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How does Australia's largest dolphin-watching industry affect the behaviour of a small and resident population of Indo-Pacific bottlenose dolphins?

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ABSTRACT

The small, genetically distinct population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Port Stephens, New South Wales (NSW), is the target of the largest dolphin-watching industry in Australia and is located within the Port Stephens – Great Lakes Marine Park that was created in 2005. The effects of this industry have been identified as of significant management importance by the Marine Parks Authority NSW. Accordingly, the impact of commercial dolphin-watching boats was investigated from boat-based surveys from August 2008 to August 2009. Presence of dolphin-watching boats altered both the dolphins' behavioural states and activity budgets. Dolphins spent 66.5% less time feeding and 44.2% less time socialising, spent four times more milling, and were never observed to rest in the presence of dolphin-watching boats. Moreover, dolphin groups were more cohesive during dolphin-watching boat encounters and dolphins tended to avoid tour boats. These effects were exacerbated as the number of boats increased and the distance from boats decreased. The rate of approach was high with boats approaching each dolphin group three times per day in winter and six times in summer. Moreover, groups of dolphins with newborns were approached closer than state regulated minimum approach distances in nine out of ten encounters. Globally, dolphin-watching industries frequent small resident groups of coastal dolphins and effects are likely to be similar. We suggest that existing controls are inadequate and that these together with additional regulations be enforced by a regular presence of authorities. We suggest no more than one dolphin-watching boat within 50 m of a group of dolphins, or 100 m if calves are present. Operating times of dolphin-watching boats should be restricted in numbers after 1pm, i.e., during preferred foraging times for dolphins. Additionally, exclusion zones should be considered to reduce pressure on dolphins undertaking critical activities such as feeding and resting. We recommend monitoring the effectiveness of new regulations that are incorporated in the reviewed marine park management plan in 2012 for a period of three years.

1. Introduction

The coastal habits of many cetacean species, combined with continued human population growth and development in coastal areas (Crossett et al., 2004), has resulted in many cetacean populations being increasingly exposed to anthropogenic threats (Constantine et al., 2004; Nowacek et al., 2001). One potential threat is the increased exposure of dolphin and whale populations to high levels of boat-based tourism and any concomitant disturbance (e.g., Bejder et al., 2006b; Gregory and Rowden, 2001).

Australia is a hotspot of the whale- and dolphin-watching industry, with more than 1 600 000 national and international participants each year and a high rate of growth averaging 8.3% per annum between 1998 and 2008 (O'Connor et al., 2009). Within Australia, coastal dolphin-watching is common year round in areas where resident populations of bottlenose (*Tursiops* spp.) and Indo-Pacific humpback dolphins (*Sousa chinensis*) occur, and seasonal whale-watching on migrating humpback (*Megaptera novaeangliae*) and southern right whales (*Eubalaena australis*) also often includes dolphin-watching (O'Connor et al., 2009). Bottlenose dolphins are the most targeted species by far, not only in Australia but also other areas around the world (e.g., Bejder et al., 2006b; Constantine, 2001; Lusseau and Higham, 2004).

While there are many common elements in practice, the legislation and therefore management of cetacean-based tourism varies throughout the world. In Australia, the *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment, Water, Heritage and the Arts, 2009) regulates actions that address significant impacts on all listed threatened and migratory species,

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including all whales and dolphins in Australian waters at a federal level. Within New South Wales (NSW) state waters (from shore out to three nautical miles), the NSW Department of Environment and Climate Change (DECC) manages commercial whale and dolphin-watch operations through the *National Parks and Wildlife Act* (DECC, 1974), the *Australian National Guidelines for Whale and Dolphin Watching 2005* (DECC, 2005), and the *National Parks and Wildlife Amendment (Marine Mammals) Regulation 2006* (DECC, 2006). However, marine protected areas in NSW, including the study area (Fig. 1) can have additional strictures as they are also managed by the Marine Parks Authority NSW. The latter may impose specific regulations to manage populations within their boundaries and these may vary from those recommended in the *Australian National Guidelines for Whale and Dolphin Watching 2005*.

The small, genetically distinct population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) inhabiting Port Stephens, NSW (Möller et al., 2002, 2007; Wiszniewski et al., 2009), is the focus of Australia's largest dolphin-watching industry. Port Stephens attracted the largest number of boat-based whale- and dolphin-watch tourists in Australia with more than 270 000 visitors in 2008. Over 80% of these tourists were there for dolphin-oriented tours (O'Connor et al., 2009). The industry started in the early 1990s and has operated year round at high intensity ever since, with up to 15 boats watching dolphins at any one time (Allen et al., 2007). In 1996, the Port Stephens Commercial Dolphin Watch Association developed a voluntary code of conduct. The code of conduct prescribes responsible behaviour for tour boats around dolphins in Port Stephens but is not applicable to recreational boats and has no legislative power. As part of the code of conduct there is a stipulation that operator boats should keep a distance of 50 m from a group of dolphins. However, in 2006 the NSW regulations prescribed a minimum approach distance of 50 m from a group of dolphins that applied to groups composed of only adults or 150 m from groups that included calves (DECC, 2006). The code of conduct also recommends that no more than three vessels should be with a group of dolphins at any given time, that the time spent with a group should be limited to 20 min and it also specifies methods of approach, cruising frequencies, and operating times (Allen et al., 2007). The code of conduct was introduced by industry as a proactive response to perceived threats to the industry of over exploitation of the dolphin population in Port Stephens. However, despite relatively high levels of compliance, the code of conduct has not been effective in reducing the overall time that dolphins are exposed to boats (Allen et al., 2007).

