19
December 2007	29 (0.244)	0.375	7.075	15 - 43
January 2008	37 (0.216)	0.375	7.981	22 - 53
February 2008	16 (0.327)	0.375	5.225	6 - 26
March 2008	13 (0.205)	0.375	2.660	4 - 23

7.4.2.5. Potential exposure of identifiable individuals to vessel traffic

Percentage change

Comparison of the monthly percentage change between Hector's dolphins' estimated abundance of identifiable individuals and vessel traffic per hour during the season 2007/2008 revealed a very similar pattern (Fig. 7.13). As the number of estimated marked dolphins in Akaroa Harbour increased and then declined, so did the number of vessels per hour. For both variables, the biggest increase in percent change occurred between November and December (Fig. 7.13). Before starting to decline in February, both vessel traffic and estimated abundance continued to rise between December and January, but at a slower rate than observed between November and December (Fig. 7.13).

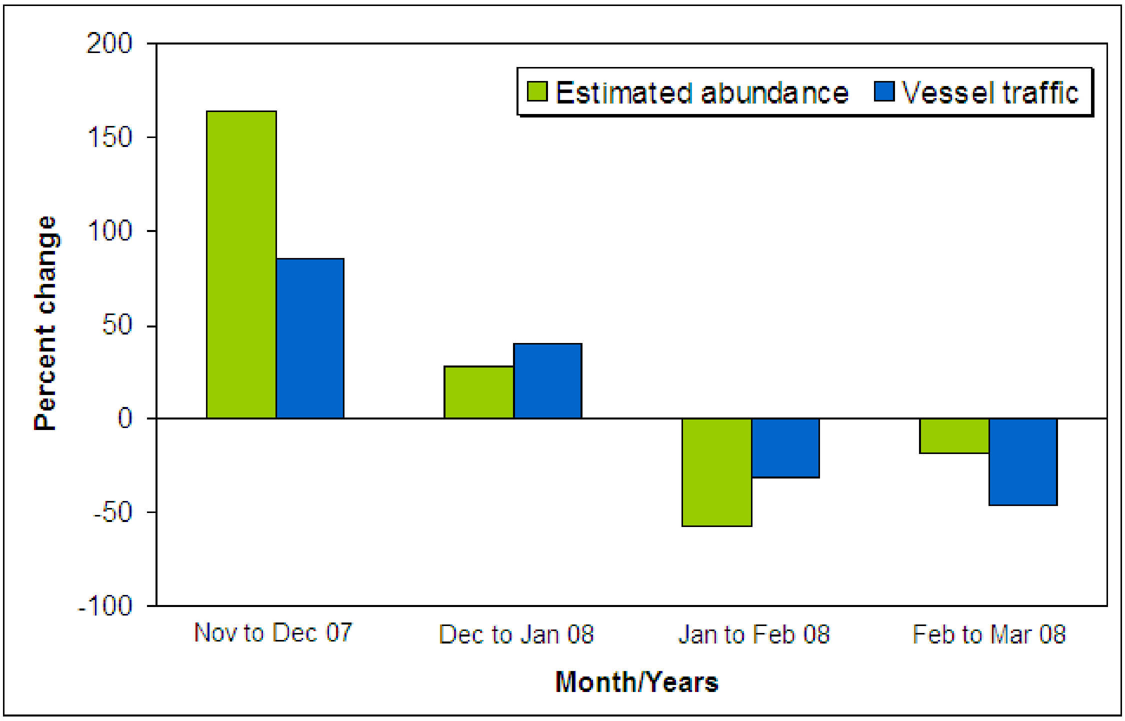


Fig. 7.13: Comparison between the monthly percent change in estimated abundance of marked individuals and vessel traffic per hour during the 2007/2008 season.

Optimal number of trips calculated using Baker's formulae (2004)

Allum (2009) estimated that the maximum daily trips in Akaroa Harbour should not exceed 25 based on Baker's formulae (2004). The author calculated that any individual Hector's dolphin would be typically exposed to a commercial vessel 1.01 times a day (Table 7.10). These figures are derived from the number of dolphins in the harbour, *i.e.* 62 (95% C.I. = 40 - 97; DuFresne *et al*., 2001), divided by the average mean group size for the Banks Peninsula area, *i.e.* 2.5 (Rayment *et al*., 2006).

Using the same approach and abundance data but with a mean group size of 3.2 (Chapter II) for Akaroa Harbour, the number of daily trips, according to Baker's formulae (2004), should not exceed 20 (or 19.4, range 12.5 - 30.3; Table 7.10). Until 2007, there were a maximum total of 25 permitted commercial trips per day targeting the dolphins. Based on that number and the average number of groups in the harbour (*i.e.* n = 19.4), dolphins were typically exposed to a commercial vessel 1.3 times a day (range = 0.4 - 8.5; Table 7.10); *i.e.* exceeding the recommended number exposure level of once per day. The addition of new permitted dolphin-watching trips in 2007 (Chapter I) will potentially increase the exposure level to 1.7 times per day (range = 0.5 - 10.8; Table 7.10).

When compared to two other delphinid species (dusky dolphins in Kaikoura and bottlenose dolphins in the Bay of Islands), the typical level of exposure experienced by Hector's dolphins as of 2007 is slightly above that reported in these other species (Table 7.10). According to Baker's formulae (*i.e.* the number of trips should not exceed the number of groups present), all three species are potentially exposed to more trips per day than should be allowed. Notably, in the Kaikoura case, only small groups were taken into account, although commercial tour operators tend to target mainly large groups (above 50 individuals; Markowitz *et al*., 2009a). Results presented here are, therefore, likely to be conservative for this species.

Extrapolation from commercial operators' effort

The identifiable individuals in the catalogue (n = 50) were sighted on average 3.6 trips (S.E. = 0.6, median = 2, range = 1 - 17). Using the median re-sight rate of two, it was estimated that Hector's dolphins in Akaroa Harbour are typically exposed to *ca.* 28 (inter-quartile range = 13.9 - 55.6) encounters between November and March (Table 7.11). The most frequently sighted individuals (SIHD001 and SIHD003), which are both females, were potentially exposed to *ca.* 237 commercial tourism tours (including both dolphin-watching and swim-with-dolphin trips) from November to March.

Table 7.10: Estimated exposure levels of different delphinids to commercial vessels in New Zealand waters using Baker's formulae (2004).

Species	Area	Max. number of permits/day	Population estimate (range)	Group size (range)	Approximate number of groups (range)	Average exposure (range)	Reference(s)
Hector's dolphins	*Akaroa Harbour prior 2007*	25	62 (40 - 97)	2.5 (1 - 3)	24.8 (16 - 39)	1.0 (0.4 - 1.2)	Rayment *et al*. (2006) Allum (2009)
		25	62 (40 - 97)	3.2 (1 - 21)	19.4 (12.5 - 30.3)	1.3 (0.4 - 8.5)	DuFresne *et al*. (2001) This study
	Akaroa Harbour after 2007	32	62 (40 - 97)	3.2 (1 - 21)	19.4 (12.5 - 30.3)	1.7 (0.5 - 10.8)	
Dusky dolphins	*Kaikoura Small groups only*	23†	132 (75 - 230)	7.7 (4 - 49)	17.1 (9.7 - 29.9)	1.3 (0.7 - 8.5)	Markowitz (2004), Markowitz *et al*. (2009a) †A. Baxter (pers. comm.)
Bottlenose dolphins	*Bay of Islands (2004)*	10‡	126 (120 - 132)	17.2 (1 - 60)	7.3 (7.0 - 7.7)	1.4 (0.1 - 4.8)	Tezanos-Pinto (2009) Constantine (2002)
	Bay of Islands (1998)	10‡	204 (191 - 217)	16.2 (2 - 50)	12.6 (11.8 - 13.4)	0.8 (0.1 - 2.5)	‡L. Boren (pers. comm.)

Table 7.11: Estimation of the total number of trips Hector's dolphins are exposed to between November and March in Akaroa Harbour, New Zealand.

Frequency of sightings	No. observed*	Extrapolated trips from operator's (effort)	Percentage of total trips exposed
1	19	13.9	0.4
2	9	27.8	0.8
3	9	41.7	1.2
4	3	55.6	1.6
5	1	69.5	2.0
6	2	83.4	2.4
7	1	97.3	2.8
8	2	111.2	3.1
13	1	180.8	5.1
16	1	222.5	6.3
17	2	236.4	6.7

* from a total of 254 photo-ID surveys (see section 4.1)

7.5. Discussion

The use of a commercial tour vessel as a platform for research and opportunistic photo-ID has been used with success historically and, despite some constraints, this type of platform offers several benefits (refer to Robbins and Matilla, 2000 for a review; Bejder and Samuels, 2003). Using photo-ID on a tourism platform allows researchers to identify individuals or particular sex/age classes of individuals that interact with the tour vessel and/or swimmers and, therefore, estimate exposure levels as well as usage pattern of an area (*e.g.* Constantine, 2001). This study constitutes the first attempt to identify and catalogue individual Hector's dolphin interacting with commercial dolphin-watching or swim-with-dolphin trips. Determining the number of individuals that never interact with commercial vessels was beyond the scope of this study, given that photo-identification was conducted opportunistically from commercial tour vessels.

Parameters of the sub-sample population using Akaroa Harbour

The resulting photo-ID catalogue for Akaroa Harbour suggests that mainly females (2.6 females to every 1 male) and most likely sexually-mature adults (*i.e.* above seven years old) are using the harbour and interacting with tourist vessels. These results are strikingly similar in terms of sex and age ratios to the larger and longer term BPHDP (3.2 females to every 1 male), an independent catalogue of Hector's dolphins around all of Banks Peninsula. Such a result may not be surprising given: a) the presence of nursery groups (Chapter II) in sheltered and shallower waters, which may make Akaroa Harbour a preferred habitat for females with young calves; and b) that the two individuals sighted most frequently during this study (SIDH001 and SIHD003) were both breeding females.

However, the difference in sex and age ratios observed in these catalogues is more likely an artefact of sampling bias. Female Hector's dolphins are more easily identifiable because of the assumption that the presence of a calf in close proximity to an adult results in the classification of that adult as a female. Using an underwater pole-camera, Webster *et al*. (2009) more accurately determined a 1:1 sex ratio of dolphins around Banks Peninsula. The authors further concluded that there was no sex bias in dolphins that preferentially engaged in bow-riding and suggested that different sexes did not behave differently when in close proximity to research vessels.

An additional limitation of photo-ID data are that the resulting catalogue can be biased towards older age classes, as young dolphins are less likely to be recognisable than older animals with more persistent and distinct marks (Würsig and Jefferson, 1990). Furthermore, the reproductive status of individuals is unknown until sighted with a calf or present in the catalogue for at least six years. Indeed, in the present study, no calves or juveniles were found to be marked and the majority of identifiable dolphins were at least 3-6 years old, findings consistent with previous Hector's dolphin catalogues (Slooten *et al.*, 1992; Green, 2003). Consequently, until these biases can be overcome, there is no clear evidence that either female or male nor juveniles or adult Hector's dolphins are exposed to more encounters with tour vessels.

The role of breeding females in population growth, however, is significant and the cost of stressors on the success of pregnancies can be devastating (Moberg and Mench, 2000). A link between dolphin-watching disturbance exposure and reproductive success and survival probability has now been described (Bejder *et al.*, 2006b). The authors detected a significant decline in dolphin abundance as the number of tour operators increased to two in Shark Bay, Australia. While the present study cannot draw conclusions regarding the potential impact of tourism activities on reproductive success, this remains an area of concern given the endangered status of Hector's dolphins. Despite the aforementioned limitations, photo-ID use on tour vessels did identify important trends in usage of the harbour and re-sightings.

Harbour usage

Re-sighting rates of Hector's dolphins are higher than previous studies (Webster and Rayment, 2006; Rayment, 2008), with 42% of identifiable individuals sighted only once, 50% between two and eight times, and 8% more than 10 times. Biases in previous photo-ID surveys on this species were often attributed to lower or limited survey effort (Webster and Rayment, 2006), and inshore/offshore movements and/or the stratification of the population with respect to distance offshore (Rayment, 2008). In the present study, however, an intense level of search effort (attributed to multiple daily tours) within a much smaller and restricted survey area reduced the likelihood of such bias.

Based on re-sighting rate presented in this study, Akaroa Harbour is clearly a preferred habitat of several individual dolphins, although there is no truly resident population within the harbour alone, confirming previous findings (*e.g.* Bräger, 1998a; Webster and Rayment, 2006). A high turnover, coinciding with the high variability in the number of dolphins sighted per encounter, also appears evident. However, some individuals that are observed within the harbour display a high degree of site fidelity, returning multiple times within a season and over multiple seasons. For example, female SIHD001 was sighted every month (with one exception) over both field seasons. According to Bräger *et al*. (2002), each individual was typically recorded in Akaroa Harbour over the austral summer for approximately two thirds (65%) of the number of years it was known to be alive.

Frequent or core users of the harbour displayed short-term movements over consecutive days, with most sightings in a four kilometre range. Bräger (1998a) also found that animals were often re-sighted within a very small area for a few days or travelled over small distances (mean = 11 km) over a day or two. These small daily movements occurred within a restricted (*ca.* 30 km) home range (Bräger *et al.*, 2002; Rayment *et al.*, 2009), which is similar to those reported for the other member of the *Cephalorhynchus* genus (Elwen *et al.*, 2006; Heinrich, 2006). Interestingly, the four main and well-defined summer hotspots identified around Banks Peninsula were each spaced approximately 30 km apart (Clement, 2005), correlating closely with individual site fidelity regions shown by Bräger *et al.* (2002) and Rayment *et al.* (2009).

Akaroa Harbour was one of the identified high-density hotspots (Clement, 2005), with a large proportion of identified dolphins also including Akaroa Harbour as part of their home range, and with half of these using the harbour as a core use area (Rayment *et al.*, 2009). Hector's dolphins with their home ranges centred at one of these hotspots would, therefore, only have limited overlap with conspecifics of the adjacent hotspot(s) (Rayment *et al.*, 2009). This type of community structure would have important implications for the management of the population (Bräger *et al.*, 2002). In terms of findings presented here, the presence of hotspots further implies that only a proportion of the Banks Peninsula population is exposed to intensive tourism pressure, given that most of the commercial tourism activities are concentrated in Akaroa Harbour (Chapter III). Furthermore, the continued presence of core users in the harbour further suggests that, as with the bottlenose dolphins in the Bay of Islands (Constantine *et al.*, 2004), individuals using the harbour as part of their home range are unlikely to discontinue using the area, even though they face an increasing exposure to human activities.

Mark rate

The estimated mark rate of 10.8% was similar to that previously reported for the Banks Peninsula population (12.5%: Slooten *et al.*, 1992; 10.5%: Gormley *et al.*, 2005; Webster and Rayment, 2006). The proportion of identifiable individuals estimated for Hector's dolphins in Porpoise Bay was much higher than at Banks Peninsula (between 36.9% and 46.8%; Bejder and Dawson, 2001; Green, 2003). However, because the Porpoise Bay population is considered closed, these studies included subtle marks, which resulted in a higher mark rate. Conversely, the Banks Peninsula population is open (DuFresne, 2005; Gormley *et al.*, 2005; this study), so inclusion of category III individuals (*i.e.* subtle marks) could have increased the likelihood of identification errors (DuFresne, 2005). Nonetheless, compared to other New Zealand delphinids, Hector's dolphins off Banks Peninsula have a comparatively low mark rate (Williams *et al.*, 1993; Constantine, 2002; Gormley, 2002; Markowitz, 2004; Merriman, 2007; Tezanos-Pinto, 2009; Stockin, unpublished data).

Estimated abundance of identifiable individuals using Akaroa Harbour

Photo-ID studies on the Banks Peninsula population have been previously used to estimate total population abundance (Gormley *et al.*, 2005). This study, however, concentrated on Akaroa Harbour, representing only part of the known Hector's dolphin home range and, therefore, does not constitute a resident, closed population. As such, total population abundance estimates for Akaroa Harbour were not attempted here, instead estimations of the monthly minimum number of identifiable individuals was used to assess the potential level of vessel exposure to Hector's dolphins.

The CJS model, selected here as the best model, did not assume geographical and demographical closure (*i.e.* the population is open), accounted for heterogeneity, and took into account the effect of transience. Monthly results indicated that the estimated number of identifiable individuals varied between November and March, and peaked in January with 61 and 37 identifiable individuals in 2006/2007 and 2007/2008, respectively. The decrease in number over the second season could be an artefact of the lower number of good quality photos used in the analysis, rather than an actual decrease in abundance. Nonetheless, this pattern coincided with a peak in sightings in the *inner* and *mid* part of Akaroa Harbour between January and February (Chapter II). This trend is consistent with previous research (*e.g.* Baker, 1984; Dawson and Slooten, 1988; Bräger, 1998; Clement, 2005; Rayment *et al.*, 2010), which indicates Hector's dolphins exhibit an inshore affinity from December until early April (Clement, 2005). This also corresponds to their documented mating and birthing season (Slooten and Dawson, 1994). This inshore movement is more apparent in the *inner* part of Akaroa Harbour where Hector's dolphins typically only occur between December and February (Dawson, 1991b; Chapter II).

Potential exposure to commercial tourism and vessel traffic

An important aspect for a population's conservation management is to determine the level of exposure individuals are subject to (Bejder and Samuels, 2003). Hector's dolphins using Akaroa Harbour as part of their home range, and in particular *frequent* users, can be exposed to high levels of vessel traffic between the months of November and March. In 2007, the maximum permitted number of swim-with-dolphin trips per day was 18, with an additional eight dolphin-watching trips, bringing the maximum total of permitted commercial trips per day to 25 (one operator is permitted to do two swim trips or two kayak trips or one of each, on a daily basis; Table 1.3). This equates to a maximum of 175 trips per week, including 119 swim-with-dolphin trips. In comparison, the maximum number of swim-with-dolphin trips per week in Kaikoura targeting dusky dolphins is 50 (Markowitz *et al.*, 2009a,b). Considering that Akaroa Harbour covers only 44 km^2 (plus an estimated 28 km^2 outside the harbour and within the permitted zone, where operators are most likely to operate during that time period), potential exposure to tourism activities is far greater than at Kaikoura (an area of operation of 235 km^2 until a 2009 extension[3]). In the Bay of Islands (an area of 240 km^2), there is a maximum of 70 permitted trips per week (L. Boren, pers. com.). Currently, the actual number of permitted daily trips used at Akaroa Harbour still far exceeds that of all other cetacean tourism locations operating in New Zealand. Prior to 2007 (when the maximum of daily trips was 25), the weekly number of trips between November and March was 133 (76% of maximum allowed). These included 42 dolphin-watching and 91 swimming tours, representing 64.4% and 75% of permitted trips, respectively. Full capacity is, therefore, not yet reached (Appendix 1.1), implying that exposure levels can still legally rise further in the future. This is particularly apparent, given that one of the recently permitted licences is still to begin operating (Allum, 2009).

Constantine (2001) estimated that a bottlenose dolphin in the Bay of Island was typically exposed to 32 swim attempts a year and with that level of exposure, individual dolphins had, with cumulative experience, become sensitised to swim attempts. In Akaroa, Hector's dolphins were exposed to an average of 28 separate encounters (inter-quartile range = 13.9 - 55.6) with commercial tours between November and March, and potentially up to 237 tours for the most sighted female (SIHD001). The majority (54%) of these commercial tours are swim-with-dolphin trips, which also have longer encounters (25 min) than dolphin-watching trips (9 min; Chapter III). In addition, the use of auditory stimulants during swim encounters significantly increased the likelihood of a more sustained interaction with the dolphins (Chapter VI).

