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Managing the impacts of dolphin-based tourism through the definition of critical habitats: the case of bottlenose dolphins (*Tursiops* spp.) in Doubtful Sound, New Zealand

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Abstract

Marine ecotourism in New Zealand presents a challenging tourism-environment management context. This is demonstrated in the case of Doubtful Sound (New Zealand) where the recent proliferation of tour operators has brought pressures to bear upon a population of bottlenose dolphins resident in the sound. Strict methodologies are necessary to objectively interpret responses to tourism-induced anthropogenic impacts upon cetaceans. Previous research in this field has established that boat interactions with dolphins in Doubtful Sound affect the behavioural budget of the dolphin population, and that dolphins are more sensitive to interactions with boats when they are resting and to a lesser extent when they are socialising. This article reports on a programme of research that employed observational data to explore the applicability of tourism management techniques grounded in spatial ecology. The data provided scientific evidence that determining critical habitat through spatio-ecological analysis is a powerful tool to protect marine mammals in New Zealand, and elsewhere, from biologically significant tourism-induced impacts. The delineation of multi-levelled marine sanctuaries may, therefore, be an effective approach to managing the impacts of tourism upon marine mammals.
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1. Introduction

The rapid development and widening appeal of ecotourism has been associated in the New Zealand ecotourism context with various perplexing management challenges (Higham, Carr, & Gale, 2001). This is a situation with numerous international parallels (Duffus & Dearden, 1990; Reynolds & Braithwaite, 2001). The proliferation of commercial business operations in response to increased demand has generally taken place in association with concerns for the impacts that inevitably emerge (Warren & Taylor, 1994). Management responses to this course of development are typically reactive due to the swift pace of development. This is certainly so in the case of ecotourism operations that bring tourists into contact with cetaceans. Few sectors of the tourism industry have experienced the same levels of growth in such a concentrated period of time as whale and dolphin-based operations (Hoyt, 2000). Equally, few forms of tourism provide a greater challenge in accurately understanding the impacts of tourism, and appropriate management responses. This article examines the case of dolphin-based marine ecotourism in New Zealand, and explores the potential management value of a spatio-ecological approach to impact mitigation.

2. The effects of tourism activities on whales and dolphins (cetaceans)

It is difficult to assess the impact of human activities on marine mammals because they live in a different environment and use their senses differently to humans. Strict methodologies are necessary to interpret responses

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to anthropogenic impacts objectively. For the past 10 years there has been increasing interest in studying the effects of tourism activities on marine mammals (Constantine, 1999; Orams, 1999). Unfortunately, most studies have examined only one aspect of the problem without considering the potential interactions between several variables, for example acoustic communication and behavioural state. Few data have been gathered on the long-term impacts associated with boat disturbance. Some studies have been able to relate changes in habitat use as well as avoidance of previously preferred areas in response to an increase in boat traffic (Baker, Perry, & Vequist, 1988; Salden, 1988; Corkeron, 1995).

Several short-term studies have shown a variety of marine mammal responses to interaction with tourists. Most studies have focused on behavioural changes depending on the presence and the density of tourist engagements, as determined by the various platforms that exist within this form of tourism (e.g., boat-based, kayak-based, land-based viewing platforms). In most cases schools of animals tend to tighten when boats are present (e.g. Blane & Jaakson, 1995; Barr, 1996; Nowacek, Wells, & Solow, 2001). Some species show signs of active avoidance. Responses range from changes in movement pattern (Edds & MacFarlane, 1987; Salvado, Kleiber, & Dizon, 1992; Campagna, Rivarola, Greene, & Tagliorette, 1995; Bejder, Dawson, & Harraway, 1999; Nowacek et al., 2001), increases in dive intervals (Baker et al., 1988; Baker & Herman, 1989; Blane, 1990; MacGibbon, 1991; Janik & Thompson, 1996; Lusseau, 2003a) and increases in swimming speed (Blane & Jaakson, 1995; Williams, Trites, & Bain, 2002). These signs of avoidance can be a result of not only the presence of boats, but also boat manoeuvring patterns, such as sudden changes in boat speed or rapid approaches (MacGibbon, 1991; Gordon, Leaper, Hartley, & Chappell, 1992; Constantine, 2001; Lusseau, 2003a).

The presence and density of boats (Briggs, 1985; Kruse, 1991; Barr, 1996) and the distance between boats and individuals within a pod (Corkeron, 1995) can also affect the occurrence and frequency of behaviour. It is noteworthy that humpback whales in Alaska have been seen reacting to vessels up to 4 km away from the pod (Baker et al., 1988). In addition, the behavioural state of cetacean groups interacting with tourist vessels can be affected and changed (Ritter, 1996; Constantine & Baker, 1997; Lusseau, 2003b). For example interactions with boats lead to a decrease in resting behaviour in spinner dolphins in Hawaii (Würsig, 1996).