Given that dolphins live in complex fission-fusion groups of vastly different sizes and complexity, and given that they display considerable plasticity in behaviour, local variation in response to anthropogenic disturbances may well occur (Bejder and Samuels, 2003; Constantine et al., 2004; Lusseau, 2004). While there are many common elements to restrictions on dolphin-watching in many parts of the world, local management controls may be required in order to both account for this plasticity in dolphin behaviour, and to meet individual circumstances of local industry. In particular, management strategies for small, resident dolphin populations, where the same individuals are targeted for interactions on a daily basis, may need to be more stringent (e.g., Allen et al., 2007; Bejder et al., 2006b) than those operating on large, non-resident populations, where individuals will have much less frequent interactions (e.g., Stockin et al., 2008).

The aim of this study was to investigate the effects of boat-dolphin interactions on dolphin behaviour and group cohesion and composition (inter-animal distance and age class composition) in Port Stephens in order to inform management of this dolphin population. We assessed how presence, proximity, and number of boats affected dolphin behaviour within Port Stephens.

2. Material and methods

2.1. Data collection

Dolphin behaviour was investigated over three seasons from August 2008 to August 2009 from a 5.5 m aluminium/fibreglass boat with a 60 hp two-stroke outboard motor. The study included two field seasons in cooler months (August 2008 and August 2009) and one field season in warmer months (February/March 2009). The surveyed area (Fig. 1) was divided into grids of approximately 1.5 km^2, with each survey starting from a randomly chosen square. When a group of dolphins was approached by the research boat, scan sampling from focal group follows was used to obtain behavioural samples (Mann et al., 2000).

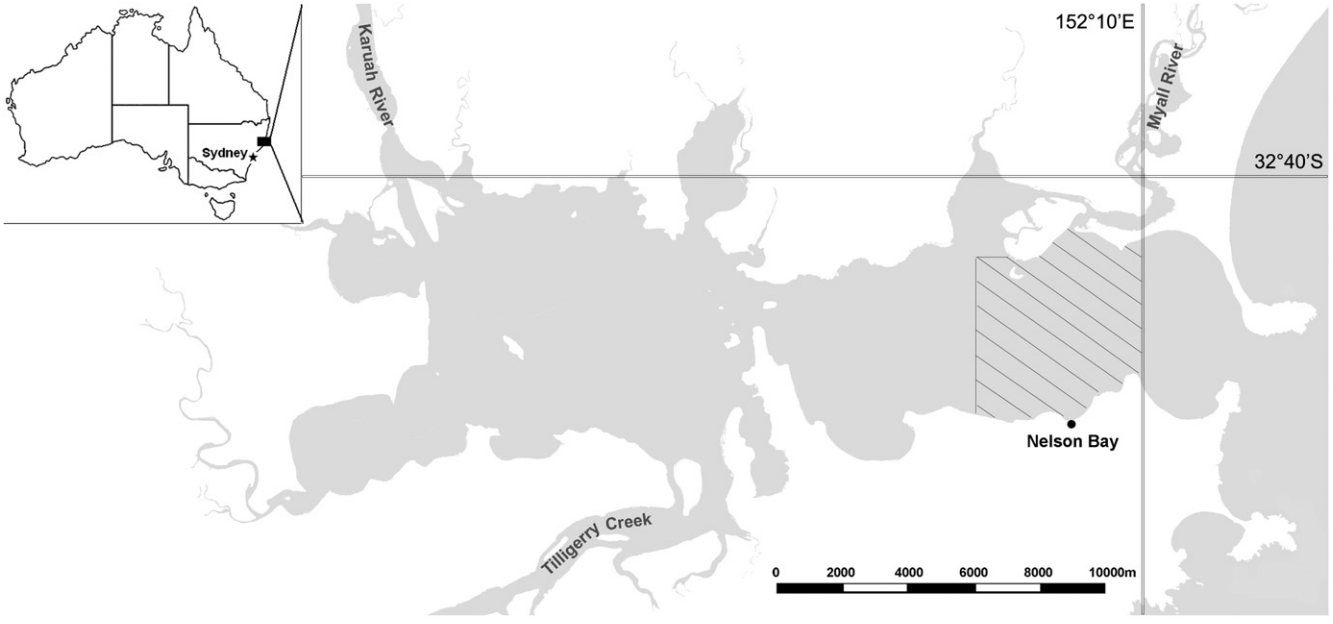

Fig. 1. Study area in Port Stephens as part of the Port Stephens – Great Lakes Marine Park, New South Wales, Australia; the hatched area resembles the study area.