Furthermore, commercial tour operators tend to head for the same area of the harbour if they had a good encounter/swim on their previous trip. "Handing over" of dolphin groups between vessels also occurred to some degree, particularly if an operator has more than one vessel in its fleet (Appendix 3.1). Based on such tactics, Nichols *et al.* (2001) estimated that Hector's dolphins in Akaroa Harbour could be collectively exposed to eight hours of vessel and/or swimmers per day due to staggered departure times. During the course of this study, Hector's dolphins were exposed to commercial tour vessels for prolonged periods throughout a busy day (up to 11 hours between

[3] http://www.doc.govt.nz/getting-involved/consultations/results/outcome-of-dusky-dolphin-tourism-review/

0600 hr and 1800 hr). The only time period when no commercial operator was offering a tour was between 0800 hr and 0900 hr owing to a gap in commercial activity (Chapter II). Swim-with-dolphin trips operate for up to ten hours per day in Akaroa Harbour compared to seven and a half hours in Kaikoura, where operators agreed upon a voluntary midday "rest period".

These findings suggest that Hector's dolphins in Akaroa Harbour currently have the longest sustained exposure time to tour vessels than any other species in New Zealand. From the present photo-ID study, it was estimated that 10% of Hector's dolphins in Akaroa Harbour were *frequent* or core users. As a result, cumulative exposure for some individuals can, therefore, be much higher, especially considering that 60% of core users were sighted on two different commercial trips within the same day, and another 60% on two consecutive days or more. SIHD001 sightings on three consecutive days were all within a kilometre. Core users may have not only repeated but also sustained interactions with both vessels and swimmers on a regular basis and, consequently, prolonged opportunities for potential habituation (*e.g.* Stone and Yoshinaga, 2000).

Finally, given that the most sighted individuals were typically spotted over the same time period over two successive years, exposure at an individual level is not expected to decrease with time. Markowitz (2004) argued that the seasonality in sightings of dusky dolphins in Kaikoura may function as an effective buffer against over-exposure to the effects of tourism. This is also likely to be the case for Hector's dolphins using Akaroa Harbour because exposure levels lessen over winter months. Indeed, the number of commercial tours per day is not as intense due to a reduction in both the number of permitted trips per day and passenger demand (Chapter 1, Table 1.3).

Appropriate tourism levels

Using an abundance estimate of 62 individuals in Akaroa Harbour at any one time (DuFresne *et al.*, 2001) and a mean group size of 3.2 (Chapter II), the recommended limit of trips per day in 2007 was calculated, using the Baker formulae, to be 20. This exceeds the current 25 permitted trips per day (as of 2007).

Additional permits issued in 2007 will potentially increase the number of trips per day to 32, or 70% higher than the threshold recommended by Baker's formulae (2004). When applying this formula to other species in New Zealand, the permitted number of daily trips in both Kaikoura and the Bay of Islands also exceeded the average number of groups in the area, although not to the same magnitude currently experienced by Hector's dolphins in Akaroa Harbour. In Kaikoura and in the Bay of Islands, the maximum number of trips should be reduced from 23 to 17 and from 10 to seven, respectively. This level of exposure is concerning given tourism activities have been shown to affect targeted species in both regions (*e.g.* Barr and Slooten, 1999; Constantine, 2002; Constantine *et al*., 2004; Markowitz *et al*., 2009a). In addition, a recent study has shown a trend of population decline for the bottlenose dolphin population in the Bay of Islands (Tezanos-Pinto, 2009).

There are, however, flaws associated with Baker's formulae (2004). This equation is simplistic and has no biological meaning. What is clear from previous research assessing the effects of tourism on cetaceans is that impacts vary greatly across species, locations and activities (*e.g.* Bejder *et al*., 1999; Nowacek *et al*., 2001; Lusseau, 2003a,b; Constantine, 2004b; Ribeiro *et al*., 2005; Bejder *et al*., 2006b; Richter *et al*., 2006; Stockin *et al*., 2008a; Williams *et al*., 2009). The formulae assume an even exposure or access to all groups present within an area. This study challenges that assumption because not all individuals frequent the harbour on a regular basis nor do they equally interact with the tour vessels. In addition, between January and February, groups that are found within the *inner* and *mid* part of the harbour (Dawson, 1991b; Chapter II), are more susceptible as they are within closer proximity to the Akaroa township, the wharf from which vessels operate (Chapters II and III).

Data describing population size (not always available) and average group size are necessary to apply these formulae. Different data can, therefore, lead to contradicting conclusions, as illustrated in this study. By using the average group size of 2.5 calculated for the entire Banks Peninsula region (Rayment *et al.*, 2006), 25 maximum daily trips were estimated (Allum, 2009). The majority of encounters occur within Akaroa Harbour (Chapter III). Consequently, this formula should only be used with a population estimate and average group size for this area, and not the whole peninsula.

Should managers decide to use Baker's formulae (2004), the maximum number of trips per day should be set at 20 and not 25, as previously suggested (Allum, 2009).

Clearly, simplistic formulae that attempt to provide a generic maximum number of trips are a poor approach to management. What is more appropriate is the use of empirical research, such as this study, to inform decision-making and to tailor permit numbers and conditions to the needs of the local targeted population. In the absence of such data, the precautionary principle, as suggested by many authors (*e.g.* IFAW *et al.*, 1995; Fennel and Ebert, 2004; Lusseau and Higham, 2004), should be applied, *i.e.* no permit should not be permitted until there is sufficient scientific data available to demonstrate that the targeted cetacean population would not be adversely affected by tourism activities (Lien, 2000).

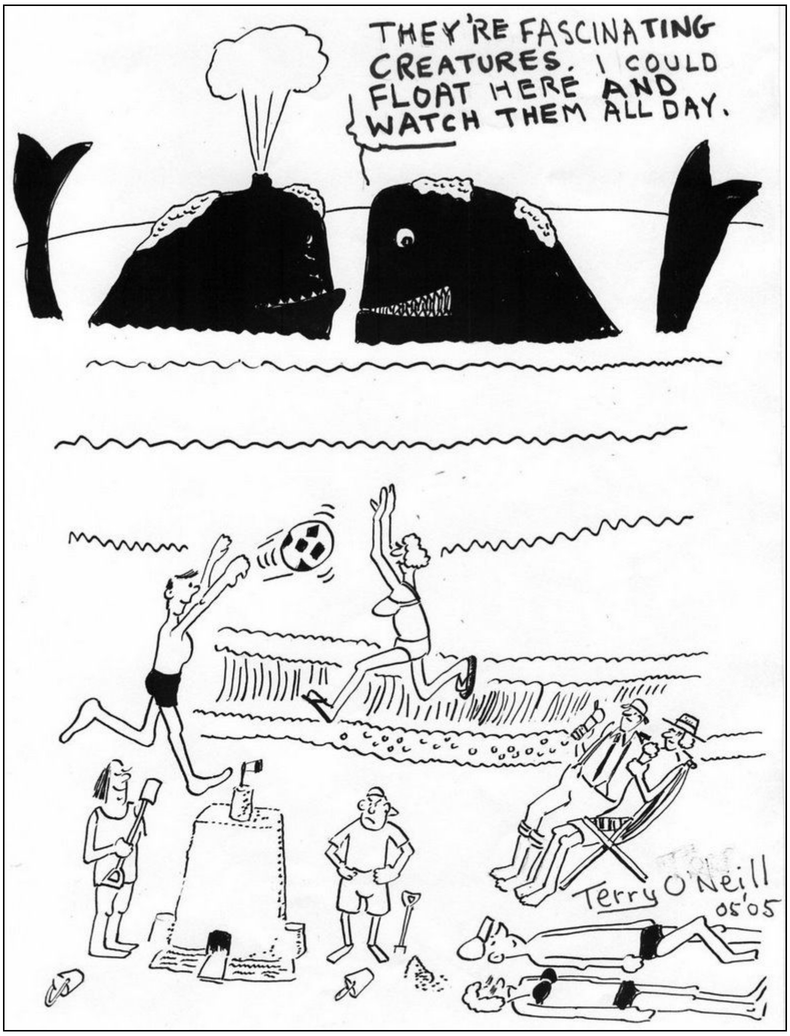
7.6. Conclusion

The endemic and endangered Hector's dolphins are important to the local tourism industry based in Akaroa Harbour, with commercial tourism operators targeting the species year-round. Findings reported here indicate that Hector's dolphins in Akaroa Harbour have the highest level of exposure to commercial marine mammal tourism activities in New Zealand, at least between the months of November and March. Hector's dolphins using Akaroa Harbour as part of their home range (Bräger *et al.*, 2002; Rayment *et al.*, 2009), in particular core users, could be particularly vulnerable, given previous studies in Porpoise Bay have shown that even low-level tourism can affect this species (Bejder *et al.*, 1999; Green, 2003). Exposure level on these core users, in particular females, is potentially a cause of concern given the role that they play in population growth (Moberg and Mench, 2000). Orams (2004) raised further concerns about the issue of stress and its long-term implications, which has been frequently overlooked in impact studies. Long-term stress could potentially reduce reproductive rates, immunity, and also reduce the biological viability of an individual or group of cetaceans (Lay, 2000). Furthermore, even though an individual can become more tolerant over time to a "stressor" associated with a human factor (*e.g.* tourism), such reduction in stress response can still lead to detrimental physiological effects over time (Walker *et al.*, 2006).

The maximum number of legally permitted trips has not yet been reached and, as a result, exposure levels may still increase for Hector's dolphins in Akaroa Harbour. As revealed in Chapter IV, current tourism activities in conjunction with vessel traffic within this area do affect the short-term behaviour of this species. Based on the findings in this study, it is recommended that no further increase in tourism activities be allowed in this region (*i.e.* maintain the moratorium), and that a reduction in current levels of exposure should be considered by managers for this particular population.

CHAPTER VIII

Summary and recommendations for dolphin tourism activities in Akaroa Harbour, Banks Peninsula



Chapter VIII draws on material that also appears in:
Martinez, E.; Orams, M.B.; Stockin, K.A. (2010). Responses of South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) to vessel activity in Akaroa Harbour, Banks Peninsula, New Zealand. Unpublished report to the Department of Conservation, Canterbury Conservancy, New Zealand. 187p.

8.1. Introduction

Akaroa Harbour is one of the two main hot-spots for cetacean-watching activities within South Island, New Zealand (O'Connor *et al*., 2009). Dolphin-watching and swim-with-dolphin tourism operations have occurred there since 1985 and 1990, respectively. The target species, the endangered and endemic South Island Hector's dolphin (*Cephalorhynchus hectori hectori*; Hector's dolphin hereafter), generates considerable tourism revenue for the local economy (Hoyt, 2001; Butcher *et al*., 2003; O'Connor *et al*., 2009). An unofficial moratorium on the number of permits was put in place in the 1990s by the Department of Conservation (DOC) due to the absence of baseline data and rigorous science investigating the potential effect of dolphin-watching and/or swimming with dolphins. As highlighted by Gales (1999), the management of cetacean-watching tourism often "has proceeded without clear scientific guidance". The author further states that "as is the case with most marine mammal/human interactions, the demand and growth of this industry has significantly outstripped the ability of scientists to develop and implement sufficiently sensitive tools that might provide some sound basis for management decisions."

In Akaroa Harbour, the precautionary principle, as recommended by the scientific committee on whale-watching at the International Whaling Commission (IWC, 2000, 2004), was consequently applied to protect the charismatic Hector's dolphin. At this point, however, there were already four operators targeting this species. This is important, given that even low-level cetacean-watching tourism can have both short- and long-term effects on a targeted population (*e.g.* Bejder *et al*., 2006a,b). The current permits in Akaroa, which allow up to 32 permitted daily trips, are due for review and potential renewal in 2012. DOC, the agency responsible for managing the industry, has received an increasing numbers of applications for tour operations to view and swim with Hector's dolphins, potentially expanding the number of permits by 78% and 57%, respectively (Allum, 2009). As a consequence, the research presented in this thesis will be useful for DOC, Canterbury Conservancy, as it provides a scientific basis for informed management of vessel-based dolphin tourism in Akaroa Harbour. This thesis, therefore, set out to make a significant scientific contribution by identifying and quantifying potential effect(s) tourism activities may have on this species. Presented here are the research findings of a study on the interactions between vessels/swimmers and Hector's dolphins in Akaroa Harbour as well as their applications and implications for management. Study limitations and future research are also discussed.

8.2. Summary of research findings

In revisiting the research objectives, a summation is provided before discussing the significance of the research findings.

Objective 1: Gather baseline and control data on the fine scale-distribution, behaviour and group dynamics of Hector's dolphins in Akaroa Harbour.

Prior to assessing the Hector's dolphin responses to viewing and swimming activities, it was important to collect baseline data in the absence of vessels and assess the level of vessel traffic that Hector's dolphins could be potentially exposed to in Akaroa Harbour. *Chapter II* provided important first data on Hector's dolphin behaviour, group composition, and density patterns during their peak occurrence in Akaroa Harbour (*i.e.* November to March). By understanding these factors, it was possible to begin to evaluate the effects of disturbance on Hector's dolphin using the harbour in the subsequent chapters. Sighting Per Unit Effort (SPUE) and calf sighting rate in Akaroa Harbour peaked in January, when dolphins were observed closer inside the harbour, corresponding with the known inshore movement of the species. SPUE was also higher in the *outer* harbour during January, as well as between 1000 and 1200 hours. Higher density patterns were also detected within Akaroa Harbour, namely between the Kaik Hill and the harbour entrance. Nursery groups were more likely encountered in the *outer* as opposed to the *inner* harbour, although, no distinct region within the area was associated with any particular behaviour nor with specific nursery areas.

While the majority of groups (92.1%) were composed of adults only and consisted of two to five individuals (83.2%), group size varied with dolphin behaviour, with larger groups typically observed socialising and smaller group sizes most frequently diving. Behavioural assessment in a *control* condition indicated that, excluding socialising, the dolphin behavioural budget in Akaroa Harbour was comparable with Le Bons Bay and Te Oka Bay, where there is low to no commercial tourism, respectively. Travelling was of notable importance, accounting for half of the activity budget, followed by diving (inferred foraging) and milling. The same difference in the activity budget of Hector's dolphins was detected in Akaroa Harbour between *control* and *distant* (*i.e.* vessels present but more than 300 metres away from the focal dolphin group) conditions.

Objective 2: Gather important information regarding vessel traffic within Akaroa Harbour, including actual traffic levels, periods of greatest effort by tour operators, encounter durations and locations.

Chapter III indicated that Akaroa Harbour is an important marine tourism destination, both commercially and recreationally. Consequently, vessel traffic levels are high (*i.e.* *distant* and *close* conditions), with Hector's dolphins rarely (14%) observed in the absence of vessels (*i.e.* under *control* conditions). *Staggered* tour vessel departure times likely exacerbate this situation. Diurnal and monthly variations in vessel traffic were apparent. Vessel traffic around Hector's dolphins was highest around midday, during weekends, and in the month of January, especially in the middle harbour. Harbour use was also not homogeneous, with vessels primarily concentrated in the middle harbour. The distribution of commercial vessels, as well as a peak in vessel traffic, coincided with that of the dolphins. However, no evidence of displacement was detected. This demonstrates that despite high vessel traffic, Hector's dolphins continue to use the harbour, supporting previous suggestions that the harbour represents a core habitat.

Commercial vessels have the greatest potential to affect Hector's dolphin behaviour, given that they represented 70.4% of encounters observed and interacted for twice as long with dolphins compared with recreational vessels (14.0 *vs.* 7.6 minutes). Association of Hector's dolphins was not analogous among the various vessel types. Dolphins were shown to associate longer with slower moving vessels (kayaks, sailing vessels, swim encounters) and avoid higher speed vessels. Finally, despite a high (91.7%) operator compliance to cumulative time restrictions, the common practice of "handing-over" a dolphin group potentially exacerbates dolphin exposure levels due to continuous contact.

Objective 3: To investigate the effect of vessel traffic and tourism activities on the behavioural budget of Hector's dolphins in Akaroa Harbour.

With an understanding of both the behavioural budget of this Hector's dolphin using Akaroa Harbour and the vessel traffic levels in Akaroa Harbour, *Chapter IV* evaluated the effects of vessel numbers and vessel type on Hector's dolphin behaviour. The use of land-based platforms proved to be an effective method to highlight disturbance. Vessel presence affected the activity budget of Hector's dolphins by changing transition probabilities, bout durations and the time taken to return to a behavioural state once disrupted. Overall, dolphins spent less time diving and travelling, and took longer to return to these behaviours as vessels approached. The reverse trends applied to milling and socialising groups. Hector's dolphins may compensate for high vessel traffic in the harbour by adjusting their behavioural budget, *i.e.* engaging less time in socialising in the absence of vessels and more time in diving (*Chapter II*). Alternatively, Hector's dolphins may have learnt over time to use the presence of vessels as a cue to find conspecifics, especially given that this species is very receptive to vessels, typically forming small groups (≤ five individuals) that display a high level of sex segregation. Travelling and diving are behaviours likely associated with foraging. As such, disruption of these states may potentially have long-term biological consequences for Hector's dolphins in Akaroa Harbour, particularly in terms of energy intake and foraging success. Furthermore, while no difference in the behavioural budget of dolphins was detected between commercial and recreational vessels, the addition of one or more vessels to an existing vessel further reduced time dolphins spent diving (or foraging). Finally, inter-species differences in behavioural responses reinforce the need to assess the impacts of cetacean-watching tourism activities on a case by case basis.

Objective 4: To assess the short-term effects of swim-with-dolphin encounters on Hector's dolphins and determine whether dolphins show any signs of habituation, sensitisation, or tolerance over time.

Akaroa Harbour is the only place in New Zealand where commercial operations can legally target Hector's dolphins for swim-with-dolphin tours. As a result, *Chapter V* examined the responses of Hector's dolphins to this type of activity. Although it was not possible to isolate those responses from the confounding effect of vessel presence, several differences were detected. The length of swim-with-dolphin trips varied in relation to the seasonal location of Hector's dolphins in the harbour, in accordance with data presented in *Chapter II*. Understanding that dolphin response to swim-with-dolphin trips is correlated with swimmer placement from the tour vessel, the number of successive attempts with a same group, dolphin group size and initial behaviour could explain why certain swim attempts were more successful than others. Approaching a large dolphin group engaged in milling or socialising for the first time using a *line abreast* or *around* method resulted in increased interaction time. In addition, Hector's dolphin behavioural budget differed in relation to vessel activity (viewing *vs.* swimming), the number of swimmers present in the water and *staggered* departure times.

Since Nichols *et al*. (2002) completed a preliminary study, swim encounter durations have increased on average by three minutes. Despite the fact that this Hector's dolphins in Akaroa Harbour have likely become more tolerant over time, they appear to display a temporal shift in their receptivity to swimmers during the austral summer months. Interaction time was longer in the mornings and in early summer (*i.e.* November and December), corresponding to a period with lower tourism activities and vessel traffic levels (*Chapter III*). When compared to other examined species within New Zealand waters, the receptivity of Hector's dolphins to contact with swimmers is further highlighted by a low mean number of swim attempts per trip (1.6), the high proportion of sustained and successful attempts (62.2%), and the duration of swim encounters (25.3 min). Finally, intra-species differences were also detected, in particular in relation to dolphin movements towards a vessel and/or swimmers, suggesting that Hector's dolphin receptivity and likelihood to approach increase as tourism activities get more and more established over time.