Hearing is the primary sense of cetaceans. They use vocalisations not only to communicate and maintain group cohesion (Janik & Slater, 1998), but also to locate prey and navigate using echolocation (Popper, 1980). Vocalisation patterns are also altered by the presence of tour boats. In the case of humpback whales in Hawaii the presence of boats affects their song phase and unit duration (Norris, 1994). The production of an 'alarm signal' as well as an increase in silence time has been related to the presence of boats in belugas and narwhals (Finley, Miller, & Davis, 1990). An increase in whistling rate has also been linked to the maintenance of group cohesion during interactions with boats in different species of dolphins (Van Parijs & Corkeron, 2001; Scarpaci, Bigger, Corkeron, & Nugegoda, 2000).

Increasingly studies show that the navigation and speed of the vessel interacting with the animals is a key parameter in the "intrusiveness" of the interaction (Nowacek et al., 2001; Williams et al., 2002; Lusseau, 2003a). The more boats are manoeuvred unpredictably and erratically, the more animals try to elude them. The observed avoidance strategies are similar to typical anti-predator responses (Howland, 1974). Until recently the commercial hunting of whales and dolphins for blubber (fat), baleen, and meat (Hoyt & Hvenegaard, 2002) has taken place in many countries. Some populations of cetaceans were also considered as pests and bounties were placed on them (e.g., killer whales along the US and Canadian Pacific Northwestern coast). Hunting (commercial or otherwise) still exists in a few countries (Ris, 1993, Hinch, 1998), but many communities have moved towards a non-destructive use of this natural resource and are now operating whale- and dolphin-watching ventures (Duffus & Dearden, 1990; Hoyt, 2001; Hoyt & Hvenegaard, 2002). However, the fact remains that whales and dolphins employ anti-predator techniques when a vessel targets them, especially when vessels attempt to out-manoeuvre or impair their movement (i.e., erratic boat navigation). While the behavioural consequences of human engagements with marine mammals are becoming increasingly clear, the consequences and significance of behavioural changes remains an open question.

3. The biological significance of tourism impacts

One important issue that is beginning to be addressed concerns the biological consequences of observed avoidance responses. What are the consequences if a dolphin spends 10 s longer underwater on average when a boat interacts with it? It is necessary to relate the effects of the responses observed to standardised parameters such as the energetic budget of the species to assess their biological significance. However, we lack the basal energetic information that can often only be collected in a controlled environment, to relate the changes observed to energetic expenses. Remote sensors that can be deployed in the field are short-lived (life span measured in hours). Therefore, they provide contentious results because it is impossible to know whether the

animal had recovered from the stress of being tagged during the sampling process. However new theoretical avenues are opening due in large part to the discovery of the emergent properties of metabolism and cellular functions (Darveau, Suarez, Andrews, & Hochachka, 2002). This theoretical work, while still in the preliminary phase, does present the possibility to extrapolate values, such as metabolic rate measured in control species to other species that can only be observed in the field (although limitations will exist in the application of findings from one species to another). Given this development the accurate measurement of the biological significance of the responses observed may be possible. While this development offers much potential it must be noted that cause and effect issues are complex and dynamic, and may be complicated by incremental chronic stress (Orams, 2004). This means that a precautionary approach should be applied to the management of cetacean-watching activities until the biological significance of tourism impacts are established scientifically.

Moreover, relating the effects observed to their energetic cost would allow the comparison of the impacts of ecotourism on cetaceans as they vary between focal species. Such comparisons would allow the establishment of simple and appropriate management responses. This would also allow a more pro-active approach to the management of cetacean-watching activities by establishing guidelines and quotas appropriate to different species preferably before the development pressure of the tourism industry reach levels that cannot be sustained.

4. The development of marine ecotourism in Doubtful Sound, New Zealand

Doubtful Sound is the second largest of the 14 fjords that compose the Fiordland region in southwestern South Island, New Zealand. It is home to a small resident population of bottlenose dolphins (*Tursiops* spp.) that rarely leave the fjord for more than a few hours (Williams, Dawson, & Slooten, 1993; Schneider, 1999; Lusseau et al., 2003). Scenic cruises operate on this fjord, which rely significantly on bottlenose dolphins as a key natural resource (Lusseau, 2002). The tourism pressure in Doubtful Sound has dramatically increased over the past 2 years (Lusseau, 2002) and is planned to increase further in the near future. This expansion and intensification of anthropogenic pressure on Doubtful Sound, and consequently on the bottlenose dolphin population, has raised concern and heightened the need for management responses aimed at impact mitigation.

In this case, as in many others, marine mammal operations are only one aspect of the marine-based tourism industry at the location (Lusseau, 2002). Many coastal communities will also perhaps operate fishing charters, scenic cruises and adventure-sport activities (among many others) as forms of marine tourism development. Because marine mammal-watching activities are the only sector that is dedicated to specifically utilising whales and dolphins as natural resources, they are often the only ones considered in the management plans. However, the other sectors of the industry can not only spend a significant amount of time with these animals, but also rely on them as a key natural resource (Lusseau, 2002). Whales and dolphins will often attract tourists to one location and keep them there for several days. During that time tourists may engage in other forms of tours (e.g., scenic flights, fishing charters, pelagic bird tours). In addition, tourists may partake in a scenic cruise because it is cheaper than whale-watching tours in anticipation of an equal probability of engaging in whale and dolphin encounters.