At the beginning of each encounter we recorded time, geographic coordinates using a global positioning system (GPS), estimated group size, group composition, sea state, wind direction, wind speed, and cloud cover. Observations were terminated in the event of precipitation, when sea state reached Beaufort three, or visibility deteriorated due to fog or rain. Scan sampling was used to assess predominant behavioural state , i.e., most group members engaged in the same activity for more than half of the observation time, of the dolphins in a group – resting, milling, feeding, socialising, and travelling (Table 1) at five minute intervals. This sampling assumed that the behaviour observed at the surface was representative of that underwater. A group of dolphins was defined as a set of individuals within a 100 m radius of a central animal and engaging in similar behaviour for periods of minutes to hours (Irvine et al., 1981).

Distances were estimated. The error of distance measures was estimated to be less than approximately 5%. This was determined by estimating distances to objects across a body of water and verifying those with a rangefinder at regular intervals.

The number and the type of vessels within a distance of 100 m, referred to hereafter as *present*, for the duration of each sighting were also recorded. Where two or more boats were present with a group of dolphins at the same time the distance of the closest vessel was noted.

The distance of a dolphin group from a vessel was recorded in two categories; closer than 50 m (*close*) and between more than 50 m and less than100 m (*far*). Observations were only reported for interactions with dolphin-watching boats or with other types of boats. Observations were not reported for when recreational or other boats were present with dolphin-watching boats. Dispersal consisted of three categories; *dispersed* (more than five body lengths between individual dolphins), *average* (one to five body lengths apart), and *cohesive* (less than one body length apart). For single dolphins, dispersal was computed as the modal value for categorical data, i.e., single dolphins were considered to have average dispersal. Composition and size of the group were also recorded. Dolphins were defined as:

1) *adults*, animals of full size, i.e. approximately 2.5 m in length;
2) *juveniles*, animals half to two thirds of the length of an adult;
3) *calves*, animals less than half the length of an adult.

The categories juveniles and calves were used when the overall group composition in comparison with other variables was investigated. However, the category of calves was considered for comparisons with the NSW regulations for whale- and dolphin-watching. In addition, categories for direction of movement were recorded and defined as *towards* (dolphins turn to approach the boat, often coupled with bow-riding in the pressure wave of the boat), *neutral* (individuals do not change direction from that originally recorded), and *away* from the boat (dolphins change direction and move actively away).

To minimise the research boat's potential effects on the dolphins' behaviour, the boat was manoeuvred slowly and carefully (no wake) and where possible a distance of 50–100 m from the group was maintained, although this varied with the group's behavioural state (Table 1). If the dolphins were stationary, milling, or moving slowly for a period of time the engine was turned off or placed in neutral. Despite these precautions the presence of the research boat must still be considered as a potential disturbance factor (Constantine et al., 2004).

Table 1
Ethogram with definitions of behavioural states used in this study (modified from Shane et al., 1986).

Behavioural state	Definition
Travelling	Dolphins involved in persistent directional movement at speeds greater than resting; may involve porpoising at faster speeds.
Socialising	Dolphins leaping, chasing, and engaged in body contact with each other; involves aspects of play and mating with other dolphins; may serve a social and/or sexual role.
Milling	Dolphins showing frequent changes in direction that sometimes appear as a transitional behaviour between other behavioural states and is sometimes associated with foraging, socialising, or play.
Feeding	Dolphins involved in any effort to capture and consume prey as evidenced by chasing fish on the surface, coordinated deep diving with loud exhalations but without contact between individuals, and rapid circle swimming; prey is sometimes observed in the mouth and frequently observed during the foraging bout.
Resting	Dolphins engaged in very slow movements as a tight group, occasionally stationary; lacks the active components of the other behaviours described above.

2.2. Data analyses

A multinomial regression for nominal data that consist of more than two categories was performed using the software R (R Development Core Team, 2009). The resulting figures illustrate the proportion of a pair of a determinant (i.e., type, number, and distance of boats), intervening variable (i.e., behaviour), and an outcome (i.e., group dispersal and direction of movement). Conclusions were based on confidence intervals of the specified determinant category and the corresponding percentage of the specified outcome, i.e., if a confidence interval did not cross the vertical black line corresponding to the mean denoting the expected value for the outcome category, then the corresponding percentage was different from the mean. All statistical tests used a significance level of $p \leq 0.05$.

3. Results

Behavioural data were collected during boat-based surveys during 14 days in August 2008, 13 days in March 2009 and 10 days in August 2009 (total of 37 days) starting randomly in one of nine assigned quadrants. The data included 1435 five minute time intervals for a total of 107 focal group follows with 2602 dolphins encountered. Dolphin groups ranged from one to 60 individuals. The average overall group size was 7.4 (SE = 0.4; range = 1–60) individuals with smaller groups in winter, average 5.3 (SE = 0.3; range = 1–25) individuals, and larger groups in summer, average 11.8 (SE = 1.0; range = 1–60) individuals.

3.1. Behavioural state and activity budget

The analysis suggested that certain behavioural states were affected by the presence of dolphin-watching boats compared to times when only the research boat was present. These activity budgets significantly changed ($\chi^2 = 124.1$, $p < 0.0001$) with the presence of dolphin-watching boats. Dolphins were observed to feed 66.5% less, socialise 44.2% less, mill 406.8% more, and travel 28.8% more when dolphin-watching boats were present (Fig. 2). Resting was never observed when operator boats were present (Fig. 2). The category of other watercraft included all encounters with vessels other than dolphin-watching boats, for example, kayaks, sailing boats, other personal watercraft, ferries, and oyster farm boats. There was no significant effect of other watercraft on the dolphins' behaviour.