Objective 5: To assess whether the use of auditory stimulants during swim-with-dolphin encounters is affecting how dolphins interact with swimmers and discuss whether these could potentially disturb their natural activity patterns.

The effects of swim-with-dolphin trips reported in *Chapter V* could potentially be exacerbated by the use of auditory stimulants. In *Chapter VI* the effects of stones and other human-induced noise on Hector's dolphin behaviour was investigated and empirically quantified. The use of stones, in particular, significantly affected how dolphins interacted with swimmers. Specifically, swimmers who used stones had a greater probability of approaches by dolphins than those who sang or simply floated on the surface of the water. The number of close and sustained approaches was also significantly higher for swimmers using stones. Dolphins were also more interactive with active swimmers (*e.g.* duck diving), approaching closer and engaging for longer than with non-active swimmers. Dolphins socialising had a tendency to be engaged longer with swimmers, which is consistent with findings in *Chapter V*. The use of stones as an auditory stimulant to sustain or enhance interactions with dolphins by artificial means may, therefore, not be in the best interest of an endangered species, which already faces a range of challenges due to human activity.

Objective 6: To determine the level(s) of tourist-related interactions to which individual Hector's dolphins are potentially subjected.

Interactions between Hector's dolphins and commercial dolphin-watching and/or swimming vessels in Akaroa Harbour were identified for the first time at the individual level in *Chapter VII*. The use of photo-identification techniques proved to be effective for understanding the potential exposure level of this species at an individual level. A peak detected in the estimated number of identifiable individuals in January complements data presented in *Chapter II* and corresponds with the period when vessel traffic (both commercial and recreational) is at its highest level (*Chapter III*). Opportunistic photo-identification also indicated that the majority of identifiable individuals were either infrequently (46%) or occasionally (44%) captured interacting with commercial tourism vessels. This is consistent with previous research findings that there is no truly resident population within Akaroa Harbour. Individuals using

Akaroa Harbour are exposed to the highest level of cetacean-based tourism in New Zealand. This implies that *frequent* or core users of the harbour are likely to be more susceptible to intensive tourism pressure as a consequence of cumulative interactions. The high re-sighting rates confirm that Akaroa Harbour is a core habitat for some individual dolphins and further suggest that *frequent* users are unlikely to discontinue using the harbour, even though they face increased human disturbance. Finally, this study also stressed that while the management of anthropogenic effects on Hector's dolphins is essential for their conservation, appropriate scientific methods must be used on which to base management decisions.

Summary of objectives

This research study was unique, representing the first comprehensive assessment of the behavioural responses of the endangered and endemic Hector's dolphin to vessel traffic and vessel interactions in Akaroa Harbour. To achieve this aim, all objectives were linked in a logical manner in order to provide a more complete representation of the issue posed by tourism activities. Objectives 1 and 2 focused particularly on gathering baseline-data on Hector's dolphin and vessel traffic, respectively, which in turn allowed meeting objectives 3 and 4, *i.e.* assessing the short-term responses of Hector's dolphins to vessel and swimmers interactions. Finally, objective 5 addressed the issue, often overlooked, of the use of auditory stimulants during swim encounters, while objective 6 focused on determining the exposure levels at the individual level.

8.3. Significance and contribution of research findings

Meeting the objectives set by this thesis has led to a significant contribution towards a better understanding of the short-term responses of Hector's dolphins to tourism activities and, more specifically, to both watching and swimming commercial operations. Until now, research had primarily focused on populations subjected to low tourism levels in Porpoise Bay (Bejder *et al.*, 1999; Martinez *et al.*, 2002; Green, 2003) and at Timaru (Travis, 2008). Comparing preliminary work by Nichols *et al.* (2001, 2002) also permitted a longitudinal study, which detected signs of increased tolerance towards swim-with-dolphin encounters over time. Given that short-term responses associated with the current levels of tourism activities have been detected in Akaroa Harbour and are now better understood for Akaroa Harbour, DOC will be able to base future management decisions on stronger scientific merit to minimise the effects of tourism activities on this endemic and endangered species.

Other populations of Hector's dolphins are being targeted by commercial tourism operations around New Zealand (*e.g.* West Coast of the South Island and Marlborough Sounds), although research is yet to assess whether the tours provided at these locations are having any effect on the targeted populations. This study has emphasised intra-species differences in the responses of Hector's dolphins to vessel interactions, which are probably linked to cumulative exposure levels over time. Consequently, it has reinforced the need to manage each population separately in accordance with the IWC (IWC, 2000, 2004, 2006a,b) recommendations. In addition, there is now a broader spectrum of research findings available, *i.e.* from low to high levels of tourism activities for Hector's dolphin. This should help managers to draw strong influence from these documented sites and develop adequate adaptive management policies for commercial dolphin-based tourism and apply the precautionary principle: a) at locations where impact assessment is unavailable; and b) prior to the establishment of a commercial operation. For example, in the first case scenario, there is now enough evidence (Bejder *et al.*, 1999; Green, 2003; Martinez, 2003; this study) to support a moratorium on the dolphin-based tourism industry at any location. Such moratorium should remain in place until it can be demonstrated that the level of tourism activities has no effect that could be considered potentially detrimental to the targeted population. Should any effect detected be considered as non-disturbing, then managers could then permit an extra trip/permit using an integrative and adaptive management approach (Appendix 8.2).

This study has also resulted in an improved appreciation of the potential influence of the use of certain auditory stimulants during swim-with-dolphin encounters with Hector's dolphins, whose effectiveness was only reported anecdotally until now.

The topography around locations where commercial cetacean-watching ventures are operating can sometimes preclude the use of land-based platforms. In addition, financial constraints can also prevent researchers from using an independent research-vessel. This study has shown that the use of commercial tourism vessels as research platforms can still yield important information for tourism impact assessment studies (Chapters V, VI, and VII).

Finally, although the Banks Peninsula population of Hector's dolphins is the most comprehensively studied, what has not been documented until now, is the fine-scale distribution of these dolphins within Akaroa Harbour and their behavioural activity budget. Intra-species differences in activity budget between locations around the South Island of New Zealand highlights the fact that a generalisation of the species behavioural budget could be misleading. This is important for the management of this species because erroneous assumptions could ultimately result in inappropriate management decisions. Let us hypothetically assume, for example, that no *control* data could have been collected in Akaroa Harbour and data analyses had to be based on the activity budget in Porpoise Bay. Hector's dolphins in Porpoise Bay spent 70% of the observation time engaged in foraging (Green, 2003). The reduction in time spent diving detected in this study (Chapter IV) would have had even more severe implications for the dolphins in terms of energy acquisition. Such disparity reinforces once again the value of baseline data, the need to study each population independently and manage them as independent units.

8.4. Application of research findings and population management implications

The perception, at first, that cetacean-watching has no potential to alter the resources on which it is based, is now redundant. Research on short-term responses of cetaceans to vessels and/or swimmers is mounting (refer to Parsons *et al.*, 2006a,b; Scarpaci *et al.*, 2008, 2009, 2010, for reviews; Chapter I, section 1.2.4.4). While tourism levels (as of 2008) have been linked to short-term effects, it is difficult to infer biological significance and long-term effects of tourism from these responses (Bejder *et al.*, 2006b). The scarcity of studies with adequate controls or conducted over long-time periods can lead to the false, or at least early conclusion, that moderated behavioural responses to tourism activities have no long-term detrimental effects on the targeted populations (Bejder *et al.*, 2006b). The opposite may also be true. Although this study is the longest investigation into tourism effects on Hector's dolphins in Akaroa Harbour, it does not qualify as a long-term study because Hector's dolphins can live up to 20-25 years (*e.g.* Webster, 2008; *Chapter VII*). Due to the lack of baseline data prior to commercial activity in 1985, it is difficult to assess long-term changes quantitatively.

Although our understanding about the long-term effects of cetacean-watching is limited, it is now clear that this type of activity can affect the targeted populations in several ways, including displacement from their habitats, alteration of energetic budgets and biological parameters (*e.g.* Bejder *et al*., 2006a,b; Lusseau *et al.*, 2006a; Williams *et al*., 2006). It can even be argued that, in some cases, cetacean-watching has the possibility to introduce new evolutionary selection pressures and alter population dynamics (Bejder *et al*., 2006b). Even in circumstances where a link between short- and long-term consequences have not been established, it is important to take into consideration other more pressing human threats such as by-catch in fisheries or pollution. In comparison to these factors, cetacean-watching effects may appear "trivial" (Corkeron, 2004; Lusseau, 2007). When added to other human influences, however, tourism-related effects may be sufficient to prevent a population from recovering or tip that population towards further decline (Lusseau, 2004b). This is pertinent for the endangered Hector's dolphin, given that this species has a relatively limited home-range and high site fidelity (*e.g.* Rayment *et al*., 2009), its distribution is patchy (*e.g.* Clement, 2005), and populations are still in decline primarily as a result of by-catch in fisheries (*e.g.* Slooten, 2007). Consequently, effects of human activity will likely be amplified. Furthermore, dolphin-based tourism companies around Banks Peninsula, whether in Lyttelton or Akaroa Harbour, or even Le Bons Bay, have a limited range of operation (Allum, 2009). This implies that tourism efforts are concentrated on an even smaller number of individuals. Akaroa Harbour has also the highest number of permitted daily trips (32) compared to Lyttelton Harbour (16) and Le Bons Bay (2) (Allum, 2009). Individuals whose core habitat overlaps with Akaroa Harbour are, therefore, the most exposed to tourism and the most potentially at risk from the cumulative effects of human activities.

The regular presence of Hector's dolphins in Akaroa Harbour does not necessarily indicate that the current levels of tourism activities do not cause any detrimental effects to the dolphins. The peak in the tourism industry (December to February) coincides with the known calving period for this species. Furthermore, the harbour is one of the four core habitats for this population distributed around Banks Peninsula (Clement, 2005). While no evidence of displacement was detected, dolphins appear to respond behaviourally to minimise the effects, which is consistent with other studies (*e.g.* Williams *et al*., 2002a; Lusseau, 2003b). For individuals frequenting Akaroa Harbour waters, the costs of tolerance have, therefore, not yet exceeded the benefits of remaining in a preferred habitat. The displacement of more sensitive individuals (*e.g.* Bejder *et al*., 2006a,b) cannot, however, be ruled out given that the tourism industry has been operating for more than 25 years. The significant reduction in the proportion of time dolphins engaged in diving (foraging), while in the presence of vessels (< 300 m) is a concern, given that this behaviour is related to energy intake and, therefore, important for the long-term health of a population (*e.g.* Williams *et al*., 2006). Additionally, even though Hector's dolphins have become more tolerant of vessels and swimmers over the years, there is evidence of a potential seasonal sensitisation related to high levels of vessel interactions. Consequently, the short-term effects of vessel exposure on Hector's dolphins should be reduced, especially when taking into consideration other threats faced by the species.

The mitigation of adverse anthropogenic impacts on the Hector's dolphin is important. Being endemic, its protection is the sole responsibility of the New Zealand government. The multilateral discussions and agreements required for the conservation of more wide ranging species is not needed. New Zealand has legislation in place protecting cetaceans and is often considered, rightly or wrongly, to have a highly developed and carefully managed eco-tourism industry. Given that there is a good understanding of the demographics and distribution of this species, as well as a good knowledge of the threats it faces, effective measures can, therefore, be taken at a population level to ensure the conservation of this species. As a consequence of the research presented in this thesis, a series of management recommendations directed at contributing to the conservation and welfare of Hector's dolphins in Akaroa Harbour have been developed. These recommendations are detailed in Appendix 8.1.

8.5. Study limitations

One of the main challenges of tourism impact studies on cetaceans is the lack of baseline data. Tourism operations commenced in 1985 in Akaroa Harbour, which is approximately at the time when research on Hector's dolphin was initiated around Banks Peninsula. Although in this study, important baseline or *control* data could be collected from different land-based platforms, data collection occurred post-tourism. As a result, research findings do not necessarily reflect how dolphins truly behave in Akaroa Harbour in the absence of vessel traffic and tourism activities. This is evident at Banks Peninsula, wherein the behavioural budget of Hector's dolphins under *control* conditions differed between Akaroa Harbour and two other locations. In contrast, no differences in activity budget were detected between Le Bons Bay and Te Oka Bay given that tourism in those areas is low or non-existent, respectively.

This research has shown that Akaroa Harbour is a core habitat for some individuals and *frequent* users are unlikely to discontinue using the harbour, despite high levels of tourism activities. In addition, Hector's dolphins do not appear to be yet habituated to swim-with-dolphin interactions, in particular. However, it is also important to consider the possibility that less tolerant individuals might have already been displaced since the implementation of commercial tourism operations in the mid-1980s (*e.g.* Bejder *et al.*, 2006a). This implies that this research would only have measured the responses of more tolerant individuals using Akaroa Harbour at the time of sampling.

Another challenge in researching the effects of cetacean-watching on targeted species is to design studies that isolate the effects of tourism. In Akaroa Harbour, all swim-with-dolphin trips are run from a vessel platform and not from the shore. As such, the effects of swimmers on the short-term responses of Hector's dolphins detected in the present study could not be isolated from the confounding effect of vessel presence.

Controlled experiments allow for data collection under both control and experimental exposures while minimising confounding influences of different variables, facilitating the interpretation of results (Bejder and Samuels, 2003). An experimental design was implemented to assess whether the use of auditory stimulants might affect how Hector's dolphins interact with swimmers (Chapter VI). Permission to conduct such experiment, however, was only given for the first ten minutes of a swim-with-dolphin trip by tour operators, rather than the entire encounter. Only opportunistic observations for the whole duration of encounters were used for analysis purposes because the short-time period of ten minutes limited the detection of trends (Martinez, unpublished data).

Land-based studies using a theodolite have now widely been used on a variety of cetacean species in New Zealand (*e.g.* Barr and Slooten, 1999; Richter *et al.*, 2006; Lundquist and Markowitz, 2009), being an appropriate choice for small, coastal species such as Hector's dolphins (*e.g.* Bejder *et al.*, 1999; Nichols *et al.*, 2001; Green, 2003; Martinez, 2003; Travis, 2008). The method has the advantage of not having any effect on the population of interest (Bejder and Samuels, 2003) and to collect *control* data. However, there are some limitations associated with theodolite tracking. Firstly, an error in theodolite elevation can result in a position error (Würsig *et al.*, 1991). Most stations in this study were 100 metres or more above sea level. The majority of dolphin groups were observed within 2.5 kilometres from the stations. Consequently, an error of +10 centimetres (error margin in elevation measurement of the instrument) at a height of 100 metres would cause a position error of one metre at a range of 500 metres and two metres at 2,500 metres (Würsig *et al.*, 1991). The height and position of the theodolite were measured using a Trimble GeoExplorer III GPS receiver with a calculated error margin of ± 0.2 metres (a total of six points were measured and average taken). This type of error is not considered to have affected the results of this study.

Secondly, the distance between the theodolite station (or observer) and the targeted species cannot be controlled. As a result, range can become an important factor in estimating group size and observing behavioural patterns (Elwen *et al.*, 2009). In this study, the proportion of sightings decreased significantly with distance, resulting in a cut off point at two kilometres from each station. This implies that although the majority of Akaroa harbour was clearly visible from the different stations, parts were not taken into account in the distribution analyses.

Finally, some behavioural events described in Slooten (1994) such as *copulation with intromission noted* or *penis out*, are difficult to observe from land. Recording behavioural states rather than events, coupled with a cut off point mentioned above, limited the mis- and over-representation of some behaviours.

8.6. Recommendations for future research

This study has demonstrated that the current level of tourism in Akaroa Harbour is having short-term effects on the Hector's dolphins frequenting harbour waters. In order to ensure the sustainability of tourism activities in the long-term at that location and on Hector's dolphins in general, several proposed areas of research have been identified.

Firstly, it is vital to continue the monitoring of potential effects of vessel activity on Hector's dolphins given that longitudinal studies are indeed essential in detecting any potential long-term detrimental biological impacts. Permits to view and swim with Hector's dolphins in Akaroa Harbour undergo renewal every five to ten years. A scientific monitoring scheme should, therefore, be undertaken regularly, prior to and post a renewal and/or any management scheme revision, allowing comparison with previous research findings. Any management decision regarding permits and its efficiency would then be based on sound scientific information. This process is part of a long-term integrated and adaptive approach to tourism management (refer to Appendix 8.2), which has been recommended to reduce the pressure and responses of Hector's dolphins to both vessels and swimmers. Furthermore, experimental designs would also be very valuable in evaluating issues associated with tourism activities, wherein situations can be manipulated by a researcher to optimise data collection (*e.g.* assessing responses of Hector's dolphins to vessel manoeuvring and/or swimmer placement). Such experimental designs could be implemented on different Hector's dolphin populations to confirm whether this species tolerance towards vessels and/or swimmers increases as exposure to vessels and tourism intensifies.

Secondly, photo-identification from both research and opportunistic platforms should form part of the scientific monitoring scheme. It is also important that such research is conducted in areas outside Akaroa Harbour (*i.e.* within the minimum known range of the species). This will allow a better understanding of the tolerance levels of identifiable individuals (*e.g. frequent vs. infrequent* users) to vessel interactions. Tolerance level assessment should be supplemented by individual focal follows using independent research platforms. Such follows will allow determining the exposure levels identifiable individuals are subjected to by: a) using Before/During/After analyses; b) by calculating time between interactions with vessels and/or swimmers; and c) time taken to return to a previous behavioural state. Data could then be implemented in a model framework developed by Lusseau *et al*. (2006b; see below)

Thirdly, not all populations of Hector's dolphins are exposed to the same level of vessel traffic and tourism activities. Akaroa Harbour represents the extreme spectrum of the tourism scale with 32 legally permitted daily trips. Due to the genetically fragmented population structure of the species (Pichler *et al*., 1998; Hamner *et al*., 2009), each population needs to be managed as a separate unit. An intra-species assessment of behavioural budgets and responses to tourism activities is, therefore, required. Should similar responses be reported (*e.g.* in transition probabilities across behavioural states; Chapter IV), these could further assist the management of the tourism industry where no data are available and permit applications have been lodged to target the species.

Fourthly, the effects of man-made noise on both Hector's dolphins and their prey should be investigated. While tourism activities contribute to the rising sound levels in the oceans, few studies have focused on quantifying sound produced by tour vessels and assessing their effects on cetaceans (Martinez and Orams, in press). This can be surprising given that marine organisms use sound and acoustic energy sensors to adapt to their environment (*e.g.* Stocker, 2002). Man-made sound (from engine noise to the use of sonar systems for navigations, depth and fish finders) covers the frequency bandwidth that most marine vertebrates use (Stocker, 2002). It is, therefore, possible that the reduction in the dolphin foraging activity in the presence of vessels detected in many studies (*e.g.* Williams *et al.*, 2006; Dans *et al.*, 2008; Stockin *et al.*, 2008a; Christiansen *et al.*, 2010) may be linked to underwater noise (*e.g.* maskingnoise), warranting further research using experimental designs. Moreover, sound generated by cetacean-watching operations and vessel traffic in Akaroa Harbour should be recorded in order to determine whether these should be considered “loud or disturbing” (*e.g.* causing temporary threshold shift in hearing; Erbe, 2002), breaching section 20(d) of the MMPR. The incidence of tail-slaps during swim-with-dolphin encounters should also be examined, while taking into consideration both swimmer activities and underwater noise level.