Tourism operations in New Zealand are governed by a multitude of laws, regulations and bylaws depending on their location and the nature of their operation. In New Zealand all tourism companies fall under one piece of national legislation, the Resource Management Act (RMA, 1991) that is managed by local regional councils. In addition, all commercial passenger carrying marine tourism operations in Doubtful Sound need to have a licence from the Ministry of Transport, be registered with the Maritime Safety Authority and, if fishing, be permitted by the Ministry of Fisheries (see Orams, 2003). Whale and dolphin-watching activities are managed under the Marine Mammal Protection Act (MMPA, 1978) and the Marine Mammal Protection Regulations (MMPR, 1992). The MMPR fall under the jurisdiction of the Department of Conservation, a national governmental body, and are managed by the regional conservancy offices of this government department. Doubtful Sound is utilised by scenic cruises. None of these companies are dedicated dolphin watchers, yet dolphins are a key resource in this location and are encountered daily by most cruises (Lusseau, 2002). Some operators acknowledged their interest in utilising the resident bottlenose dolphin population and they are therefore managed under the RMA, MMPA, and MMPR. Other companies operate scenic cruises as well as fishing charters. There is no direct road access to Doubtful Sound, one must first cross a lake (20 km) and drive 20 km on a road located inside Fiordland National Park to access the head of the fjord. Because of this remoteness few private boats utilise the area, yet there is a general trend of increasing private boat traffic (Lusseau, 2002). Scenic cruises, fishing charters and private boat users do not directly utilise dolphins as a resource and are therefore only managed under the RMA. However these vessels, especially scenic cruises, spend a significant amount of time with dolphins (Lusseau, 2002).

Because of the remoteness of the area it is difficult and expensive to carry out policing activities. Moreover, the MMPR do not prevent non-permitted vessels interacting with marine mammals if they happened to encounter them. Therefore the prosecution of non-permitted operators can only take place where intentional interactions with dolphin schools can be demonstrated. This legal impracticality effectively undermines marine mammal protection legislation, a situation that understandably fosters tension between permitted and non-permitted tour operators. The former naturally argue that there is no benefit in holding a permit because other operators can freely access the same resources. Moreover, there are considerable commercial disadvantages associated with holding a permit because it ties operators to national responsibilities and an extra level of management. Thus, the operations of non-permitted companies can be freely expanded (that is, increase the number of trips per day and the number of boats the company operates) under the regional management plan, while permit holders cannot do so because of the national guidelines under the MMPR.

5. Defining critical habitat from behavioural data for the bottlenose dolphin population (Tursiops spp.) of Doubtful Sound, New Zealand

Previous research in this field has established that boat interactions with dolphins in Doubtful Sound affect the behavioural budget of the dolphin population (Lusseau, 2003b). Furthermore, dolphins are more sensitive to interactions with boats when they are resting and to a lesser extent when they are socialising (Lusseau, in press). These earlier findings suggest that minimising tourist vessel–dolphin school interactions during these behavioural states may be an important element in the management of tourism impacts upon members of the studied dolphin population. Such a management response fundamentally requires the collection of rigorous spatial ecology data. Determining critical habitat is a powerful tool to protect marine mammals in New Zealand (Dawson & Slooten, 1993) and in other countries (Buckingham, Lefebvre, Schaefer, & Kochman, 1999; Thompson, Van Parijs, & Kovacs, 2001; Hooker, Whitehead, & Gowans, 2002). It allows critical locations that need to be safeguarded under the Marine Mammal Protection Regulations (MMPR, 1992) to be identified and therefore permits the management of dolphins under only one piece of legislation. Such an approach was effective in reducing Hector's dolphin (*Cephalorhynchus hectorii*) by-catch in gillnets around Banks Peninsula, on the East Coast of the South Island (Slooten, Fletcher, & Taylor, 2000), a location where Hector's dolphins are concentrated (Dawson & Slooten, 1993). Similarly the Robson Bight-Michael Bigg Ecological Reserve in Canada helped to minimise boat interactions with killer whales (*Orcinus orca*) (Kruse, 1991; Williams et al., 2002). Marine mammal sanctuaries have been established in other locations to regulate and minimise interactions between humans and marine mammal species that are the subject of tourist interest. Examples include: (1) manatee (*Trichechus manatus*), Crystal River National Wildlife Refuge, Florida, created in 1983; (2) humpback whale (*Megaptera novaeangliae*), Stellwagen Bank Sanctuary, Maine, created in 1989; (3) humpback whale, Hawaiian Islands Humpback Whale Sanctuary, Hawaii, created in 1997.

In the past, the establishment of sanctuaries has mainly relied on abundance information (i.e., locations where the highest number of animals are generally present) (Dawson & Slooten, 1993; Buckingham et al., 1999; Thompson et al., 2001). The goal of these sanctuaries is to protect locations with high concentrations of animals in order to decrease the probability of exposure to anthropogenic impacts. The situation in Doubtful Sound can be addressed more specifically using behavioural information. The sensitivity of dolphins to specific impacts is known to be dependent on behaviour (Lusseau, 2003b). This approach allows the size of protected areas to be optimised, maximising its effectiveness without compromising the use of Doubtful Sound by tour operators (Meffe & Carroll, 1997). The goal of this study was to identify locations in Doubtful Sound where dolphins are more likely to rest and socialise, and to establish the appropriateness and likely effectiveness of a sanctuary as a management tool. Furthermore, it was intended that the research would contribute to delineating the most appropriate parameters of a sanctuary in Doubtful Sound based on rigorous observational data.