The diurnal patterns of dolphins' activity budgets in the absence of boats were also investigated. We separated the data into three categories; before 10 am (morning), between 10 am and 1 pm (midday), and between 1 pm and 5 pm (afternoon). The results

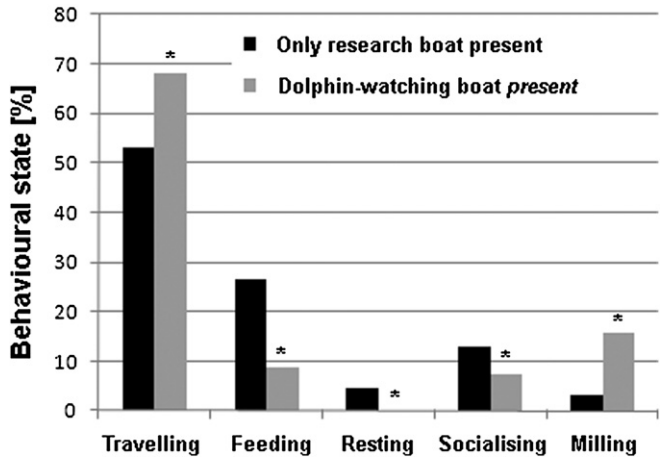

Fig. 2. Activity budgets of Indo-Pacific bottlenose dolphins in the presence and absence of dolphin-watching boats in the Port Stephens – Great Lakes Marine Park, New South Wales, Australia; * indicates significant difference.

showed that there was a significant difference in activity budgets throughout the day ($\chi^2 = 44.3$, $p < 0.0001$; Fig. 3). Dolphins socialised less in the afternoon, rested more in the afternoon, fed more during mornings and afternoons, and travelled more at midday but less in the morning.

3.2. Boat distance

Dolphins spent significantly less time feeding when dolphin-watching boats were close (i.e., closer than 50 m) to the group. They also spent an increased amount of time milling and less time socialising when dolphin-watching vessels were close. Dolphins were not observed to rest when dolphin-watching boats were present, independent of whether boats were far or close to the group ($\chi^2 = 134.3$, $p < 0.0001$; Fig. 4A).

3.3. Boat number

We analysed the potential effects of the number of boats present. We found a significant increase of milling with an increasing number of dolphin-watching boats, less socialising with one operator boat present, no resting observed with any number of dolphin-watching boats, and a significant decrease in feeding with an increasing number of dolphin-watching boats present ($\chi^2 = 128.9$, $p < 0.0001$; Fig. 4B).

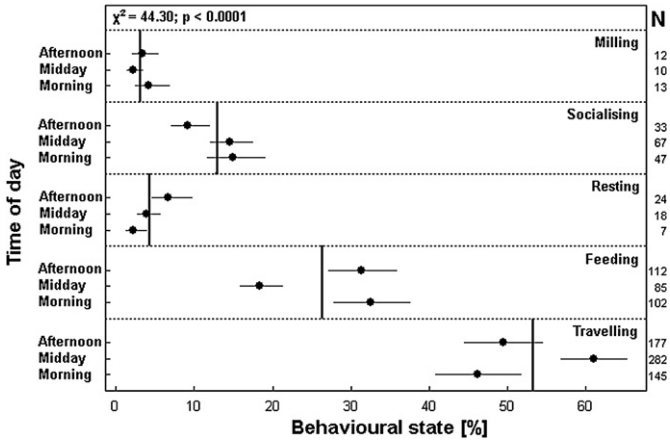

Fig. 3. Effect of the time of day on the behaviour of Indo-Pacific bottlenose dolphins in the Port Stephens – Great Lakes Marine Park, New South Wales, Australia, when only the research boat was present; morning = before 10 am, midday = between 10 am and 1 pm, afternoon = between 1 pm and 5 pm.

3.4. Direction of movement

The general presence of dolphin-watching boats affected the direction of movement of dolphin groups (Fig. 4C). Dolphins showed significantly less neutral direction of movement in the presence of dolphin-watching boats compared to times when only the research boat was present ($\chi^2 = 314.3$, $p < 0.0001$). Dolphins either moved away or towards operator boats. There was no significant impact of other watercraft on the dolphins' direction of movement. There was also a significant increase in the direction of movement away from the boat with an increasing number of dolphin-watching boats and a significant decrease in neutral direction of movement ($\chi^2 = 320.0$, $p < 0.0001$). The distance of dolphin-watching boats to the group of dolphins also affected the direction of movement. There was a significant increase in direction of movement away from the boat with a decreasing distance of dolphin-watching boats and a significant decrease in neutral direction of movement ($\chi^2 = 374.5$, $p < 0.0001$). The movement away from dolphin-watching boats was also positively associated with more cohesive dolphin groups ($\chi^2 = 29.85$, $p < 0.0001$).