Fifthly, this study established that banging stones underwater had a significant effect on the type and length of interactions between Hector’s dolphins and swimmers. An explanation as to why the use of stones resulted in more approaches was beyond the scope of this study. Acoustic experimental designs could, therefore, be implemented to investigate this further. The vocal repertoire of Hector’s dolphin is considered relatively simple, consisting almost exclusively of ultrasonic clicks (Dawson, 1991a). Arguably, tapping stones together underwater more likely resembles dolphin clicks than does singing given that it is likely to fall within the frequency band of the species clicks. Intra- and inter-species comparisons could also be considered, for example: a) Hector’s dolphins not previously exposed to the use of stones *versus* dolphins in Akaroa Harbour; and b) species with a vocal repertoire consisting of clicks and whistles (*e.g.* common dolphins *Delphinus* sp.; Ansmann *et al.*, 2007; Petrella *et al.*, in press) *versus* species using clicks almost exclusively (*e.g.* Harbour porpoises *Phocoena phocoena*; Carlström, 2005). Furthermore, auditory stimulants are also used with other delphinid species around New Zealand. How these influence interactions between dolphins and swimmers is unknown, warranting further investigation.

Finally, the energetic budget of Hector’s dolphins should be investigated to better understand the relationship between short-term effects and potential long-term consequences (*e.g.* Williams *et al.*, 2006). Furthermore, the Banks Peninsula population is the most comprehensively studied, spanning over *ca*. 25 years, providing data that can be applied for modelling (*e.g.* Martien *et al.*, 1999; Slooten, 2007). Lusseau *et al.* (2006b), for example, developed a model framework in which the implication of long-term effects of tourism activities can be explored and applied to many species and locations. This model framework is hierarchical in its nature. More complex relationships can, therefore, be added as data become available (*e.g*. the effects of the length of interactions, the behaviour of vessels during interactions, or physiological ecology). The influence of uncertainty relating to the relationships between vessel exposure and cetacean-watching can also be incorporated by randomising these components of the model (Lusseau *et al*., 2006b). The application of such framework is an avenue worth exploring for Hector's dolphins.

Finally, effort should also concentrate on investigating the use of various auditory stimulants and how they may influence how dolphins interact with swimmers in other areas around New Zealand and on different species. The frequency band and noise level of auditory stimulants known to be used during dolphin encounters should be recorded in order to determine whether these should be considered "loud or disturbing", breaching section 20(d) of the MMPR. The incidence of tail-slaps during swim-with-dolphin encounters should also be examined, while taking into consideration both swimmers' activity and underwater noise level.

8.7. Concluding statement

Dolphin-based tourism in Akaroa Harbour can play an important role in increasing the public awareness and education about the plight of the endemic and endangered Hector's dolphin. The sustainability of dolphin-based tourism is also vital, not only for the Hector's dolphin welfare and conservation, but also to the local, regional, and even national economy. Unlike other cetacean species targeted by the tourism industry in New Zealand, this delphinid is both endemic and endangered. New Zealand is, therefore, solely responsible for its *kaitiakitanga* or guardianship. "There comes a moment when we all have to choose between doing what is easy and doing what is right" (Obama, 2009[1]).

[1] "This is the moment we have been waiting for" speech given in August 2009.

IX REFERENCES

The scientist is not a person who gives the right answers,
(s)he is one who asks the right questions.

Claude Levi-Strauss (1908-2009)

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X APPENDICES

Photos: Areva Project, © 2005.

APPENDIX 1.1: Number of permitted daily trips used by commercial tour operators in Akaroa Harbour, Banks Peninsula

To determine whether commercial tour companies based in Akaroa Harbour were operating at full capacity (*i.e.* the maximum number of permitted daily tours is reached), the total number of trips conducted each month was calculated for the different dolphin-watching and swimming companies, using data provided by the Department of Conservation (DOC). The percentage of trips used in relation to the maximum number of permitted trips was then determined from November to March (Fig. A). In 2007, three more permits were granted, although one company had yet to commence operation. Consequently, the percentage of permits used was assessed across three time periods to reflect differences in the number of operators and maximum trips allowed. The post 2008 period is an approximation. It was assumed that the new operator would use the same percentage of trips each month as other dolphin-watching companies.

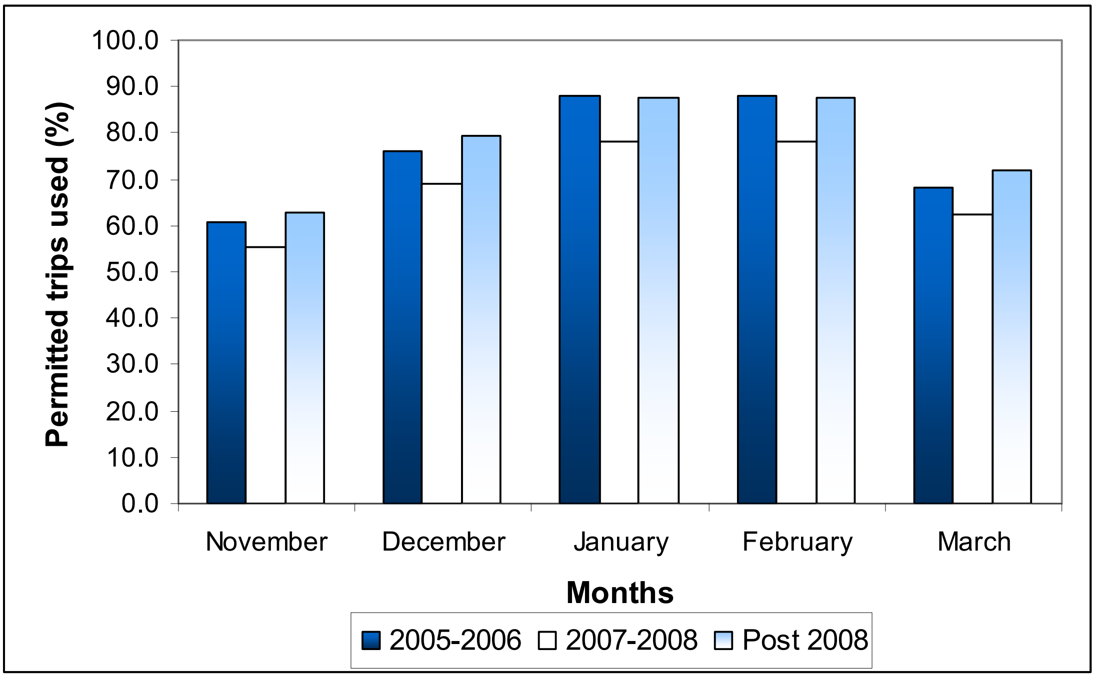


Fig. A: Percentage of permitted trips used by all commercial operators per month in Akaroa Harbour, Banks Peninsula, New Zealand, from 2005 onwards. Note: the post 2008 period is an approximation.

APPENDIX 1.2: Number of visitors participating in a dolphin-watching or swimming-with dolphin tour in Akaroa Harbour, Banks Peninsula

Until 2006, all commercial tour operators in Akaroa Harbour had to provide an annual summary of their activity to DOC, Canterbury Conservancy. From 2006 onwards, a new system was put in place but data on the total number of passengers participating in a commercial tourism activity was more difficult to calculate. Consequently, data provided by DOC (Allum, pers. comm.) only cover the period from 2000 to 2006 only (Fig. B).

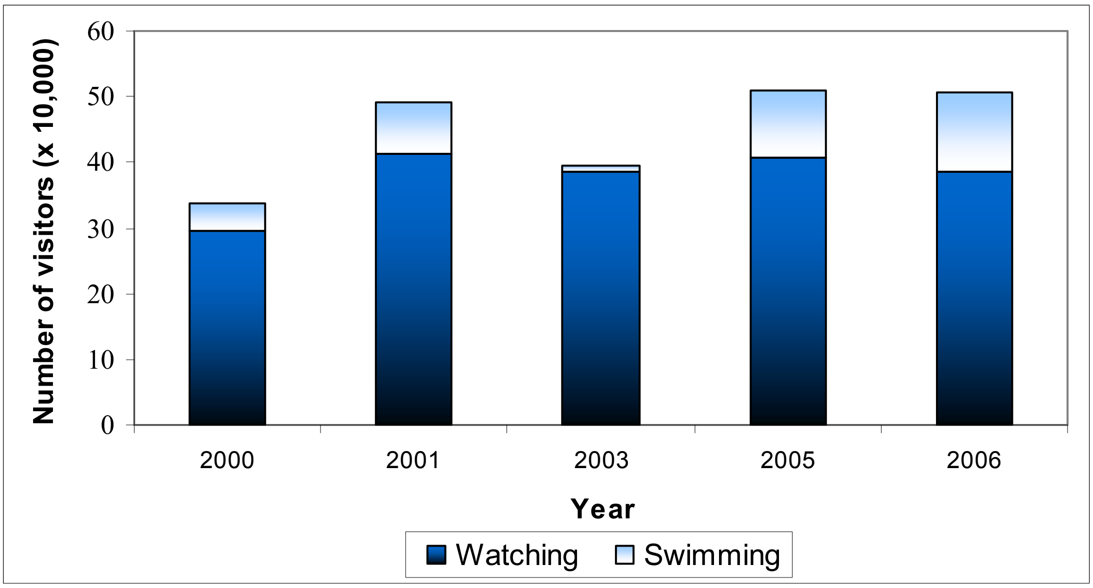


Fig. B: Number of visitors participating in a dolphin-watching or swimming-with-dolphin tour from 2000 to 2006 in Akaroa Harbour, Banks Peninsula, New Zealand.

APPENDIX 1.3: Relevant sections of the Marine Mammals Protection Act (1978)

3A. Department of Conservation to administer marine mammals and sanctuaries

- The Department of Conservation shall administer and manage marine mammals and marine mammal sanctuaries in accordance with—
  - (a) Any statements of general policy approved under section 3B of this Act; and
  - (b) Any conservation management strategy and any conservation management plan for the time being in force for the area concerned.

4. Restrictions on taking marine mammals

(1) Notwithstanding anything in any other enactment, but subject to this Act, no person shall—

- (a) Hold a marine mammal in captivity; or
- (b) Take any marine mammal, whether alive or dead, in or from its natural habitat or in or from any other place—

without first obtaining a permit to do so from the Minister or from any person or persons authorised in that behalf by the Minister.

(1A) The Minister may from time to time, by notice in the *Gazette*, prescribe criteria and standards in respect of any kind of permit referred to in subsection (1) of this section; and the prescribed criteria and standards shall be deemed to form part of permits of that kind and shall be complied with accordingly.

(2) Subject to section 5(3) of this Act and to any regulations made under section 28 of this Act, no person shall import into New Zealand or export from New Zealand any marine mammal or marine mammal product except pursuant to a permit issued under this Act.

(3) Nothing in subsection (2) of this section shall apply with respect to any whale product the subject of an order made under section 54 or section 56 of the Customs and Excise Act 1996.

(4) [Repealed]

(5) A permit shall not be required—

- (a) By any person who finds or collects bones, teeth, ivory, or ambergris that have already separated naturally from a marine mammal if that person, as soon as practicable, notifies the Director-General or an officer of the find, and gives details of the time, place, and circumstances under which the find was made:

- (b) By any person who finds any dead marine mammal or part of one and, if authorised to do so by an officer and acting pursuant to his directions, sends the mammal or part to the Department of Conservation or to any approved research establishment, laboratory, or public museum:
- (c) By any person taking from or bringing into New Zealand any marine mammal product, being an ornament or an item for personal use or adornment made wholly or principally from any part or parts of a marine mammal, if the marine mammal product accompanies that person from or into New Zealand or comprises part of that person's belongings and was in existence in a similar form as at the commencement of this Act.

7. Conditions of permit

- (1) Subject to such conditions as may be prescribed by regulations made under this Act, the Minister may attach to any permit such conditions as he thinks fit, including conditions relating to—
    - (a) The taking of marine mammals solely for the purpose of research:
    - (b) The taking of marine mammals to be held in zoological gardens or aquaria or other places of a similar nature for observation by the public under such conditions as may also be specified in the permit:
    - (c) The methods by which any species of marine mammals may be managed:
    - (d) The boats, gear, equipment, and methods to be used in taking any marine mammal:
    - (e) The payment of a deposit or fee not exceeding such amount as may be prescribed by regulations made under this Act in respect of any marine mammal:
    - (f) The entering into of a bond in favour of the Crown, either with or without sureties, for such amount as the Minister thinks will give

security for the performance by the permit holder of any obligation incurred under this Act or the permit:

- (g) The records that are to be kept by the permit holder in relation to any marine mammal, and any information which is to be supplied to either the Minister or the Director-General.

(2) Any permit may be revoked and the conditions attached to it amended at any time by the Minister or by any person authorised by him.

(3) No permit shall be transferred to any other person except with the consent in writing of the Minister.

22. Marine mammal sanctuaries

- (1) Subject to this section, the Minister may, by notice in the *Gazette*, define any place and declare it to be a marine mammal sanctuary, and may in like manner, after considering any submissions in writing he may have received within 28 days after the date of publication of a notice in the *Gazette* indicating his intention, vary, redefine, or abolish the sanctuary.

(2) Where any other Minister of the Crown has the control of any Crown-owned land, foreshore, seabed, or waters of the sea which is declared to be a marine mammal sanctuary or which forms part of one, the consent of that Minister to the declaration shall be notified concurrently with the notice given under subsection (1) of this section.

(3) When defining and declaring a sanctuary under this section, the Minister may specify the activities that may or may not be engaged in within the sanctuary, and may impose restrictions in respect of the sanctuary.

(4) No marine mammal sanctuary shall be declared in any Maritime or National Park, in any reserve within the meaning of the Reserves Act 1977, or in any marine reserve declared under the Marine Reserves Act 1971.

(5) Every constable, and every ranger appointed under section 38 of the Wildlife Act 1953, section 27 of the National Parks Act 1952, or under section 8 of the Reserves Act 1977 shall have the authority to exercise any of the powers conferred on a ranger under section 39 of the Wildlife Act 1953 in any marine mammal sanctuary.

APPENDIX 1.4: Relevant sections of the Marine Mammals Protection Regulations (1992)

PART III – Behaviour around marine mammals

17. Application of this Part

18. Conditions governing commercial operations and behaviour of all persons around any marine
mammal

19. Special conditions applying to whales

20. Special conditions applying to dolphins or seals

R. 17. Application of this part

Nothing in regulation 18 or regulation 19 or regulation 20 of these regulations shall apply to persons, vessels, aircraft, or vehicles rendering assistance to stranded or injured marine mammals.

R. 18. Conditions governing commercial operations and behaviour of all persons around any marine mammal

Every commercial operation, and every person coming into contact with any class of marine mammal, shall comply with the following conditions:

(a) Persons shall use their best endeavours to operate vessels, vehicles, and aircraft so as not to disrupt the normal movement or behaviour of any marine mammal

(b) Contact with any marine mammal shall be abandoned at any stage if it becomes or shows signs of becoming disturbed or alarmed

(c) No person shall cause any marine mammal to be separated from a group of marine mammals or cause any members of such a group to be scattered

(d) No rubbish or food shall be thrown near or around any marine mammal

(e) No sudden or repeated change in the speed or direction of any vessel or aircraft shall be made except in the case of an emergency

(f) Where a vessel stops to enable the passengers to watch any marine mammal, the engines shall be either placed in neutral or be switched off within a minute of the vessel stopping:

(g) No aircraft engaged in a commercial aircraft operation shall be flown below 150 metres (500 feet) above sea level, unless taking off or landing

(h) When operating at an altitude of less than 600 metres (2000 feet) above sea level, no aircraft shall be closer than 150 metres (500 feet) horizontally from a point directly above any marine mammal or such lesser or greater distance as may be approved by the Director-General, by notice in the Gazette, from time to time based on the best available scientific evidence

(i) No person shall disturb or harass any marine mammal

(j) Vehicles must remain above the mean high water spring tide mark and shall not approach within 50 metres of a marine mammal unless in an official carpark or on a public or private slipway or on a public road

(k) No person, vehicle, or vessel shall cut off the path of a marine mammal or prevent a marine mammal from leaving the vicinity of any person, vehicle, or vessel

(l) Subject to paragraph (m) of this regulation, the master of any vessel less than 300 metres from any marine mammal shall use his or her best endeavours to move the vessel at a constant slow speed no faster than the slowest marine mammal in the vicinity, or at idle or "no wake" speed

(m) Vessels departing from the vicinity of any marine mammal shall proceed slowly at idle or "no wake" speed until the vessel is at least 300 metres from the nearest marine mammal, except that, in the case of dolphins, vessels may exceed idle or "no wake" speed in order to outdistance the dolphins but must increase speed gradually, and shall not exceed 10 knots within 300 metres of any dolphin

(n) Pilots of aircraft engaged in a commercial aircraft operation shall use their best endeavours to operate the aircraft in such a manner that, without compromising safety, the aircraft's shadow is not imposed directly on any marine mammal.

R. 19. Special conditions applying to whales

In addition to complying with the provisions set out in regulation 18 of these regulations, every commercial operation and every person coming into contact with whales shall also comply with the following conditions:

(a) No person in the water shall be less than 100 metres from a whale, unless authorised by the Director-General:

(b) No vessel shall approach within 50 metres of a whale, unless authorised by the Director-General:

(c) If a whale approaches a vessel, the master of the vessel shall, wherever practicable,--

(i) Manoeuvre the vessel so as to keep out of the path of the whale; and
(ii) Maintain a minimum distance of 50 metres from the whale
(d) No vessel or aircraft shall approach within 300 metres (1000 feet) of any whale for the purpose of enabling passengers to watch the whale, if the number of vessels or aircraft, or both, already positioned to enable passengers to watch that whale is 3 or more
(e) Where 2 or more vessels or aircraft approach an unaccompanied whale, the masters concerned shall co-ordinate their approach and manoeuvres, and the pilots concerned shall co-ordinate their approach and manoeuvres
(f) No person or vessel shall approach within 200 metres of any female baleen or sperm whale that is accompanied by a calf or calves
(g) A vessel shall approach a whale from a direction that is parallel to the whale and slightly to the rear of the whale
(h) No person shall make any loud or disturbing noise near whales
(i) Where a sperm whale abruptly changes its orientation or starts to make short dives of between 1 and 5 minutes duration without showing its tail flukes, all persons, vessels, and aircraft shall forthwith abandon contact with the whale.

R. 20. Special conditions applying to dolphins and seals

In addition to complying with the conditions set out in regulation 18 of these regulations, any commercial operation and any person coming into contact with dolphins or seals shall also comply with the following conditions:
(a) No vessel shall proceed through a pod of dolphins
(b) Persons may swim with dolphins and seals but not with juvenile dolphins or a pod of dolphins that includes juvenile dolphins:
(c) Commercial operators may use an airhorn to call swimmers back to the boat or to the shore
(d) Except as provided in paragraph (c) of this regulation, no person shall make any loud or disturbing noise near dolphins or seals
(e) No vessel or aircraft shall approach within 300 metres (1000 feet) of any pod of dolphins or herd of seals for the purpose of enabling passengers to watch the dolphins or seals, if the number of vessels or aircraft, or both, already positioned to enable passengers to watch that pod or herd is 3 or more

(f) Where 2 or more vessels or aircraft approach an unaccompanied dolphin or seal, the masters concerned shall co-ordinate their approach and manoeuvres, and the pilots concerned shall co-ordinate their approach and manoeuvres

(g) A vessel shall approach a dolphin from a direction that is parallel to the dolphin and slightly to the rear of the dolphin.