6. Field research methodology

From December 1999 to February 2002 systematic surveys were conducted in Doubtful Sound (Fig. 1) using a 4.8 m aluminium boat powered by a four-stroke, 50 hp outboard engine. While the collection of data from a boat raises issues of researcher impact and habituation, it was for practical reasons deemed the most appropriate approach to collecting the data required for the intended analysis. Researcher impacts were mitigated through appropriate boat navigation at all times. The same survey route, leaving from Deep Cove (Fig. 1), was followed everyday until a school of dolphins was encountered (Fig. 1). The route allowed for a complete survey of the fjord and even spatial effort. Effort was also evenly distributed across seasons. Once a school was detected the identity of individuals in

the school was determined using photo-identification. The behavioural state of the school was then sampled every 30 min along with its geographic position. The location of the school was recorded manually on a map in the field using landmarks. The principal individual and collective behavioural states (Table 1) of the school were categorised via scan sampling (Altmann, 1974). These behavioural states were defined to be mutually exclusive and cumulatively inclusive (as a whole they described the entire behavioural budget of the dolphins). Scan sampling of individuals within the school was preferred to focal group sampling because of the observer bias inherent to the latter technique (Mann, 2000). The scan sampling of individual animals provided the required detail of data collection to afford insights into the relationship between individual animal behaviour and the collective behaviour of the school. Observations ended when the weather deteriorated, the focal school was lost, or the day ended, therefore the end of a sequence of observations was not dependent on the behaviour of the focal school.

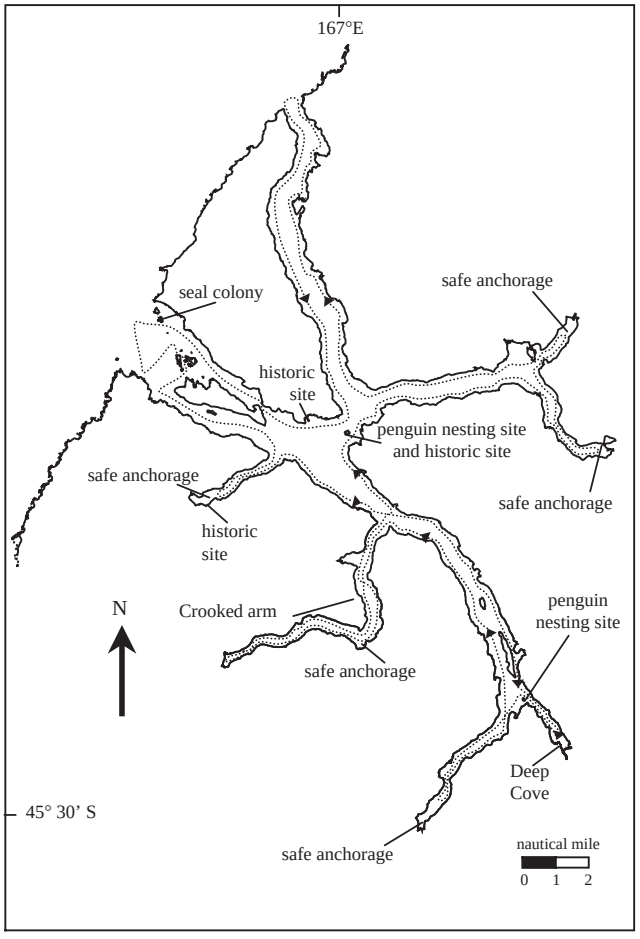

Fig. 1. Map of Doubtful Sound showing the locations of other resources utilised by tour operators (penguin nesting sites, seal colony and historic sites). The survey route is displayed with a dotted line (arrows showing the direction).

7. Analytical techniques

A database of sightings was established using Atlas-GIS® 3.0 (developed by ESRI) in which the position of the school, along with date, time and behavioural state, was recorded. These sightings were overlapped over a map of Doubtful Sound. A gridline was then applied to the map with one-nautical mile (square) quadrats. The size of the quadrats was chosen to maximise both the number of quadrats that contained sightings and the number of sightings per quadrat, while still maintaining a detailed division of the fjord. The effort spent looking for dolphins in each quadrat was not calculated because the distribution of dolphins in Doubtful Sound was not relevant to the analysis. However the number of sightings in which dolphins were resting or socialising in each quadrat (region) was

Table 1
Definitions of individual and group behavioural states employed in the collection of data

State	Definition
Travelling (TR)	Individuals moving steadily in a constant direction (faster than the idle speed of the observing vessel). Swimming with short, relatively constant dive intervals. The group spacing varies.
Resting (REST)	Individuals moving slowly in a constant direction (slower than the idle speed of the observing vessel). Swimming with short, relatively constant, synchronous dive intervals. Individuals are tightly grouped.
Milling (MI)	No net movement. Individuals are surfacing facing different directions. The school often changes direction as well. Dive intervals are variable but short. The group spacing varies.
Diving (DIVE)	Direction of movement varies. Individuals dive synchronously for long intervals. All individuals perform "steep dives", arching their back at the surface to increase their speed of descent. The group spacing varies. Diving most likely represented the "feeding" category in other studies (Shane, 1990).
Socialising (SO)	Many diverse interactive behavioural events are observed such as body contacts, pouncing, and hitting with tail. Individuals often change their position in the group. The group is split in small sub-groups that are spread over a large area. Dive intervals vary.

recorded and standardised by the total number of sightings in each region. In essence, the percentage of time spent resting and socialising in each region was measured to provide an understanding of precisely where either of these two behavioural states was most likely to take place.