3.5. Group dispersal

Analysis of the potential effects of boat type on group dispersal suggested that groups were significantly more cohesive in the presence of dolphin-watching boats compared to times when only the research boat was present ($\chi^2 = 52.88$, $p < 0.0001$). There was no significant effect of other watercraft on group dispersal (Fig. 4D). Dolphin groups were not observed to be dispersed when two or more dolphin-watching boats were present and groups were significantly more cohesive whether one or two operator boats were present ($\chi^2 = 50.13$, $p < 0.0001$). When dolphin-watching boats were present, dolphins were in significantly more cohesive groups regardless of distance ($\chi^2 = 51.22$, $p < 0.0001$).

3.6. Group composition

Dolphin groups that consisted of adults and juveniles/calves had an average of 0.20 (SE = 0.01; range = 0.06–0.5) juveniles/calves per group. The ratio was larger in winter (0.25; SE = 0.02; range = 0.08–0.5) and smaller in summer (0.17; SE = 0.01; range = 0.06–0.4). However, the overall group size (see 3) has to be taken into account for interpretation of these results. In summer, the group size was more than double than it was in winter. Thus, it can be concluded that dolphin groups consisted of approximately one juvenile/calf per four adults in winter and one calf per three adults in summer.

We investigated group composition in terms of behavioural changes in the presence of boats. There was significantly more travelling and resting, and less feeding observed when juveniles/calves were in the group ($\chi^2 = 64.97$, $p < 0.0001$). Cohesive groups were positively associated with groups including juveniles/calves ($\chi^2 = 67.71$, $p < 0.0001$) and groups including juveniles/calves were larger ($\chi^2 = 47.1$, $p < 0.0001$).

Dolphin-watching boats had significantly more encounters with groups of dolphins including juveniles/calves ($\chi^2 = 11.17$, $p = 0.00375$) but there were no significant differences by group composition for other watercraft. For dolphin-watching boat encounters, 13.5% of dolphin groups contained juveniles. 68.9% of all dolphin-watching boat encounters with a dolphin group were at 50 m or closer, at least for a period of time during each encounter. This increased to 90.0% for encounters by dolphin-watching boats