APPENDIX 3.1: Compliance of commercial tourism and recreational vessels to the MMPR (1992)

To manage pressures of tourism activities on cetaceans, managers typically require tour operators, as well as anyone interacting with a target species, to abide to regulations (legal requirement) or code of conducts (non-legal requirement) (Garrod and Fennell, 2004). Compliance to selected permit conditions and MMPR (1992; Appendix 1.4) regulations by both commercial tourism and recreational vessels was, therefore, assessed in Akaroa Harbour, New Zealand. Research outcomes were shared with the New Zealand Department of Conservation (DOC), Canterbury Conservancy.

Methods

To determine skippers' adherence to the regulations and guidelines, the behaviour of skippers was evaluated during encounters with Hector's dolphins, observed from both land- and vessel-based platforms. All tour operators were aware that a researcher was onboard to observe dolphin behaviour and interactions between the vessel and/or swimmers and dolphins. Percentage compliance with the selected conditions (Table A) was calculated and assessed as follows between November 2005 and March 2008:

Approaching Marine Mammals

Once a vessel approach was made, the approach type was recorded. Any manoeuvre towards a dolphin group or individual within the no waiting (*i.e.* in path) or approach zone (*i.e.* rear), as shown in Figure (C), was considered as not complying with condition 1.

During an encounter, the number and type of all vessels within 300m of the targeted group (condition 2) were recorded during each encounter using three-minute scan sampling (Altmann, 1974; Mann, 1999). The vessel to approach a dolphin group last, when three were already present, was the one recorded as breaching the MMPR (Fig. D1).

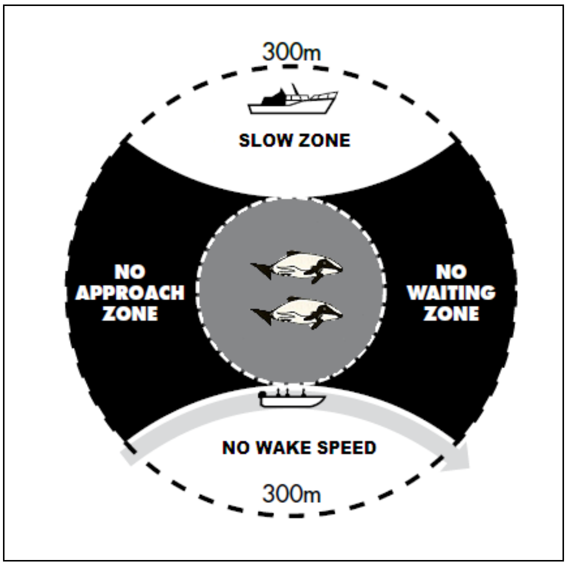


Fig. C: Recommended approach towards a group of dolphins within New Zealand waters (adapted from IFAW, 2008a).

Table A.: Permit conditions and MMPR regulations taken into consideration to assess compliance of commercial dolphin viewing/swimming and recreational vessels in Akaroa Harbour, New Zealand.

Condition	**Reference**
Approaching Marine Mammals	
1. A vessel shall approach a dolphin from a direction that is parallel to the animal and slightly to the rear of the animal	MMPR 1992 20(g)
2. A maximum of three vessels can approach within 300 m of marine mammals to watch them at any one time	MMPR 1992 20(e)
Interacting with Marine Mammals	
3a. No sudden or repeated change in the speed or direction if any vessel shall be made except in the case of emergency	MMPR 1992 18(e)
3b. No person shall cut off the path of a marine mammals or prevent a marine mammal from leaving the vicinity of a person or vessel	MMPR 1992 18(k)
3c. No vessel shall proceed through a pod of dolphins	MMPR 1992 20(a)
4a. Vessels less than 300 m from a marine mammal must move at a constant slow speed no faster than the slowest marine mammal, or at idle or no wake speed.	MMPR 1992 18(l)
4b. Vessels departing from the vicinity of marine mammals must proceed slowly at idle or no wake speed until the vessel is at least 300 m from the nearest marine mammal.	MMPR 1992 18(m)
5. Gear changes should be kept to a minimum, and reverse gear should be avoided	COC
Swimming with dolphins	
6. Persons may not swim with juvenile dolphins or a pod of dolphins that include juvenile dolphins (less than 1 m in length)	MMPR 1992 20(b)
7. Clients in the water should not reach out and touch or interfere with any mammals. A “hands off” policy should apply.	COC
8. There should be no more than ten swimmers in the water collectively at any one time with any one pod of dolphins	Permit
9. Maximum period of time spent swimming with one pod of Hector’s dolphins at one time shall be no more than 60 min (until 2007), 45 min thereafter.	Permit.

Interactions with Hector's dolphins

When tracking vessels from land-based stations, it was possible to assess the vessel handling techniques of skippers and whether they complied with condition 3 (keeping a steady and predictable path; Fig. D5), 4 (no wake speed within the slow zone; Fig. D2), and 5 (reversing).

Swimming with dolphins

All swim-with-dolphin encounters were observed to assess compliance with the last four remaining conditions from vessel-based platforms only (Figs. D3 and D6), except for condition 7 (Fig. D4). In addition, all observations were undertaken continuously, except for the maximum number of swimmers, which was recorded using a three-minute scan sampling (Fig. D6; condition 8; refer to Chapter V, section 5.3.2.3., for further details). Finally, the total swim encounter length (condition 9) was calculated as the time between the first swimmer entering the water and all swimmers returning to the vessel (Chapter V, section 5.3.2.3., for more details).

For ethical reasons, operator compliance was measured collectively. Behaviour of both commercial and recreational skippers during an encounter was assessed as either *complying* or *non-complying*. The frequency of non-compliance to the nine different conditions was then calculated from these binary response variables. Observations made from land- and vessel-based platforms were analysed separately because recreational vessels could only be followed from land-based stations.

Results and Discussion

Compliance to the different nine conditions was observed from commercial vessels on 444 trips over the same three five-month periods discussed previously. Over three consecutive austral summers (November to March), starting in 2005. In addition, a total of 144 commercial and 51 recreational vessels were tracked from the various land-based stations while interacting with a dolphin group during that same time period. Results are not stratified by individual company as it was considered ethically inappropriate and unnecessary.

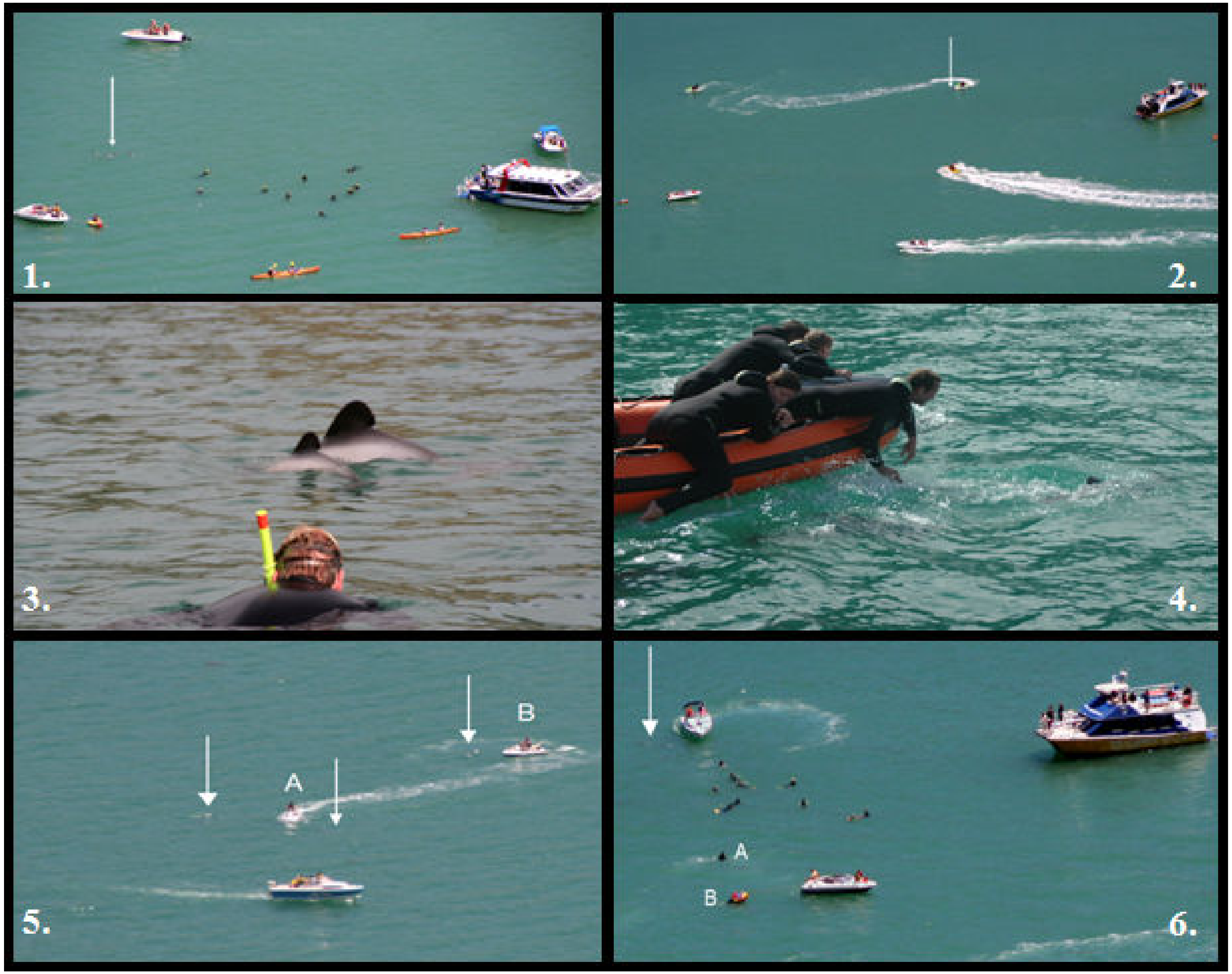


Fig. D: All photos: A.R.E.V.A. Project. Arrows point towards Hector's dolphin groups.

1. Example of an interaction with a group of Hector's dolphins where the number of vessels breaches section 20(e) of the MMPR (1992).

2. Example of a jetski not keeping a steady and predictable path and moving at more than wake speed within 300 m of a dolphin group. Violation of section 18 of MMPR.

3. Snorkeler with a mother and her calf.

4. Swimmers reaching out and attempting to touch dolphins. Violation of the Code of Conduct.

5. Example of a jetskis (A and B) cutting the path of a dolphin group. A group that was separated into three smaller sub-groups. Violation of section 18(k) of MMPR.

6. A total of 12 swimmers in the vicinity of a dolphin group, including two recreational swimmers (A and B). Under permit conditions, no more than 10 swimmers.

Results from this study indicate a high level of compliance of commercial dolphin-watching and/or swim-with-dolphins operators in Akaroa Harbour (Tables B and C). Operators maintained complete compliance with the maximum number of vessels permitted around a dolphin group. In terms of interaction time limit, operators adhered during 93.3% of interactions. In Port Stephens, Australia, 14% of all interactions exceeded the recommended time limit (Waples *et al.*, 2003), which fitted within the 74-98% range documented by Allen *et al.* (2007). Compliance levels in Port Phillip Bay, Australia, were even lower (Scarpaci *et al.*, 2003).

Table B: Percentage compliance for the five conditions studied from the various commercial tour operator vessels in Akaroa Harbour, New Zealand.

Condition	Non-compliance Dolphin-watching	Non-compliance Swim-with-dolphins
1- Approach type	21.4%	24.2%
6- No swim with juvenile	n/a	5.5%
8- No more than 10 swimmers	n/a	3.4%
9- Swim time limit	n/a	6.7%

Table C: Percentage compliance for the five conditions studied from the various land-based stations in Akaroa Harbour, New Zealand.

Condition	Non-compliance Commercial vessels	Non-compliance Recreational vessels
2- Maximum number of vessels	0%	11.8%
3- Vessel manoeuvring	11.1%	64.7%
4- Wake speed	3.5%	29.4%
5- Reversing	22.2%	2.0%
7- Hands off	5.6%	9.8%

Adhesion to regulations, while swimming with dolphins, was generally very high (more than 90%; Table B). Unlike other regulations, these are simple to measure and do not require any special skills. Tour operators tend to comply to simple conditions with a single numerical value (*e.g.* Scapaci *et al.*, 2004; Whitt and Read, 2006; Duprey *et al.* 2008).

Conditions regarding how to approach a dolphin group and avoiding to reverse in the presence of dolphins (conditions 1 and 5) were the two conditions most likely not to be adhered to (between 20 and 25% of the time; Table C). Compliance levels, however, were still relatively high and similar to those recorded in Clearwater, Florida, USA (Whitt and Read, 2006) and Port Stephens, Australia (Allen *et al.*, 2007). Skipper experience might play a role, especially in distance estimation (Baird and Burkhart, 2000), although it was not investigated here.

Research findings concur with Nichols *et al*. (2001), which was also based in Akaroa Harbour. The authors found that commercial swim-with-dolphin tours usually operated according to regulations and adhered to the mandatory time limit of interactions. Already in 2000, Nichols *et al*. (2001) noted the common practice of "handing over" the dolphins between tour operators. A practice that was still relatively common during the course of this study. In 34.5% of commercial trips, another commercial vessel was present during the encounter, however, never breaching condition 2 (Table A). This primarily occurred between January and March (Fig. E). Finally, under the local Code of Conduct, a "hands-off" approach should be applied. However, in 5.6% of encounters, commercial operators did not comply, (Table C). Typically, if not in the water with dolphins, people would try to touch a dolphin from the bow of a vessel (Fig. D4).

Overall level of compliance by commercial tour operators in Akaroa Harbour was high (72.1%). Nonetheless, it was still below the 80% threshold deemed acceptable in Port Stephens (Allen *et al*., 2007).

Such conclusions, however, cannot be applied to recreational vessels as previously observed by Nichols *et al*. (2001). Scarcapi *et al*. (2003) noted that previous studies on the effects of tourism on cetaceans had the tendency to ignore whether recreational vessels complied with existing regulations (*e.g.* Waples *et al*., 2003). In Akaroa Harbour, they represent 72.9% of the vessel traffic, and 25.4% of interactions with dolphins, which is non negligible (Chapter III). Akaroa Harbour is long and narrow. Consequently, commercial vessels targeting Hector's dolphins to either view or swim with them are readily visible and easily approached by any recreational vessel. As a result, especially during peak traffic time in December and January, non-compliance to the MMPR regulations is high. This suggests that recreational vessels are either unaware of the regulations or simply choose to ignore them.

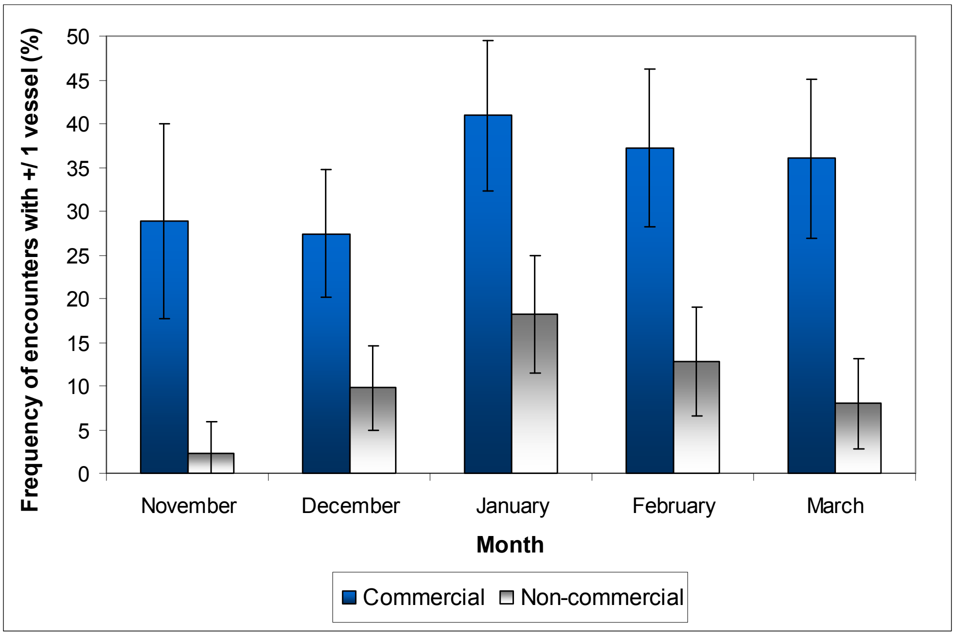


Fig. E: Encounters with more than one vessel involved, whether commercial or non-commercial, in Akaroa Harbour, New Zealand, between 2005 and 2008. Bars represent the 95% confidence intervals.

Of particular concern is the tendency for recreational vessels to manoeuvre improperly around dolphin groups (64.7% of non-compliance, Table C; Figs. D5, D6, and D2), especially by encircling a dolphin groups, rather than putting their gear in idle or neutral. Jetskis were twice as more likely to be engaged in such activities than other recreational vessels (66.7% *vs*. 35.2%), sometimes resulting in the separation of a group, breaching several regulations in the process (Fig. D5). This type of harassment and careless vessel-handling could result in further dolphin injury or fatality due to collision (*e.g*. Stone and Yoshinaga, 2000). Mother and calves do frequent the harbour waters (Chapter II) and are particularly vulnerable to collisions with vessels risk (Stone and Yoshinaga, 2000). The Hector's dolphin calving period coincides with the peak in the austral summer vessel traffic (Stone and Yoshinaga, 2000; Nichols *et al*., 2001; Chapter III). Not surprisingly, the majority of non-compliance events by recreational vessels recorded occurred during December (54.1%) and January (24.1%), two months traditionally associated with the holiday season in New Zealand. Non-compliance during the other three months, was less than 10% (8.3%, 9.7%, and 3.8% in November, February and March, respectively).

The second condition most likely to be breached by recreational vessels was moving around or leaving a group of dolphins at more than wake speed (29.4%, Fig. D2) (Table C). Furthermore, although not under the MMPR (1992), but under Maritime Navigation Safety, rule 91.6 (1c) stipulates that “there are no circumstances under which any vessel may exceed a speed of 5kts within 200m of a vessel displaying a dive flag”. All swim-with-dolphin vessels display such a flag. In 8.6% of cases, however, recreational vessels would not-comply with this rule (Fig. D2). This is a cause of concern for the safety of people in the water, including divers with the area being a popular fishing spot. This is not entirely surprising given that no license is required to operate a pleasure vessel within New Zealand waters.

In conclusion, there is a need to educate recreational vessels and enforce MMPR in Akaroa Harbour. Regulations have indeed inadequately been policed at both a local and national level until now. It is not uncommon, for example, to witness commercial tour operators engaging with recreational vessels that breached the MMPR regulations in an attempt to educate them about how to behave around Hector’s dolphins. Given the high exposure of this species to vessel interactions in Akaroa Harbour (Chapters VII), high compliance levels are crucial to protect this endangered species from the effects of vessel-based disturbance.

APPENDIX 5.1: Tolerance, sensitisation and habituation

Over time, cetaceans can respond to anthropogenic interactions in three different ways: tolerance, sensitisation, and habituation (Bejder *et al*., 2009; refer to Table D for definitions). Most studies are, however, limited in their ability to demonstrate a waning or waxing of cetacean responses to tourism activities because they are often short-term and/or unable to monitor known individuals and/or physiological responses indicating stress (Orams, 2004). Consequently, designating appropriate levels of tolerance may be more correct than using the term habituation (Bejder *et al*., 2009).

Table D: Definitions of the terms habituation, sensitisation, and tolerance (adapted from Bejder *et al*., 2009).