8. Defining critical and important regions

The definition of a critical region in this study is focussed on the issue of the impacts of tourist vessel interactions on the behaviour of the dolphin population. A critical region is defined as a location that is predominantly used for socialising or resting. An important region is an area where socialising and resting are often observed. The overall behavioural budget of the population was used to define 'predominantly' and 'often'. Dolphins in Doubtful Sound spend 11% of total observed time resting and 20% socialising (Lusseau, 2003b). If more than 11% of the sightings in a region were resting, the region was defined as important for resting. If more than 22% of the sightings in a region were resting, the region was defined as critical for resting. Similarly the levels for important and critical socialising regions were set at 20% and 40%, respectively. These thresholds are arbitrarily set because, to our knowledge, this is the first study trying to base habitat protection on quantified behavioural information. However, these values are biologically meaningful because they are based on the behavioural budget of the population.

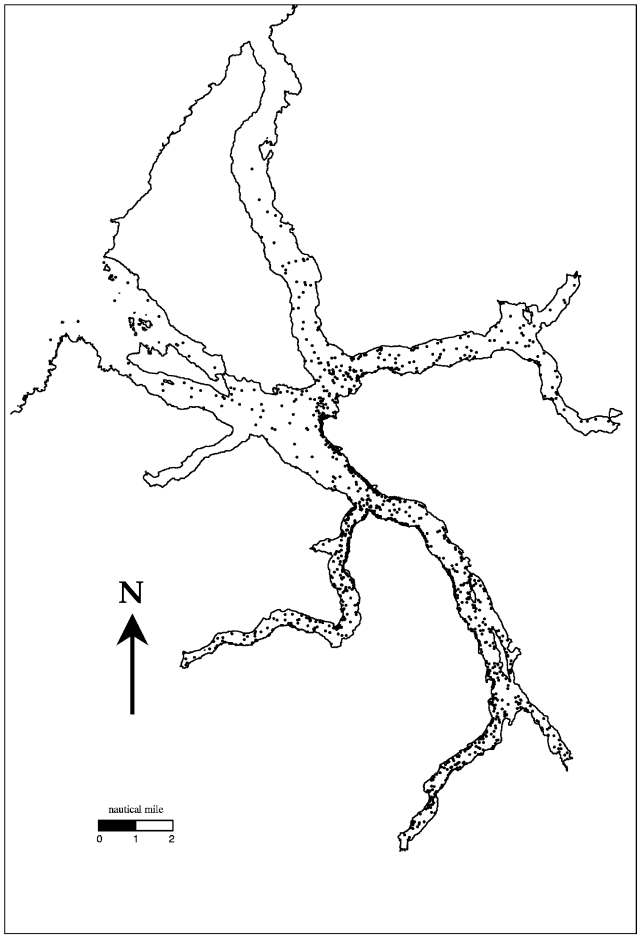

Fig. 2. All sightings recorded in Doubtful Sound between December 1999 and February 2002 ($n = 1234$).

9. Temporal variation of the behaviour observed in the regions

Temporal variation, that is seasonal variations in the proportion of time spent socialising or resting in a quadrat, could only be assessed reliably where sufficient sightings were recorded. For quadrats that had more than 20 sightings over the study period the difference in proportion of time spent socialising or resting between warm (December–May) and cold (June–November) seasons were assessed. The difference between proportions was then tested using a Z-ratio test (Fleiss, 1981).

10. Results

During the study period 886.3 h were spent looking for dolphins and 686.5 h with them. These observations resulted in 1234 sightings (Fig. 2) of which 128 were sightings in a resting state and 220 in a socialising state. Sightings were evenly distributed between the winter and summer seasons (601 and 633 sightings, respectively). So too were sightings in different behavioural states (resting: 53 sightings in winter, 75 in summer; socialising: 117 sightings in winter, 103 in summer). The fjord was divided into 134 quadrats.

There were eight quadrats that could be classified as critical regions for resting and 11 as important (Fig. 3). However most of these quadrats had few sightings, only five of these 19 regions had 20 or more sightings. Similarly only six of the 11 critical (six quadrats) or important (five quadrats) regions for socialising had 20 or more sightings (Fig. 4). Six quadrats were important for both socialising and resting (Figs. 3 and 4).

For the six socialising regions with more than 20 sightings there was no significant difference in the amount of time dolphins spent socialising depending on seasons (all Z-ratios <1 and $p > 0.15$). Only one quadrat varied significantly with season for resting behaviour (Fig. 3, quadrat marked with an asterix '$*$', Z-ratio $= 2.29$, $p = 0.011$). All other resting regions stayed consistent across seasons (Z-ratio <0.5, $p > 0.69$).