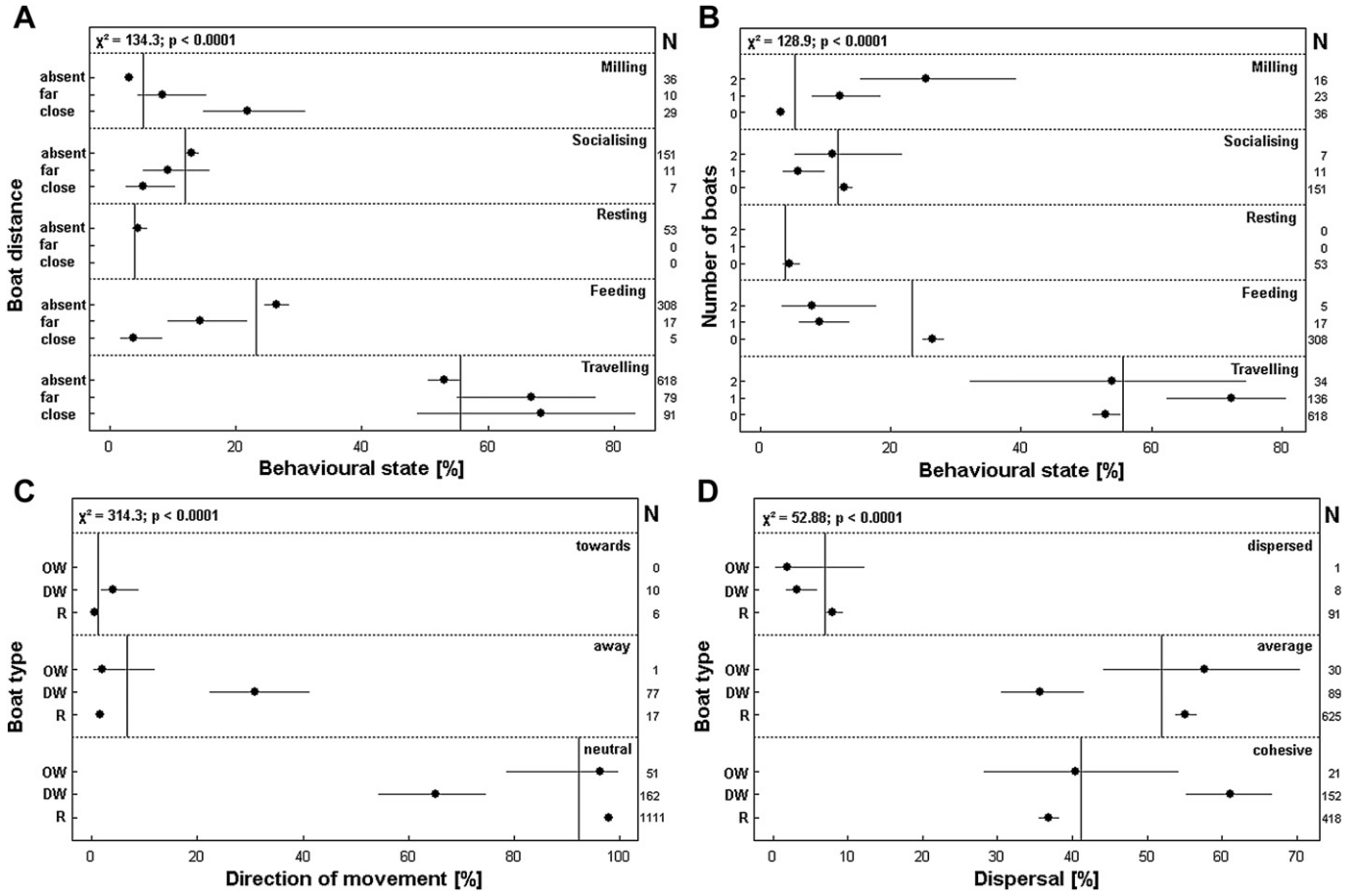

Fig. 4. (A) Effect of the distance of boats on the behaviour of Indo-Pacific bottlenose dolphins in the Port Stephens – Great Lakes Marine Park, New South Wales, Australia; absent = only research boat present, close = dolphin-watching boat present within a distance of 1–50 m, far = dolphin-watching boat present within a distance of 51–100 m. (B) Effect of the number of boats on the behaviour of Indo-Pacific bottlenose dolphins in the Port Stephens – Great Lakes Marine Park, New South Wales, Australia; 0 = only research boat present, 1 = one dolphin-watching boat present, 2 = two or more dolphin-watching boats present. (C) Effect of the boat type on the direction of movement behaviour of Indo-Pacific bottlenose dolphins in the Port Stephens – Great Lakes Marine Park, New South Wales, Australia; OW = one or more other type of watercraft present, DW = one or more dolphin-watching boat(s) present, R = only research boat present. (D) Effect of the boat type on the dispersal behaviour of Indo-Pacific bottlenose dolphins in the Port Stephens - Great Lakes Marine Park, New South Wales, Australia; OW = one or more other type of watercraft present, DW = one or more dolphin-watching boat(s) present, R = only research boat present.

with a group of dolphins including calves. Of these encounters only 1.8% were initiated by dolphins, i.e., direction of movement towards the boat.

3.7. Daily group encounters

Currently, there are eight full time dolphin-watching boat operators in Port Stephens each offering up to three dolphin-watch trips per day. This means on any one day there may be as many as 24 trips per day. The population of identified resident dolphins ($n = 87$; Möller et al., 2002) in Port Stephens is separated into two dolphin communities based on genetic and behavioural measures; the eastern and western community (Wiszniewski et al., 2009). The eastern community makes up 74% of the population (Wiszniewski et al., 2009) and is the main target of dolphin-watching. This suggest that approximately 64 dolphins were targeted by the dolphin-watching industry on a daily basis due to their residency status and core use area in the eastern part of the embayment. The western community dolphins are not targeted by dolphin-watching boat operators due to agreements under the code of conduct. Group size in the current study varied by season, with smaller groups in winter and larger groups in summer (see 3). This means, on average eastern community dolphins were divided into 12.1 and 5.4 groups for winter and summer, respectively. Dolphin-watching boats encountered one to four (mean 1.4; SD = 0.6) dolphin groups per dolphin-watching trip (Allen et al., 2007). The total number of trips per day were multiplied by the mean number of encounters per trip, resulting in 33.6 total encounters per day. This suggests that each group of dolphins was encountered on average 2.8 and 6.2 times per day in winter and summer, respectively.

4. Discussion

This study has provided evidence that in the presence of dolphin-watching boats dolphins spent less time on critical activities, such as feeding, resting, and socialising (see also Lusseau and Higham, 2004), with a change in overall activity budgets. They actively avoided dolphin-watching boats as was apparent from a significant increase in the direction of movement away from the boat. Both responses may negatively influence the long-term viability of this small, local dolphin population (see 4.1). These behavioural changes were generally stronger when dolphin-watching boats were closer or when there were more of them. The avoidance of these boats together with more cohesive dolphin groups in the presence of dolphin-watching boats are typical

responses to anthropogenic disturbance, which is similar to predation risk (see 4.1). Dolphin groups that include juveniles and calves are particularly vulnerable to those impacts as dolphin-watching boats were more likely to approach them and minimum approach distances to these particular groups were exceeded on a regular basis (see 4.2).

4.1. Effects of dolphin-watching boats on dolphin behaviour

Dolphins, as long-lived animals with a complex fission-fusion social structure, may respond to interactions with boats in many different ways (Mann et al., 2000). The results of this study showed that the type, number, and distances of boats affected behaviour states of Indo-Pacific bottlenose dolphins in Port Stephens. There was no resting, less feeding and socialising, and more milling and travelling when dolphin-watching boats were present to within 100 m. When these changes were converted into activity budgets (Fig. 2) they showed a similar trend to that reported in Allen et al. (in press) for the same dolphin population five years earlier. The earlier study was methodologically different as Allen et al. (2007) conducted shore-based observations with binoculars and a scope and examined only general characteristics, such as group formation and direction. In the current study, we were able to distinguish between the distance and number of dolphin-watching boats present with a group of dolphins. With this sampling design, which incorporated more rigorous data collection and more behavioural parameters through focal follows, it was possible to detect an absence of resting in the presence of tour boats.