Term	Definition
Tolerance	Intensity of disturbance that an individual tolerates without responding in a defined way (Nisbet, 2000). Tolerance levels can help determine whether sensitisation or habituation may occur in the long-term.
Habituation	Relative persistent waning of response as a result of repeated stimulation which is not followed by any kind of reinforcement (Thorpe, 1963). Tolerance levels increase as individuals became habituated to specific stimuli.
Sensitisation	Increased behavioural responsiveness over time when animals learn that a repeated or ongoing stimulus has significant consequences for the animal (Richardson *et al*., 1995). Tolerance levels decrease as individuals became sensitised to specific stimuli.

The implication of habituation on the conservation of cetaceans is an important issue. The inappropriate application of the term *habituation* could mislead managers to conclude that tourism activities have neutral, or even benign, consequences on dolphin populations, when their effects are actually detrimental (Bejder *et al*., 2009). Displacement from critical habitats, for example, is usually considered as a significant response a population can demonstrate to a disturbance with time and has been documented (*e.g.* Bryant *et al*., 1984; Salden, 1988; Baker and Herman, 1989; Forest, 1999; Allen and Read, 2000; Lusseau, 2005a; Bejder *et al*., 2006b). In Fiordland, New Zealand, bottlenose dolphins (*Tursiops truncatus*) that regularly visit Milford Sound avoid this fjord when vessel traffic is heavy (Lusseau, 2005a). There are, however, a number of factors that influence displacement such as the quality of the current site, quality and distance to alternative sites, and the risk of predation at each site (Gill *et al*., 2001). This implies that the failure of a population to move from a specific location may not necessarily indicate that the level of disturbance is tolerable, but rather that no alternative site of quality is available to where the population can shift (Gill *et al.*, 2001). Alternatively, less tolerant individuals may have already been displaced and only tolerant individuals remain in the area of tourism operation. It may also be that segregation of the animals has already occurred depending on levels of tolerance, experience or status within the population (Constantine, 2004).

APPENDIX 5.2: Akaroa tour operator data sheet

This data form needs to be completed for every trip, when possible. You can either complete this form during the trip or immediately after the passengers have departed. Please collect the GPS position during the trip at every location where a dolphin interaction[1] occurs. Please circle the appropriate response.

Date:_______ Departure time: ________ Return time: ________ Vessel Name:________
POB: _____ including # Viewers:______ # Swimmers:______
Kayaks:________ # Kayakers: ________ Guided motorised vessel present: Yes No

Weather Conditions *Overall*: Rain Drizzle Overcast Partly cloudy Sunny
Sea Condition: Calm Moderate Rough Very Rough *Wind* (speed/direction):______

Dolphin-watching/ Swim-with-dolphin trip:

- No. of dolphins in group(s) you interacted[1] with?

					Best estimate
(1)	1-2	3-5	6-10	>10	_______
(2)	1-2	3-5	6-10	>10	_______
(3)	1-2	3-5	6-10	>10	_______
(4)	1-2	3-5	6-10	>10	_______

- Was there any calf present within the group?

(1) Yes, how many: _______ No
(2) Yes, how many: _______ No
(3) Yes, how many: _______ No
(4) Yes, how many: _______ No

- **Initiation of the interaction:** Who approached who first?

(1) Boat Dolphins (2) Boat Dolphins
(3) Boat Dolphins (4) Boat Dolphins

- **Location:** please give the GPS position of dolphins that have been interacted[1] with as well as time of contact:

(1) ___________________ S
___________________ E
Time: _____________

(3) ___________________ S
___________________ E
Time: _______________

(2) ___________________ S
___________________ E
Time: _____________

(4) ___________________ S
___________________ E
Time: _______________

- Overall how would you rate your viewing encounter with the dolphin group (see code):

(1)	VG	G	A	P	VP	EP
(2)	VG	G	A	P	VP	EP
(3)	VG	G	A	P	VP	EP
(4)	VG	G	A	P	VP	EP

- Were recreational vessels present within 200m of the boat?
If yes, for which interaction? (1) (2) (3) (4)
how many? (1) _____ (2) _____ (3) _____ (4) _____
and what % of time?[2] <25% ____ 25-50% ____ 50-75% ____ >75% ____

- Were any other species encountered on the trip? Yes No
If Yes, what species? __________________________

[1] An interaction is defined as the boat/kayak stopping and coming into contact with dolphins for at least 5 minutes
[2] Write down the interaction number next to the appropriate percentage.

For swimming-with-dolphin trips only:

▪ Overall how would you rate your swimming encounter with the dolphin group (see code):

(1)	G	A	P	(3)	G	A	P
(2)	G	A	P	(4)	G	A	P

▪ Were recreational vessels present within 200m of the swimmers? Yes No
If Yes, how many? (1) _____ (2) _____ (3) _____ (4) ____
Did their presence affect the success of your swim? (1) Y N (2) Y N (3) Y N (4) Y N

▪ Has the pod been interacted with by another vessel? Yes No
If Yes, for which interaction? (1) (2) (3) (4)
And how long? (1) _____ (2) _____ (3) _____ (4) ____

▪ Were recreational vessels present within 200m of the swimmers? Yes No
If Yes, how many? (1) _____ (2) _____ (3) _____ (4) ____
And what % of time? <25% _____ 25-50% _____ 50-75% ____ >75% _____
Did their presence affect the success of your swim? Yes No

Additional Comments:
____
____
____
____

<u>Contact rating for Viewing (including motorised vessels and kayaks):</u>

VG: Very good
Dolphins stay with the boat, for as long as we are there and engaging mostly in recreational play. Many photo opportunities.

G: Good
Dolphins stay with the boat, long enough for people to view dolphins. Some photo opportunities

A: Average
Dolphins come and go, showing occasional interest in the boat. Rare photo opportunities

P: Poor
Dolphins seen swimming past the boat, showing no interest in the boat. No photo opportunities.

VP: Very Poor
Sighting of single dolphins in the distance.

EP: Extremely Poor
No Dolphins seen

<u>Contact rating for Swimming:</u>

G: Very good
Sustained swimming interactions with swimmers. Dolphins stay with swimmers for as long as swimmers are in the water and mostly engaging in recreational play.

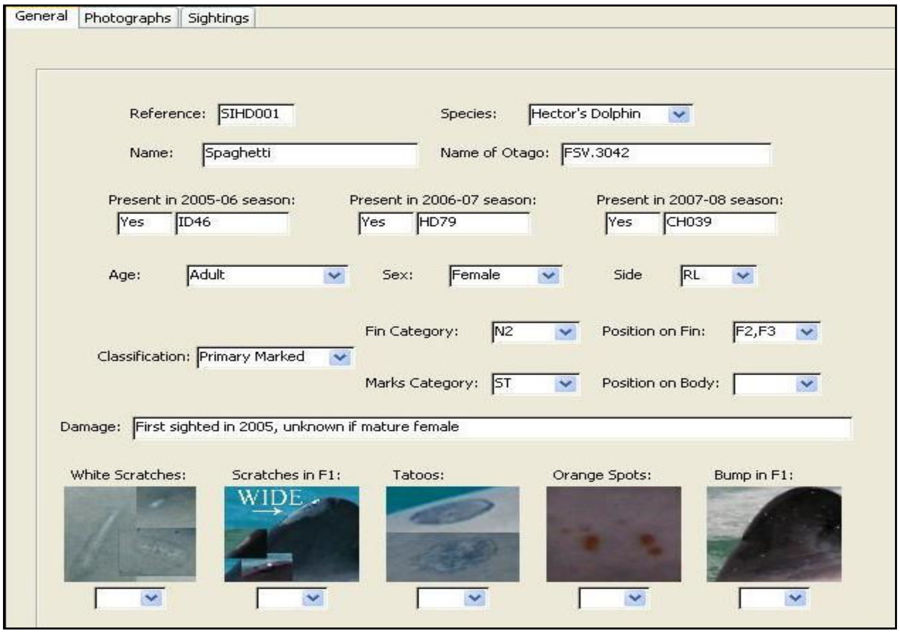
A: Average
Dolphins come and go and occasionally interact with swimmers.

P: Poor
Dolphins showing no interest in interacting with swimmers.

APPENDIX 7.1: Definitions of markings used to catalogue individuals

Primary Markings	**Code**	**Definition**
	N0	No notch
	N1	1 notch
	N2	2 notches
	N3	3+ notches
	PM	Part of fin missing
	HD	Highly damaged
	DE	Deformation
Secondary Markings	*Code*	*Definition*
	SM	Round and small dark spots on the body, similar to moles
	SR	Round or tattoo-like marks caused by skin disease etc.
	ST	Tooth-rake marks or any other kind of scratches (non permanent)
	WP	White patches
	SC	Large scar caused by shark attack or other
	OT	Any other particular mark that is predominant.
Section of the fin damaged	*Code*	*Definition*
	F1	Frontal part
	F2	Rear-upper part
	F3	Rear-lower part
Position of marks on body	*Code*	*Definition*
	L	Left side
	R	Right side
	F	Front (from snout to the frontal attachment of the dorsal fin)
	B	Back (from the frontal attachment of the dorsal fin to the tail)

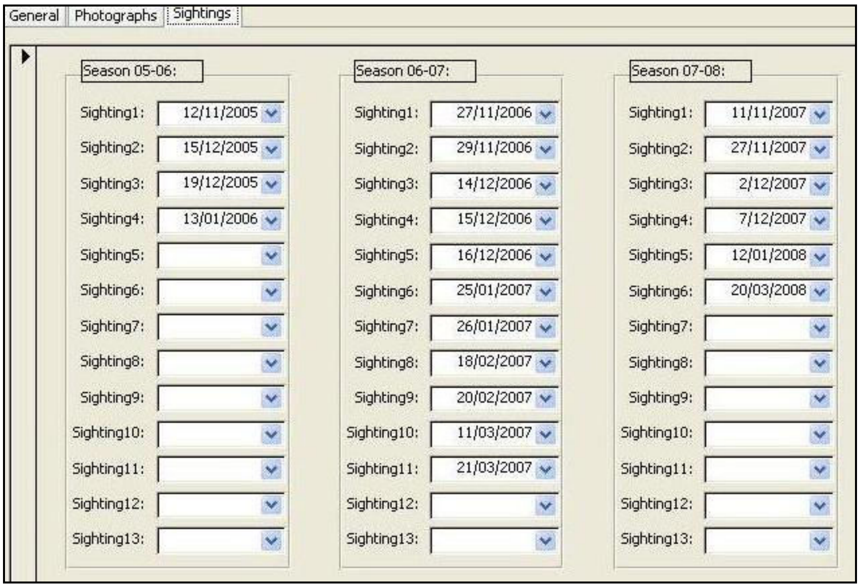
APPENDIX 7.2: Example from the AHHD catalogue and associated database created using Microsoft Access (here Individual SIHD001 (female) with her encounter history)


General | Photographs | Sightings

Reference: SIHD001
Species: Hector's Dolphin
Name: Spaghetti
Name of Otago: FSV.3042
Present in 2005-06 season: Yes ID46
Present in 2006-07 season: Yes HD79
Present in 2007-08 season: Yes CH039
Age: Adult
Sex: Female
Side: RL
Fin Category: N2
Position on Fin: F2,F3
Classification: Primary Marked
Marks Category: ST
Position on Body:
Damage: First sighted in 2005, unknown if mature female
White Scratches:
Scratches in F1:
Tatoos:
Orange Spots:
Bump in F1:


General | Photographs | Sightings

Left Dorsal: C:\SIHD\SIHD001a.jpg
Right Dorsal: C:\SIHD\SIHD001b.jpg


General | Photographs | Sightings

	Season 05-06:	Season 06-07:	Season 07-08:
Sighting1:	12/11/2005	27/11/2006	11/11/2007
Sighting2:	15/12/2005	29/11/2006	27/11/2007
Sighting3:	19/12/2005	14/12/2006	2/12/2007
Sighting4:	13/01/2006	15/12/2006	7/12/2007
Sighting5:		16/12/2006	12/01/2008
Sighting6:		25/01/2007	20/03/2008
Sighting7:		26/01/2007	
Sighting8:		18/02/2007	
Sighting9:		20/02/2007	
Sighting10:		11/03/2007	
Sighting11:		21/03/2007	
Sighting12:			
Sighting13:			

APPENDIX 7.3:

PHOTO-ID CATALOGUE OF HECTOR'S DOLPHINS (*Cephalorhynchus hectori hectori*) USING AKAROA HARBOUR

Created by Emmanuelle Martinez
A.R.E.V.A. Project
Coastal-Marine Research Group
Massey University
October 2008

Department of Conservation
Te Papa Atawhai

The compilation of this photo-identification catalogue[3] was funded by the Department of Conservation, Canterbury Conservancy.

The author would like to thank all the volunteers who participated in the A.R.E.V.A project. In alphabetic order: Helen Augu, Jessica Banning, Thomas Barreau, Chiara Bertulli, Sharon Bond, Nicolas de la Brosse, Daniele Cagnazzi, Carla Christie, Casey Clark, Laura Colombo, Soledad Esnaola Scotto, Nicky Filby, Henrique Garcia, Danièle Gibas, Paulina Guzman, Aidan Hubbard, Jenny Lamb, Maryse Leguèbe, Daniela Mello, Lucy Phillips, Adam Rosenblatt, Barbara Saberton, Ronan Scullion, Maria Fernanda Souza, Andrea Traub, Andrea van Nierkerk, Stephanie Whyte. A special thank you is extended to Monica Mariani.

The author would also like to thank the following tour operators for their support (by alphabetic order): Akaroa Dolphins, the Black Cat Group, and Dolphin Experience.

[3] The name of each identifiable individual Hector's dolphin was deliberately left blank so each operator could choose how to call these dolphins.

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:

Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

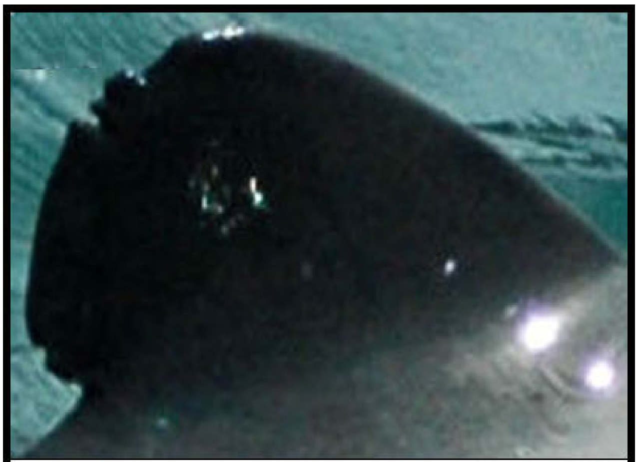
Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Female

Name:
Sex: Unknown



Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

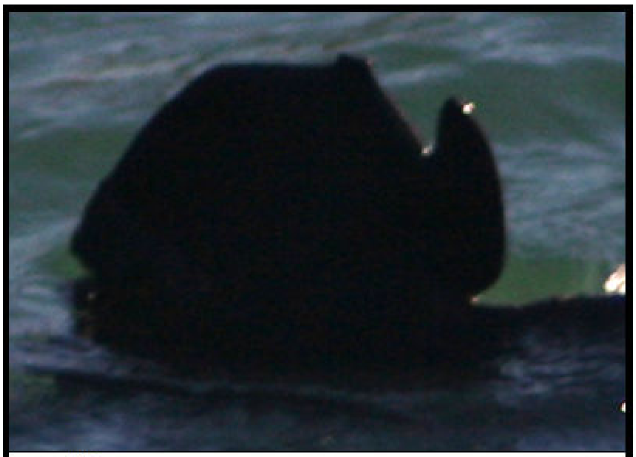
Name:
Sex: Female

Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown

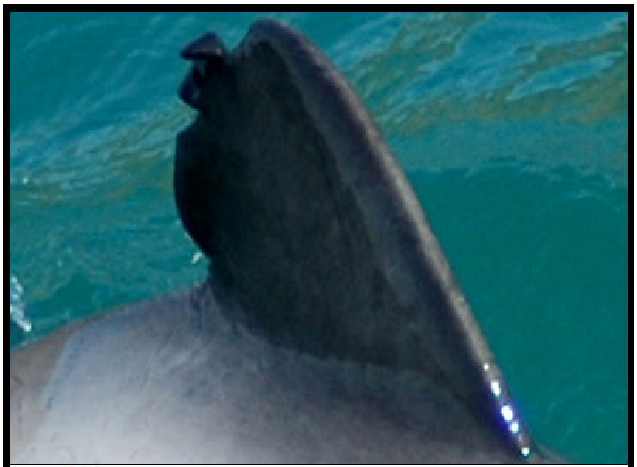
Name:
Sex: Unknown



Name:
Sex: Unknown

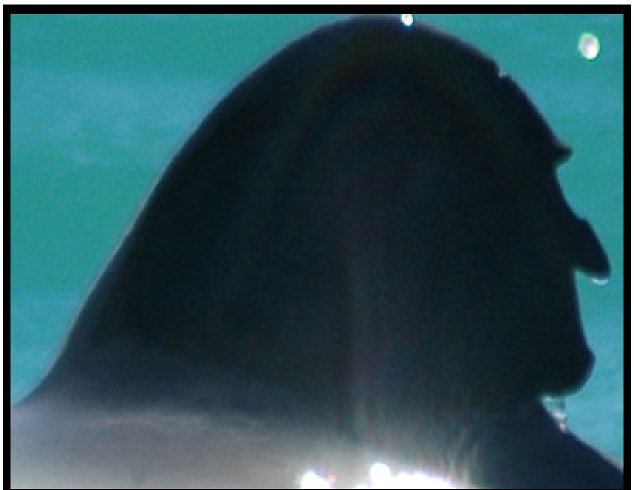
Name:
Sex: Unknown

Name:
Sex: Unknown



Name:
Sex: Unknown

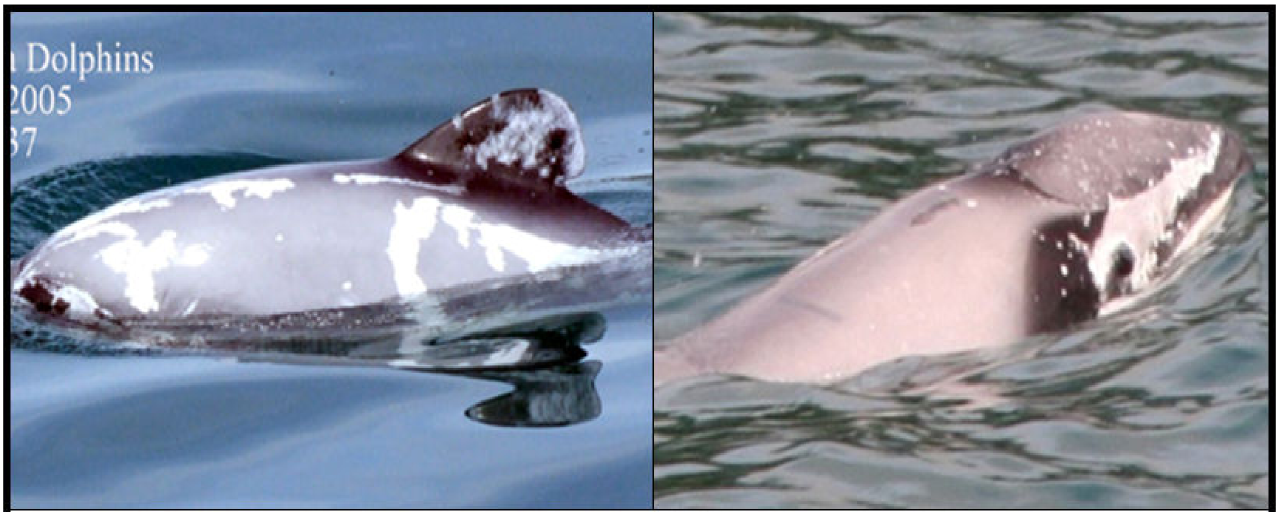
Name:
Sex: Unknown



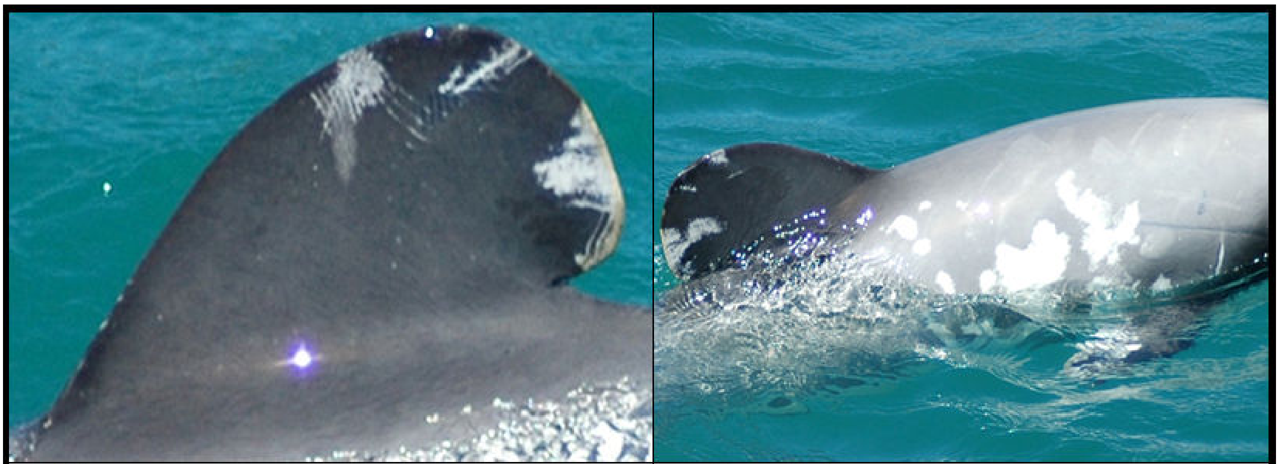
Name:
Sex: Unknown

Name:
Sex: Unknown

Name:
Sex: Unknown



Name: **Sex:** Female



Name: **Sex:** Unknown

Name: **Sex:** Female

APPENDIX 7.4: Summary of photo-ID data employed for the estimation of the mark rate from data collected in 2006/2007 and 2007/2008 in Akaroa Harbour, New Zealand