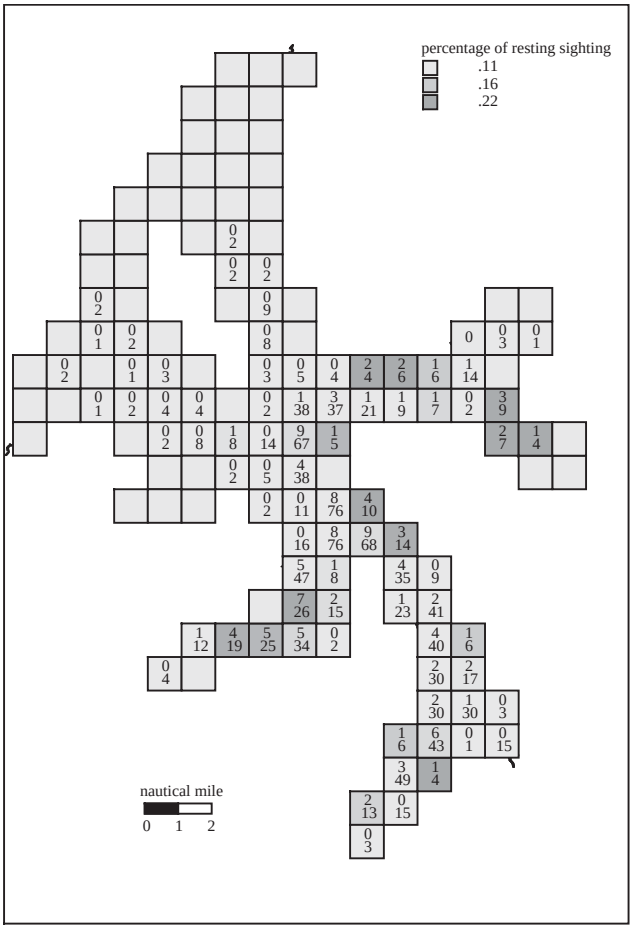

Fig. 3. Gridline overlayed on the sighting information. Top number in each quadrat is the number of resting sightings and the bottom number is the total number of sightings. If a quadrat has only one number it means that there was no resting sighting in this quadrat. The colour of quadrats varies in intensity with the proportion of resting sighting in each quadrat. The colour labelled 0.11 corresponds to quadrats with 11% or less of sightings that were resting. The colour labelled 0.16 corresponds to quadrats with 11–22% of sightings that were resting. The colour labelled 0.22 corresponds to quadrats with 22% or more of sightings that were resting.

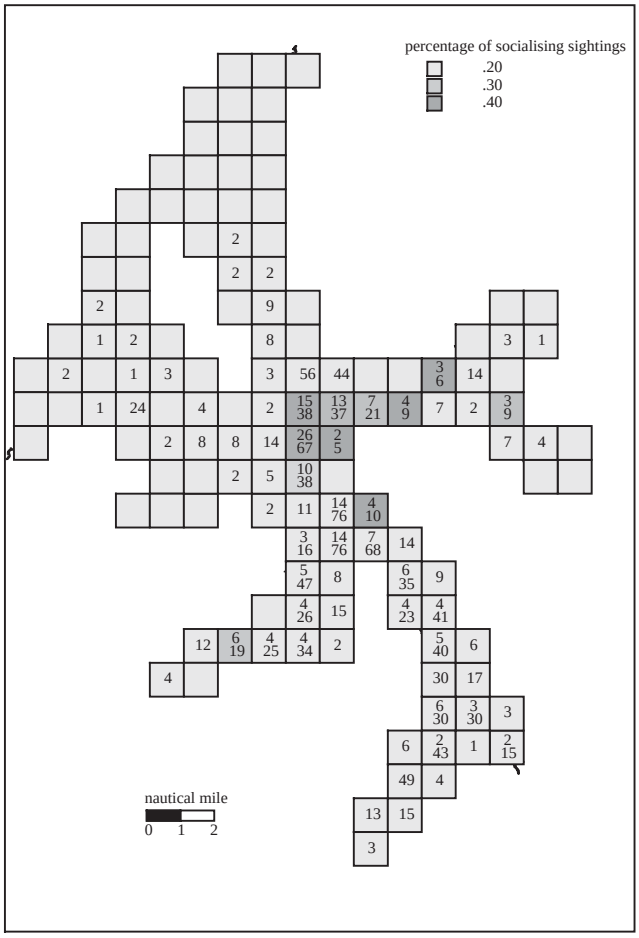

Fig. 4. Gridline overlayed on the sighting information. Top number in each quadrat is the number of socialising sightings and the bottom number is the total number of sightings. If a quadrat has only one number it means that there was no resting sighting in this quadrat. The colour of quadrats varies in intensity with the proportion of resting sighting in each quadrat. The colour labelled 0.20 corresponds to quadrats with 20% or less of sightings that were resting. The colour labelled 0.30 corresponds to quadrats with 20–40% of sightings that were resting. The colour labelled 0.40 corresponds to quadrats with 40% or more of sightings that were resting.