Other species, for example, common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand, exhibit similar changes of activity budgets in the presence of boats, albeit the intensity of boat interactions per individual dolphin is much lower due to the larger population size and lower levels of boat traffic in the area (Stockin et al., 2008). In Port Stephens, interactions with dolphin-watching boats resulted in changes in behaviour patterns, for example, spending less time feeding and resting, both of which are fundamentally important in physiological terms (Bejder and Samuels, 2003; Lusseau, 2004). If these activities are frequently disrupted, there may be an increase in energy expenditure (Bishop, 1999). Results of the current study indicated that each dolphin group was encountered approximately three times per day in winter and six times per day in summer. Consequently, this may affect the health of individuals as well as their reproductive success and may eventually lead to a decline in population size as reported in other cetacean populations (Constantine et al., 2004; Gregory and Rowden, 2001). A decline in local dolphin abundance, especially of a small, resident population such as the one in Port Stephens, could be of high impact to the dolphin population's long-term sustainability and thus the viability of the local dolphin-watching industry. Research in Shark Bay, Western Australia – which is far more remote compared to the research area in Port Stephens, with only two commercial dolphin-watching vessels operating – found evidence of negative, long-term impacts on the population, including a significant decline in dolphin abundance (Bejder et al., 2006b).

The results of our study indicated that dolphins in Port Stephens spent more time feeding in the mornings and afternoons when only the research boat was present (Fig. 3). These findings suggest that feeding of dolphins in Port Stephens may be altered by the presence of dolphin-watching boats at least during the afternoons. This was also the case for resting and milling throughout the day as there were no differences in their diurnal patterns when only the research boat was present (Fig. 3). However, this changed when dolphin-watching boats were present, with a significant decrease of resting and a significant increase of milling (Fig. 2).

Feeding and socialising budgets decreased in dusky dolphins (Lagenorhynchus obscurus) in Argentina when dolphin-watching boats were present (Dans et al., 2008). The time to return to feeding, as well as the time it took for a group of dolphins to feed, also increased in the presence of vessels. This reduced energy intake coupled with a reduction in social interactions may negatively affect the dolphins' reproductive output (Dans et al., 2008). Repeated disturbance by dolphin-watching boats could increase foraging costs and also prevent dolphins from exploiting resources within parts of their habitat. This means that the intensity of interference may be high even when resource availability is not a limiting factor (Allen and Read, 2000; Begon et al., 2006). Studies on food web relations between the local dolphin population in Port Stephens and their prey are needed to investigate these potential linkages.

The direction of dolphin group movement was also affected by the presence of dolphin-watching boats (Fig. 4C). Dolphins moved away from an increasing number and a decreasing distance of dolphin-watching boats. Other studies of bottlenose dolphins (Constantine, 2001; Lemon et al., 2006; Nowacek et al., 2001) and other cetaceans, such as spotted (*Stenella attenuata*), spinner (*S. longirostris*), and striped dolphins (*S. coeruleoalba*) (Au and Perryman, 1982), and killer whales (*Orcinus orca*; Kruse, 1991) show similar behavioural patterns. For example, the dive duration and surfacing increased and decreased, respectively, in the presence of boats (Janik and Thompson, 1996), and short-term shifts in local habitat use during periods of increased boat traffic occurred (Allen and Read, 2000; Constantine et al., 2004). The movement away from dolphin-watching boats was also positively associated with more cohesive dolphin groups.

Groups of dolphins were generally more cohesive when dolphin-watching boats were present as has been found elsewhere (Bejder et al., 2006a; Blane and Jaakson, 1994; Nowacek et al., 2001). This did not seem to be associated with the number or distance of the vessels. Previous land-based observations of the same population showed similar results and suggested that groups were 2.6 times more likely to be more cohesive when a tour boat was present (Allen et al., in press). This suggests that at least during the five years between the two different studies the animals became neither sensitised nor tolerant to the presence of dolphin-watching boats. It highlights the importance of long-term studies in order to ensure that temporary changes do not drive decision-making. The complex nature of long-lived individuals within cetacean societies (Mann et al., 2000) necessitates those long-term monitoring studies in order to develop responsible and effective management (see 4.3).

Both the impact on the dolphins' dispersal and direction of movement can be considered as typical predator avoidance responses (Blumstein et al., 2003; Howland, 1974). These responses are also perceived by animals through human disturbance, which is similar to predation risk (Walther, 1969). Disturbance can be defined as a deviation in an animal's behaviour from patterns occurring without human influences. Consequently, individuals divert time and energy from other fitness-enhancing activities, such as feeding, parental care, or mating (Frid and Dill, 2002). Hence, these impacts can indirectly affect the long-term viability and fecundity of the targeted population depending on its degree of avoidance towards the perceived disturbance (Gill et al., 2001). A number of recent studies have suggested the response of dolphins to anthropogenic disturbances are likely to be high (Bejder and Samuels, 2003; Constantine et al., 2004; Lusseau, 2004). The dolphin population in Port Stephens might not be able to avoid disturbance by moving away from its current habitat as they appear highly adapted to the environmental and ecological conditions (Wiszniewski et al., 2009, 2010). The distance to and quality of

other suitable sites, the relative risk of predation, or density of competitors in a different site (Gill et al., 2001) might restrict the avoidance of the dolphins to the current perceived pressure of the local dolphin-watching boats. Accordingly, management strategies for small resident dolphin populations including subsets within these populations may need to be more stringent (e.g., Allen et al., 2007; Bejder et al., 2006b) than those addressing large non-resident populations (e.g., Stockin et al., 2008).