Date of survey	*Number of photographs* Total quality Photographs	Marked Individuals	Unmarked Individuals	Percentage Marked
04/11/2006	21	5	16	*23.8*
28/11/2006	18	8	10	*44.4*
08/12/2006	14	0	14	*0.0*
12/12/2006	11	0	11	*0.0*
18/12/2006	13	1	12	*7.7*
19/12/2006	8	0	8	*0.0*
28/12/2006	52	9	43	*17.3*
05/01/2007	8	4	4	*50.0*
05/01/2007	30	6	24	*20.0*
08/01/2007	41	7	34	*17.1*
12/01/2007	26	4	22	*15.4*
20/01/2007	15	3	12	*20.0*
24/01/2007	26	8	18	*30.8*
08/02/2007	21	0	21	*0.0*
08/02/2007	10	0	10	*0.0*
13/02/2007	12	0	12	*0.0*
13/02/2007	16	2	14	*12.5*
19/02/2007	26	0	26	*0.0*
20/02/2007	17	0	17	*0.0*
21/02/2007	21	2	19	*9.5*
26/02/2007	9	0	9	*0.0*
26/02/2007	15	1	14	*6.7*
02/03/2007	15	0	15	*0.0*
06/03/2007	17	3	14	*17.6*
12/03/2007	17	0	17	*0.0*
21/03/2007	18	4	14	*22.2*
23/03/2007	16	0	16	*0.0*
09/11/2007	19	2	17	*10.5*
10/11/2007	7	0	7	*0.0*
16/11/2007	13	0	13	*0.0*
20/11/2007	18	0	18	*0.0*
21/11/2007	29	1	28	*3.4*
27/11/2007	25	9	16	*36.0*
02/12/2007	14	1	13	*7.1*
07/12/2007	27	0	27	*0.0*
10/12/2007	6	0	6	*0.0*
11/12/2007	15	0	15	*0.0*
06/01/2008	12	2	10	*16.7*
03/02/2008	10	1	9	*10.0*
05/02/2008	21	0	21	*0.0*
07/02/2008	16	0	16	*0.0*
13/02/2008	18	3	15	*16.7*
14/02/2008	13	0	13	*0.0*
29/02/2008	9	0	9	*0.0*
18/03/2008	12	0	12	*0.0*
Total	***797***	***86***	***711***	***10.790***
Mean	***17.711***	***1.911***	***15.800***	***9.233***

Note: In all surveys photographs were taken randomly with a digital SLR camera.

APPENDIX 8.1: Management recommendations

The following recommendations were made to the Department of Conservation (DOC) as part of a research contract to mitigate the effects of vessel exposure (including recreational vessel traffic) on Hector's dolphins in Akaroa Harbour (Martinez *et al.*, 2010). These are primarily based from a biological and conservation perspective, while taking into account the endangered status of this species and the fact that the Banks Peninsula population is likely in decline despite the establishment of the Banks Peninsula Marine Mammal Sanctuary (Slooten, 2007). With an integrated and adapted management framework in mind (Appendix 8.2), other factors such as education must also be taken into consideration when implementing effective management measures to ensure the sustainability of the local tourism industry.

Exposure levels

All commercial operations

In terms of permit numbers and the current moratorium in place, three management options were available: increase, maintain or decrease the current level of exposure from commercial vessels targeting Hector's dolphins. Given that there is: a) a demand for additional permits (Allum, 2009); b) elevated exposure levels to tourism activities (Chapter VII); and c) a contribution by tour operations towards documented short-term effects (Chapters IV to VII), results from this research do not support any increase in the level of tourism effort. The moratorium should, therefore, be maintained. Not only are additional permits not recommended but nor is the allocation of additional trips within the existing permits, since results detected in this study (Chapters IV to VI), in particular behavioural changes (Chapter IV, section 4.4) and that most operators are not operating at a maximum permitted level (Appendix 1.1). These recommendations are important if the Marine Mammals Protection Regulations (MMPR, 1992; Appendix 1.4) requirement that commercial tour operations have "no significant adverse effects" (sections 4c, 6c and 12a) on a target species is to be met.

In order to mitigate short-term effects detected (Chapters IV to VI) and reduce the level of exposure of Hector's dolphins to commercial tour operations, several management options are available. In addition, even though maximum capacity in commercial tourism effort has not yet been reached (Appendix 1.1), Hector's dolphin exhibited signs of sensitisation to seasonally high levels of vessel traffic and interactions (Chapter V, section 5.4.2.1) Existing permits for both swimming and viewing trips could be capped at a maximum of six and two daily trips, respectively for operators whose permits allow more than two trips per day (Chapter I, Table 1.3). Large groups of swimmers did not affect the diving behaviour of Hector's dolphins (Chapter V, section 5.4.2.6), a critical behaviour for their overall health. Consequently, this proposed reduction could be counter-balanced by an increase in passenger numbers and swimmers. The legal substitution of swimming for viewing trips under current permit conditions should be discontinued to prevent pressure on this population from further increasing. .

A 30 minutes "break period" between subsequent tour interactions would give dolphins time necessary to return to their initial behaviour post interaction, particularly when diving/foraging (Chapter IV, section 4.4.3.2). Based on further evidence provided in chapters II, III, and V, a time out period between 1200 and 1300 hours, corresponding to a peak in vessel traffic and dolphin sightings (Chapters II and III), should also be considered as Hector's dolphins show some level of sensitisation to seasonally high levels of vessel interactions (Chapter V, section 5.4.2.1). Finally, should a marine reserve be implemented within Akaroa Harbour (Appendix 8.3), a "no interaction zone" should be envisaged for all vessel type within the reserve boundaries, given that the proposed reserve encompasses the area of high dolphin density (Chapter II, section 2.4.3.4) and could act as a refuge.

Swim-with-dolphin operations

Swimming with Hector's dolphins is an activity less benign than commonly believed (Chapter V, sections 5.4.2.). Consequently, this study support the recommendations under the Hector's and Maui's Threat Management Plan (DOC and MFish, 2007) that no new permits for swimming with Hector's dolphins should be issued to commercial operators. To reduce the detected short-term effects (Chapters IV and V), the maximum cumulative time spent swimming (or viewing) should be reduced from 90 to 60 minutes. The maximum swimming time period with a dolphin group should also remain at 45minutes owing to the fact that Hector's dolphins exhibited random movements after 50 minutes from the onset of an encounter (Chapter V, section 5.4.2.5).

As stipulated under the MMPR (1992; Appendix 1.4) and in their permits, operators should avoid approaching and placing swimmers using an *in path* approach, while a *line abreast* approach is instead recommended. The *around* method seems to also be effective with this species (Chapter V, section 5.4.2.4), despite its limitations with bottlenose dolphins (*Tursiops truncatus*; Constantine, 2001). Overall, high levels of compliance by tour operators were observed in Akaroa Harbour (Appendix 3.1). Operators are, therefore, encouraged to continue following the guidelines.

DOC specifically asked for an expert opinion on the use of fins during swim-with-dolphin encounters in Akaroa Harbour (Fig. F). The Scientific Committee of the International Whaling Commission (2000) noted ‘‘the available evidence indicated that swim-with programmes in the wild could be considered highly invasive’’. The use of fins can facilitate patrons to swim after or even “chase” the dolphins, which can be considered as harassment (pers. obs.). Hector’s dolphins are also very receptive to both vessels and swimmers when compared to other species in and outside of New Zealand, as indicated by the length of encounters (Chapter V, section 5.5). In order to minimise effects associated with this type of activity on Hector’s dolphins, swimmers should instead let the dolphins initiate an approach and interact on their own terms. Consequently, the use of fins is not recommended.

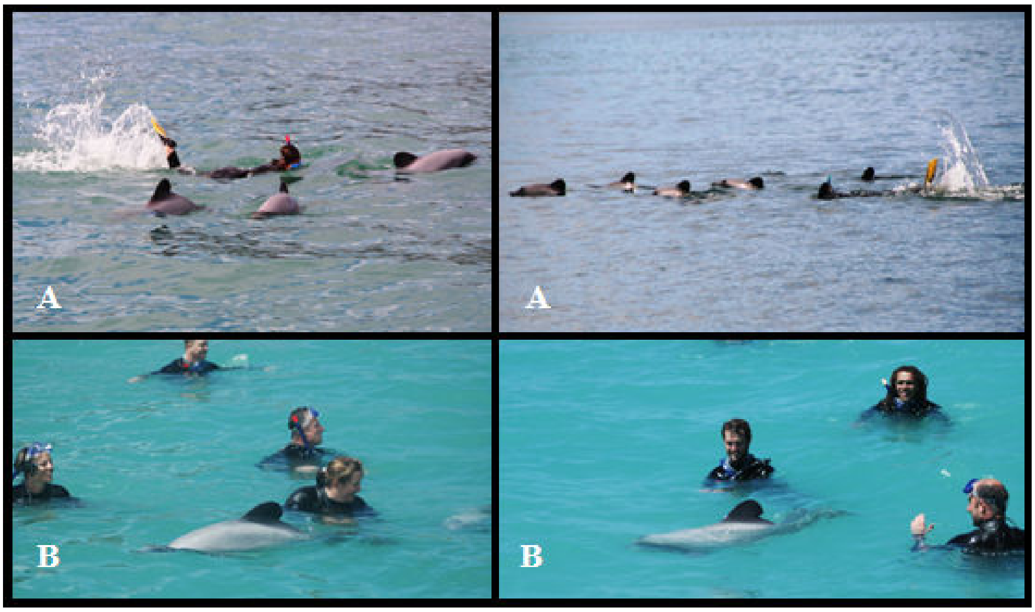


Fig. F: Examples of swim-with-dolphin encounters with (A) and without fins (B) in Akaroa Harbour, New Zealand. Swimmers without fins are encouraged to stay in a vertical position in the water and let the dolphins approach, while those with fins tend to swim after the dolphins. Photo © A.R.E.V.A. Project, 2006/2007.

Finally, under current permits, the number of approaches towards a *reluctant* dolphin group is limited to two for swimming trips and to three for dolphin-watching cruises (Allum, pers. comm.). A *reluctant* group is defined as dolphins that actively avoid approaches by vessels, *i.e.* swim away. This study demonstrates that on the few occasions when more than two swim drops were attempted, the duration of encounters was significantly compromised during the third attempt (Chapter V, section 5.4.2.2). It is, therefore, recommended that this regulation remain unchanged and that operators adhere to it. To further reduce pressure on the dolphins, the number of approaches towards *reluctant* dolphin groups during dolphin-watching cruises should also be limited to two.

The way trips and encounters are conducted

Changes in the way commercial tours are conducted could further reduce the current level of exposure Hector's dolphins are subjected to in Akaroa Harbour. Under the current permits (Allum, pers. comm.), a code of conduct stipulates that a maximum of two vessels can approach within 300 metres of a group of Hector's dolphins to view them at any one time (three vessels are permitted under the same circumstance in the MMPR, 1992; Appendix 1.4, sections 20e and 20f). The addition of one or more vessels to the one already present with a dolphin group further disrupts the behavioural budget of Hector's dolphins (Chapter IV, section 4.4.3.4). Consequently, it is recommended that only one vessel should approach and interact with a dolphin group at any one time, whether the interaction was initiated by a commercial or a recreational vessel.

Given that Hector's dolphins appear to be more receptive to interactions when in larger groups and when milling or socialising (Chapters IV and V), tour operators should be encouraged to target those groups first and to actively avoid groups engaged in diving. This behavioural state seems particularly sensitive to the presence of vessels and swimmers, as indicated by a reduction in the proportion of time spent diving (Chapter IV, section 4.4.3), the higher likelihood of remaining neutral (*i.e.* no change in the direction of movement) or vessel avoidance (Chapter V, section 5.4.2.5).

Several practices are currently being used to increase interaction time with dolphins and ensure a good encounter for patrons, which need to be reconsidered for the welfare of

Hector's dolphins. To help mitigate the effects of tourism activities, operators should also refrain from using any auditory stimulant underwater, in particular stones, to create sounds to either entice dolphins or sustain their interaction with swimmers (Chapter VI, section 6.4). This method increases the amount of time dolphins interact with humans and potentially exacerbate the changes detected in behavioural activity (Chapter IV, section, 4.4.3). No vessels should engage circling around swimmers to entice dolphins to bow-ride before slowly bringing them towards swimmers. Instead, the dolphins should be allowed to initiate any approach. Any non-approach by dolphins should be interpreted as a sign of non-willingness to interact. Finally, the common practice of "handing-over" dolphin groups between operators (Appendix 3.1, Fig. G) should cease. This technique potentially increases the cumulative interaction time between dolphin groups and vessels and/or swimmers, compounding effects demonstrated in this study. The implementation of *discrete* departure times would further reduce the likelihood of "handing-over" dolphin groups and provide Hector's dolphins with larger recovery periods between trips.

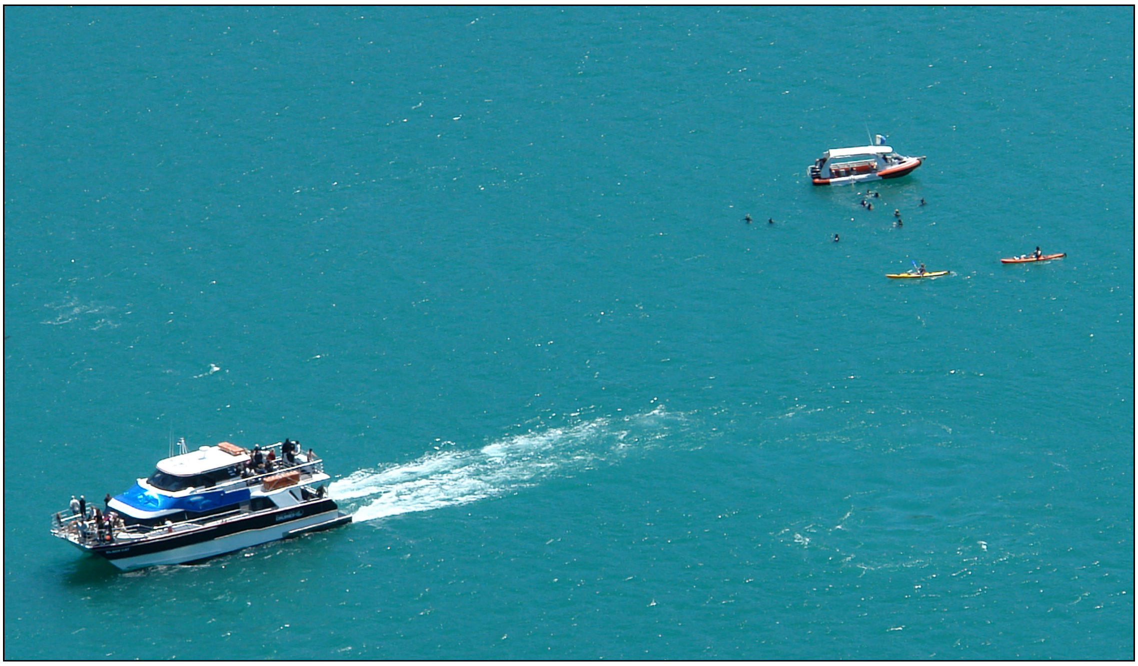


Fig. G: Example of tour operators "handing-over" a Hector's dolphin group in Akaroa Harbour, New Zealand. Photo © A.R.E.V.A. Project, 2006/2007.

More general recommendations on education and enforcement, based on previous research and personal observations, were also drafted for consideration by DOC, the commercial operators, and other stakeholders.

Education and staff training

All commercial operations

Skipper experience has been empirically linked to increased adherence to the MMPR in Kaikoura (Markowitz *et al.*, 2009c). It is, therefore, of advantage to all parties to have efficient training of skippers on approach methods and swimmer placement. Most experienced skippers, for example, typically wait before placing swimmers in the water with dolphins (*around* method) and refrain from initiating an encounter with groups engaged in diving (pers. obs.). An annual training programme or workshop to train new skippers and/or refresh more experienced boat crew should, therefore, be considered. Newly employed guides could also participate in such training programme or workshop to gain accurate information about the target species (*e.g.* biology, ecology, threats, etc.). Guides could also be taught to recognise different behaviours, including those that display aggression or receptivity to human interactions. Finally, researchers could also be encouraged to share updated information on the species on an annual basis and participate in the aforementioned workshops.