11. Discussion

Currently the scenic cruise industry of Doubtful Sound is composed of tour operators that both do and do not possess a dolphin-watching permit (Lusseau, 2002). Both types of operations are managed under the Resource Management Act (RMA, 1991) by the Southland Regional Council and only permitted operators are legally managed by the New Zealand Department of Conservation under the MMPR. Yet, both types of operators utilise dolphins significantly as part of their tours (Lusseau, 2002). This division in management makes it difficult to regulate dolphin–boat interactions. The establishment of a marine mammal sanctuary, managed solely under the MMPR, would allow strict regulation of all types of operations.

This study aimed to identify locations in Doubtful Sound where dolphins are more likely to rest and socialise. This task was performed to provide critical insights into the probable effectiveness of the proposed establishment of a multi-level marine mammal sanctuary in Doubtful Sound. Such a sanctuary may be deemed effective only if it will significantly minimise interactions between boats and dolphins where dolphins are resting and socialising. It may also serve in this case to minimise interactions between dolphins and tour operating vessels that do not possess a dolphin-watching permit. It would therefore restore the benefits of holding a watching permit in this location (Lusseau, 2002).

Once critical and important regions were determined in Doubtful Sound (Figs. 3 and 4), several decision rules were applied in order to select the areas to be protected.

Table 2
Guidelines for the delineation and management of critical habitats

Rule 1	All critical resting regions need to be allocated a no-boat zone status.
Rule 2	Most critical socialising regions need to be allocated a no-boat zone status.
Rule 3	The boundaries of protected areas need to be at least 400 m away from most resting and socialising sightings in a region and at best 1 km away because dolphins were observed reacting to the presence of vessels at these distances (Lusseau, in press).
Rule 4	The restriction to access other natural resources (penguin nesting sites, seal colony, significant scenery and historic sites) must be minimal.
Rule 5	The restriction of access to safe anchorage locations and safe navigation routes must be minimal.
Rule 6	Tour operators that possess watching permits, and researchers, must be able to access more locations where dolphins are likely to be seen than other operators can.
Rule 7	Tour operators that possess watching permits, and researchers, must be able to access some locations where some socialising can be observed to match the expectation of their tourists (and meet study requirements in the case of researchers).

These rules were defined a priori and discussed with some of the tour operators (Table 2). They were set to maximise the sustainability of tourism operations. That is, they maximise the protection of dolphins without endangering the economic viability of commercial operations. Moreover, they effectively increase the benefits of possessing a dolphin-watching permit. Such an algorithm of design priorities provides a systematic approach to planning protected areas (Villa, Tunesi, & Agardy, 2002). It also takes into consideration all parties in the decision process.

Applying the decision rules (Table 2), it is possible to include respectively, 53.1% and 48.6%, of resting and socialising sightings in no-boat zones (Fig. 5). However, the no-boat zones would cover less than 15% of the total area of Doubtful Sound (Fig. 5). These zones would prevent access to only one safe anchorage, one historic site, and one penguin nesting site (Figs. 1 and 5). In addition, setting zones for exclusive access by tour operators with watching permits would restrict further the number of dolphin–boat interactions for an additional 19.6% and 24.6% of resting and socialising sightings, respectively (Fig. 5). Overall this sanctuary network would allow a complete control of interactions over 73.2% of socialising sightings and 72.7% of resting sightings.

This research clearly demonstrates that the bottlenose dolphins resident in Doubtful Sound do rest and socialise in preferred locations in the fjord. These locations are utilised similarly year-round. Some seasonal variations appear that could be related to shifts in distribution. Dolphins tend to spend more time in the main body of the fjord and less time in the arms during colder months (Schneider, 1999). However when dolphins visit these locations during cold seasons, they still utilise them as critical/important regions. For example the status of critical and important resting areas in Crooked Arm (Fig. 3) did not vary significantly with season. This is the first study providing an indication of seasonal consistency in spatial use for socialising and resting in bottlenose dolphins. Other studies have focussed on feeding behaviour and showed that dolphins tend to follow their prey in their home range