Under the MMPR (section 6h), operators must provide educational material during their tours. The information provided is usually passed down from more experienced skippers/guides to new recruits, which can be perceived by the latter as known facts. As a result, false information can be transmitted over the years between staff and more importantly to the public (*e.g.* “Hector’s dolphins feed for 11 hours per day”; pers. obs.). The fact that people do not always question the educational material being given highlights the importance of relaying factually accurate information during tours. This is imperative given that tourists have demonstrated that they would like to receive more information, especially on the wider marine environment (Lück, 2003). The scientific literature has until now, primarily concentrated on the patron attitude/belief changes, interpretation and its efficacy, learning experiences, knowledge retention and other benefits of a cetacean-watching experience (*e.g.* Orams, 1995b, 1997, 2000; Higginbottom, 2002; Lück, 2003; Finkler and Higham, 2004; Stamation *et al.*, 2007;

Zeppel and Muloin, 2008), but rarely on the accuracy of the information being delivered. Information provided during tours could also be scrutinised during undercover onboard monitoring.

Recreational vessels

Orams and Hill (1998) state that "education is an important strategy when compliance with management regulations is necessary to protect wildlife in ecotourism settings". In Akaroa Harbour, recreational vessel owners are often unaware of the New Zealand legislation (MMPR and MMPA). The ignorance or lack of education of even simple Maritime Safety Regulations (MSR) is also of concern. All swim-with-dolphin operators display a dive flag when swimmers are in the water, for safety reasons. One of the rules commonly violated (Fig. H) is the "maximum speed of 5 knots within 200 metres of a vessel with a dive flag or within 50 metres of any other vessel or swimmer[1]". The non-requirement of a licence to operate a pleasure vessel in New Zealand[3] may explain this lack of knowledge. An increased presence of the harbourmaster on the water, coupled with an enforcement of the MSR, would likely decrease infringements observed (Appendix 3.1), which would also be beneficial to the dolphins.

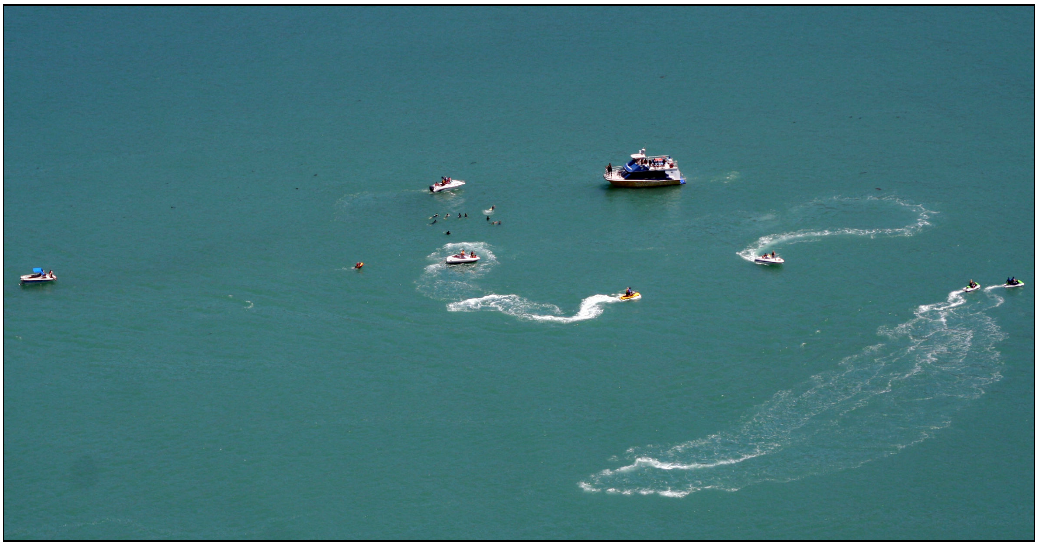


Fig. H: Example of recreational vessels in Akaroa Harbour, New Zealand, travelling at speeds exceeding 5 knots within 200 metres of a commercial swim-with-dolphin vessel displaying a dive flag, in violation of Maritime Safety Regulations. Photo © A.R.E.V.A. Project, 2006/2007.

[1] http://www.maritimenz.govt.nz/Recreational-Boating/Skipper-responsibilities/Skipper-responsibilities.asp (accessed 20/05/2010)

The presence of commercial vessels and/or swimmers in the water inadvertently encourages recreational vessels to approach and interact with the dolphins. Unfortunately, this often results in MMPR regulations being breached (Appendix 3.1) and causes further disturbance to the dolphins (Chapter IV). Recreational vessels were often more likely to approach a dolphin group as the third or more vessel (pers. obs.). During the austral summer 2008/2009 (December and January), DOC initiated an educational programme by distributing educational material on a wide range of marine related issues at boat ramps. Over the same time period, daily patrols using the DOC vessel were also conducted, weather permitting, for the same purpose (Cox, pers. comm.). Anecdotal reports from commercial operators indicate an improvement of the behaviour of recreational vessels on the water (Allum, pers. comm.). Given this positive outcome, this programme should be continued on an annual basis and be extended to all weekends from 1 November to 31 March as well as to any holiday periods. Such a programme could be mirrored on the *Soundwatch*[2] programme in the USA. Finally, awareness of the regulations could also be supplemented by effective information panels (*e.g.* Cole *et al.*, 1997) erected at the main boat ramps around Akaroa Harbour. These could be installed adjacent to the existing Ministry of Fisheries panels.

Enforcement

Effective management of the cetacean-watching industry is dependent on compliance to the management regimes in place. Appropriate legislative controls, monitoring, and enforcement are also crucial if the tourism industry is to develop sustainably. This is particularly true when effects on the targeted population, here the Hector's dolphins, have been detected. Whether in New Zealand or overseas, management options in place are frequently rendered ineffective by a lack on monitoring and/or enforcement. This inadequacy is often due to a lack of staff and/or resources.

In Akaroa Harbour, the commercial operators generally adhere to the different conditions stipulated in their permits (Appendix 3.1), although there is still room for improvement. Of greater concern is the non-adherence of recreational vessels to the MMPR. Several measures could be instigated to increase enforcement. A stronger presence of officials on the water and a patrol of the harbour, in association with an

[2] http://www.whalemuseum.org/programs/soundwatch/soundwatch.html (Last accessed 20/05/2010)

extended the education programme, could act as an incentive to adherence of the regulations. The topography of Akaroa Harbour could facilitate lookouts strategically placed around the elevated cliffs that could monitor vessel activities and compliance from different vantage points. A proportion of tourism levies could be set aside to fund such a monitoring scheme. Coupled with the use a video to record infringements, this suggestion could also serve as an education tool for skippers on how to best approach and interact with Hector's dolphins.

Commercial companies operating in Akaroa Harbour, which are currently not permitted to target Hector's dolphins, can react opportunistically when dolphin groups are detected. This constitutes another potential enforcement issue if an operator is intentionally approaching a dolphin group. The fact that the species is attracted to vessels, particularly sailing vessels (Chapter III, Section 3.4.5), can only increase the probability of these types of interaction. It can be argued that implementing "incidental permits" is more appropriate, given that it offers further control of such interactions via the permit system. Conversely, this also increases opportunities for operators to approach and view dolphins on a more regular basis, and more likely in a full-time capacity when given the opportunity to do so. Considering the high level of tourism in Akaroa Harbour (Chapter VII), this would further increase the pressure on dolphins, when it is apparent that it needs to be reduced. This is not considered advisable and furthermore, it is likely unnecessary because non-permitted operators must still adhere to the MMPR (1992) regardless.

APPENDIX 8.2: Integrated and adaptive management framework

Higham *et al.* (2007) identified a lack of a comprehensive integrated and adaptive management framework for cetacean-watching to counteract the shortcoming in the long-term sustainable management of such activity. Recently, such a framework, based on limits of acceptable change or LAC parameters (*e.g.* Stankey *et al.*, 1985), has been proposed by Higham *et al.* (2009).

In this management framework (Fig. I), the initial responsibility is placed on developing a legislation and licensing system of the industry with the support of the community (Fig. I, C1-C2, A1) during the pre-tourism stage. This model also integrates the critical collection of baseline data during that stage, establishing monitoring criteria and a control site as well as generating frameworks for management action, where necessary (Fig. I, D1-D3). Baseline data then facilitate the establishment of quantifiable LAC criteria (Fig. I, C3), which are necessary to set up guidelines (Fig. I, C4), which in turn determine the issue of permits (Fig. I, B2) by managers. Once all of these steps have been negotiated, tourism operations can commence.

During the tourism stage, new phases in continuing social and science research come into place (Fig. I, A2, D4) with the establishment of a new commercial operation (or when new permits are being issued where commercial tourism already exists). Social science research effort can determine visitor profiles and perceptions to develop effective educational programme (Fig. I, A2-A4) and manage the industry by modifying commercial operations if required (Fig. I, B4-C7). Scientific monitoring of the targeted population is undertaken regularly (Fig. I, D4, D5), allowing comparison with baseline data collected during the previous phase (Fig. I, T0). Regular monitoring and reporting in association with analysis, interpretation, and considered response would lead managers to take active management decisions (Fig. I, C5, C6) and, ultimately, serve as the basis for changes relating to the management regime and, if necessary, to the legislation in place. A new phase in data collection should be initiated with any modification of commercial operations (*e.g.* alterations to permit conditions, Fig. I, T2). Other human activities (*e.g.* recreational activities, commercial fishing, noise pollution) and non-human causes (*e.g.* biological disease) affecting the targeted population and, therefore, the sustainability of the cetacean-watching industry, should also be assessed and considered by managers (Fig. I, D5-C5, D7-C7). All processes are ongoing so that management decisions are both active and evolving with the tourism industry (Fig. I, D7, C7, B4) to ensure the long-term sustainable management of this industry. Regions where such models can be applied can be used as a baseline for other areas where data on impact assessment are unavailable (*e.g.* where cetacean-watching is about to be developed).

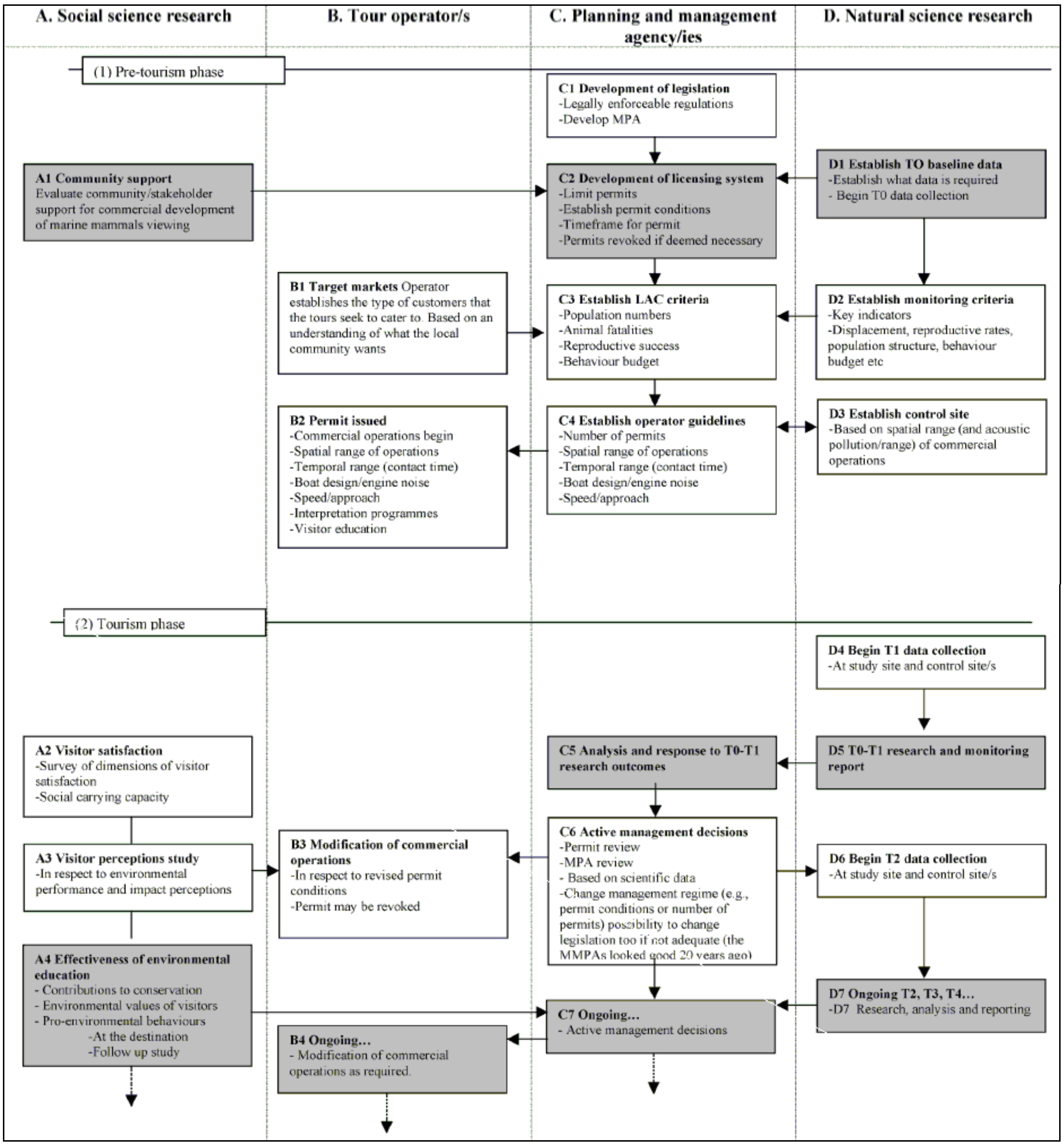


Fig. I: Model for the integrated, dynamic and adaptive management of tourism interactions with cetaceans (from Higham *et al.*, 2009).

APPENDIX 8.3: Akaroa Harbour Marine Reserve[3]

Background on the application

The application for the Akaroa Harbour (*Dan Rogers*) Marine Reserve was notified by the Akaroa Harbour Marine Protection Society on 6 January 1996[4]. The Minister of Conservation, with the agreement of the applicants and principal stakeholders, subsequently suspended consideration of the application pending the establishment of a taiāpure in Akaroa Harbour. The taiāpure came into effect on 31 March 2006. The application was, therefore, once again in front of the Minister and his first priority was to obtain updated views on the application. These submissions are currently being analysed.

Why Akaroa Harbour?

The area is notable for spectacular volcanic cliffs, sea caves, and sea stacks. The underwater topography is likewise spectacular, with the cliffs and bluffs falling vertically to the seabed and colonised by marine communities which exhibit interesting zonation patterns. At the base of bluffs in some areas (notably at Dan Rogers Bluff) there are huge room-sized boulders that provide spectacular underwater scenery and habitat for marine communities typical of parts of the exposed Banks Peninsula coastal environment.

What are the boundaries?

The proposed location of Akaroa Harbour Marine Reserve is in the south eastern area of Akaroa Harbour (Fig. J), Banks Peninsula, in the vicinity of Dan Rogers Bluff, hence the colloquial reference to the application as "Dan Rogers". The proposed area extends from Manukatahi stream, near Nine Fathom Point (Lat. 43° 51.48' S and Long 172° 56.55' E) around the head of Akaroa Harbour to Gateway Point (Lat. 43° 53.52' S and Long 172° 59.05' E). The proposed area follows a line bearing 220° T (true north) from

[3] Information taken from the Department of Conservation website (last accessed 20/05/2010): http://www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserve-information/proposed-reserves/akaroa-harbour-marine-reserve/

[4] http://www.doc.govt.nz/upload/documents/getting-involved/consultations/closed-consultations/akaroa-harbour-mr-application.pdf (last accessed 20/05/2010).

the coast to the line described by the Wainui leading lights and covers an area of 530 ha (approximately 12% of the Harbour).

Fig. J: Proposed Marine Reserve in Akaroa Harbour, New Zealand.

What does the community think about the proposal?

Throughout the past 10 years the proposal has drawn both support and opposition. This is reflected in the submissions received on the first notified application in 1996. In total, 3,043 submissions were received: 709 (23.3%) opposed to the proposal and 2,334 (76.7%) were in support. In 2006, 75 submissions were received: 25 (33.3%) opposed the proposal, 48 (64.0%) were in support, and 2 (2.7%) were in conditional support.

Minister of Conservation to decide

The Minister of Conservation will decide on the Akaroa Harbour (Dan Rogers) Marine Reserve Application after considering submissions, in particular, if Iwi or users would be adversely affected by the marine reserve. The original submissions/objections will be taken fully into account by the Minister whether or not any new information from the second consultation process was submitted.

APPENDIX 9: PUBLICATIONS

The following have been produced during the PhD candidature, as a result of the research presented in this dissertation:

Publications in peer-reviewed journals

Martinez, E; Orams, M.B. (in press). ‘Kia angi puku to hoe i te wai’. Ocean noise and tourism. *Tourism in Marine Environments.*

Martinez, E.; Orams, M.B.; Stockin, K.A. (in press). Swimming with an endemic and endangered species: Effects of tourism on Hector’s dolphins in Akaroa Harbour, New Zealand. *Tourism Review International*.

Martinez, E.; Orams, M.B.; Pawley, M.D.M.; Stockin, K.A. (in press). The use of auditory stimulants during swim encounters with Hector’s dolphins (*Cephalorhynchus hectori hectori*) in Akaroa Harbour, New Zealand. *Marine Mammal Science*.

Conference proceedings

Martinez, E.; Orams, M.B.; Stockin, K.A. (submitted). The impact of swim-with-dolphins tourism on Hector’s Dolphins in Akaroa Harbour, Banks Peninsula. *Proceedings of the 2010 New Zealand Tourism and Hospitality Research Conference, Auckland, New Zealand*. (24th-26th of November, 2010).

Martinez, E; Orams, M.B. (2009). ‘Kia angi puku to hoe i te wai’. Ocean noise and tourism. *Proceedings of the 6th International Coastal and Marine Research Congress, Port Elizabeth, South Africa*.

Martinez, E; Orams, M.B. (2009). Let's rock! Using stones as auditory stimulants during swim-with-dolphins encounters with Hector's dolphins in Akaroa Harbour, Banks Peninsula, New Zealand. *Proceedings of the 18th Biennial Conference on the Biology of Marine Mammals, Québec, Canada*.

Martinez, E; Orams, M.B.; Brunton, D.H. (2007). Responses of Hector's dolphins (*Cephalorhynchus hectori hectori*) to vessel activity in Akaroa Harbour. *Proceedings of the 17th Biennial Conference on the Biology of Marine Mammals, Cape Town, South Africa.*

Martinez, E; Brunton, D.H.; Orams, M.B. (2007). Responses of Hector's dolphins (*Cephalorhynchus hectori hectori*) to vessel activity in Akaroa Harbour. In: *Balancing Marine Tourism, Development and Sustainability. Proceedings of the 5th International Coastal and Marine Tourism Congress, Auckland, New Zealand.*

Reports to the New Zealand Department of Conservation as part of a fulfilment of several research contracts

Martinez, E.; Orams, M.B.; Stockin, K.A. (2010). Responses of Hector's dolphins (*Cephalorhynchus hectori hectori*) to vessel activity in Akaroa Harbour, Banks Peninsula, New Zealand. *Internal report to the Department of Conservation, Canterbury Conservancy, New Zealand.* 187p.

Martinez, E.; Orams, M.B.; Stockin, K.A. (2009). Estimation of the exposure levels of Hector’s dolphins (*Cephalorhynchus hectori hectori*) to commercial tourism vessels in Akaroa Harbour using photo-identification. *Internal report to the Department of Conservation, Canterbury Conservancy, New Zealand.* 65p.

Martinez, E.; Orams, M.B. (2009). Report on the use of stones as auditory stimulants during swim-with-dolphins encounters with the South Island Hector's dolphins (*Cephalorhynchus hectori hectori*) in Akaroa Harbour, New Zealand. *Internal report to the Department of Conservation, Canterbury Conservancy, New Zealand.* 50p.