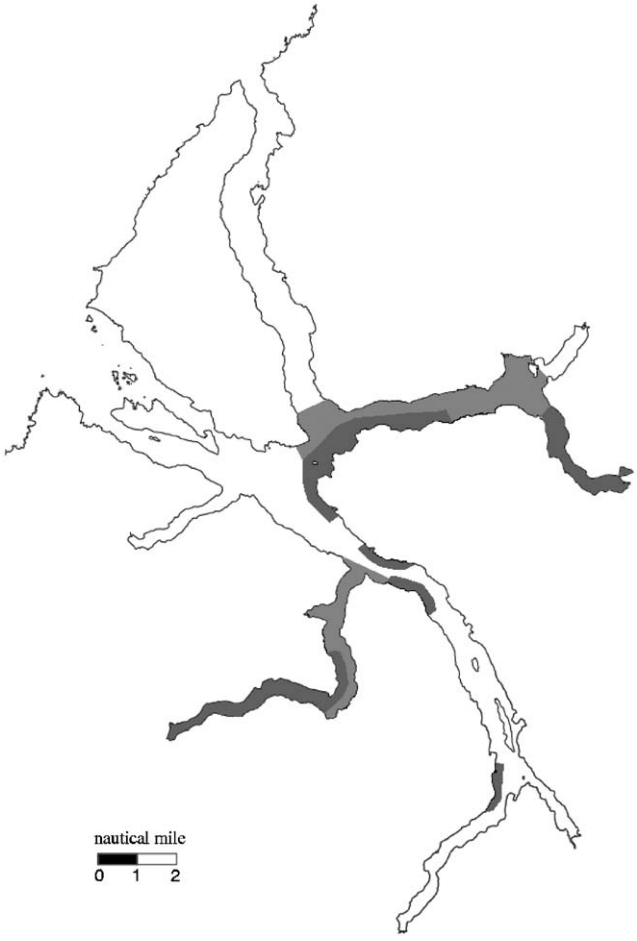

Fig. 5. Proposed multi-level marine mammal sanctuary in Doubtful Sound. Dark gray areas correspond to no-boat zones. Light gray areas correspond to locations where only tour operators that possess a dolphin-watching permit and researchers are allowed. At present this sanctuary would apply to tour operators and researchers only. Non-targeting general traffic needs to be minimised as well in the protected zones.

(Bearzi, Politi, & Notarbartolo di Sciara, 1999; Wilson, Thompson, & Hammond, 1997). However, killer whales (*Orcinus orca*) in a fjord system tend to exhibit area preferences for resting and socialising behaviour as well (Heimlich-Boran, 1988). This seasonal consistency

indicates that spatial protection is a simple and effective way to mitigate the impacts generated by interactions with tourist vessels.

11.1. Benefits for the dolphin population

Dolphins in Doubtful Sound are especially sensitive to interactions with boats when they are socialising and resting (Lusseau, 2003b). The proposed multi-level network of sanctuaries (Fig. 5) would essentially eliminate interactions in zones that are mainly used for these purposes. Overall it provides two levels of restriction on interactions in locations where three-quarters of resting and socialising bouts were observed. The core areas (no-boat zones) provide a safe haven for dolphins and encompass half of the resting and socialising sightings. A second level of restriction (zones only for permitted operators and researchers) allows for total control under the MMPR of the number of vessels, hence the number of interactions that can be present in locations where an additional quarter of socialising and resting sightings were observed.

An important issue of relevance to this study is the stability of socialising and resting areas over time. While this issue could not be addressed within the parameters of the current research, long-term site stability does need to be considered. Geographical and/or ecological factors, perhaps including preferences for certain water depth, shelter, bay configuration and/or lack of currents, may determine preferred socialising and resting areas. An understanding of these factors would afford greater confidence that the proposed areas represent critical habitats, as opposed to short-term preferred locations for these important behaviours.

11.2. Benefits for the tour operators

While no-boat zones would seem to be an effective measure to offer protection to dolphins, it is noteworthy that in this case these areas cover less than 15% of the total area of Doubtful Sound. Therefore, they do not restrict human activities significantly. Only one location regularly visited was reduced in access to tour operators. However the natural resources present in this location (Figs. 1 and 5) are present in other areas and the interpretation of this location for historic purpose (Seymour Island) does not require vessels to be within close range of the island. The proposed multi-level sanctuary would also restore the benefits of holding a dolphin-watching permit. Only permitted operators would be able to access locations where dolphins are more likely to be (Schneider, 1999), and are more likely to be observed socialising. In addition, it would be easier to police such a framework because vessels would be in infraction as soon as they enter a zone in which they are not permitted to be.

It may be argued that the establishment of no-boat zones would ultimately increase the intrinsic economic value of Doubtful Sound because they would increase its Wilderness value (Davis & Tisdell, 1996; Sloan, 2002). Ultimately the proposed boating restrictions would benefit tour operators, regardless of whether they possess a watching permit or not, because tourists would value more commercial operators as they show genuine care for the area (Higham et al., 2001). It is also noteworthy that multi-level reserve networks have proved effective in the conservation of large terrestrial mammals (Soulé & Terborgh, 1999) in areas where they have to co-habit with humans (Noss & Harris, 1986; Crooks, 2002). Regardless of these points, the effectiveness of any proposed management regime is dependent on levels of acceptance and adherence from tour operators. Thus, social science research techniques are critical to ensure that the proposed management approach is workable in terms of the commercial and practical realities of operating a tourism business in this area.

12. Conclusion

If sustainable development in the field of marine ecotourism is to be taken seriously, it is necessary that research employing rigorous scientific techniques is undertaken, and that the findings of such research are acted upon. A growing appreciation of behaviour change in marine mammal species due to engagement with tourist vessels exists. Less is known about the biological significance of behaviour changes. Recent research demonstrates that the disruption of bottlenose dolphins in two behavioural states (resting and socialising) has particularly significant consequences for the energetic budget of the species. This information provides an important starting point for the delineation of critical habitats based on the collection and analysis of spatio-ecological data. Based on this analysis it seems that in the Doubtful Sound context, and possibly other contexts too, a multi-level marine mammal sanctuary provides a solution to mitigating the effects of tourism activities on bottlenose dolphins without jeopardising (and indeed perhaps enhancing) the sustainability of commercial tourism operations.

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