4.2. Effects of dolphin-watching boats on group composition

Group composition appeared an important factor in terms of predominant behavioural state, group dispersal, and group size. Resting and travelling increased and feeding decreased in the presence of juveniles/calves and the presence of boats. At the same time, dolphin groups were more cohesive when a group contained juveniles/calves and were also larger.

In Port Stephens, the calving season generally coincides with warmer water temperatures between December and May (Möller et al., 2002) but a small numbers of calves are also born outside this period (A. Steckenreuter, pers. obs.). The current study encompassed two warmer seasons and one cooler season. Hence, the following encounter rates have to be regarded as rather conservative. Dolphin-watching boats generally encountered more groups with juveniles; 13.5% of these encounters contained calves. This may indicate that operators were specifically targeting dolphin groups including juveniles and calves. Dolphin-watching boats also approached groups closer than 50 m in 68.9% of all encounters with dolphins. In contrast to the 2006 NSW regulations (DECC, 2006) that require a minimum approach distance of 150 m when calves are present, the proportion increased to 90.0% of all encounters with groups containing calves.

This not only violates the minimum approach distance of 50 m to a group of dolphins, as agreed upon by the Port Stephens Commercial Dolphin Watch Association under the voluntary code of conduct in 1996, but also is in direct breach of the 2006 NSW regulations. Juveniles and calves may be particularly more vulnerable to disturbance by boats as this may result in fewer opportunities to nurse and rest, and also due to their naivety may increase the risk of collision with vessels (Wells et al., 2008; Wells and Scott, 1997). In Australia, tourism that focuses on free-ranging cetaceans continues to grow and thus the number of tour vessels increases (O'Connor et al., 2009). There are not only a high number of commercial dolphin-watching operators but also a consistently rising number of recreational vessels in Port Stephens (pers. comm., T. Lymant, NSW Maritime). Currently, there are more than 5400 registered recreational boats per year and also an increasing number of general commercial boat operators with 304 registered commercial vessels and an additional 107 hire and drive licences (pers. comm., T. Lymant, NSW Maritime). Concerns have been raised over disturbance to target animals and the potential for this to lead to population level impacts (e.g., Constantine, 1999; IFAW, 1995; IWC, 2001). For small, resident communities of animals that are frequently encountered by dolphin-watching boats, the effects may have a cumulative rather than a catastrophic character (Allen et al., 2007; Duffus and Deardon, 1990). For example, in one instance in this study, a group of dolphins was observed to experience nine encounters with dolphin-watching boats, with an accumulated and continuous time of at least two hours and 40 min spent in the presence of dolphin-watching boats in one day (A. Steckenreuter, pers. obs.). These repeated disruptions by dolphin-watching boats of essential behavioural patterns, such as foraging, resting, and socialising over time may have a direct impact on the health and the reproductive success of individual dolphins and consequently on the targeted population. Future investigations should incorporate Population Viability Analysis (PVA) to investigate the long-term viability of this small resident dolphin population under different hypothetical scenarios.

4.3. Management recommendations

In the case of Port Stephens, the management of dolphin-watching vessels, recreational boats, and other watercraft should be addressed separately as tour vessels generally behave differently towards dolphins than recreational boats (e.g., Connor and Smolker, 1985). So far, management techniques such as the voluntary code of conduct for dolphin-watching boat operators have not succeeded in minimising the impact of the tourism industry in Port Stephens (Allen et al., 2007). Thus, it is strongly recommended that additional local regulations be implemented and enforced. The latter may be achieved by the regular presence of authorities on shore, water, or the dolphin-watching boats themselves.

Management controls should strictly regulate the maximum number of dolphin-watching boats and the minimum distances of boat approaches to targeted dolphins of this population. The number of boats, for example, should be restricted to no more than one dolphin-watching boat within 50 m of a group of dolphins or at least 100 m if calves are present. Calves in Port Stephens are present throughout the year and thus these recommendations should be followed accordingly.

The introduction of zones that exclude dolphin-watching boats where dolphins undertake critical activities such as resting or feeding may be considered as an additional management tool (A. Steckenreuter, unpubl. data). In terms of regulations for all other watercraft a precautionary approach should be implemented. This may include a general speed restriction for all vessels within the marine park to, for example, 20 knots, to reduce potential collisions with marine life, such as dolphins and sea turtles. The emphasis of future work should be on the cooperation between the management of the marine park, research, and the dolphin-watching industry. We recommend monitoring the effectiveness of new regulations that are incorporated in the reviewed marine park management plan in 2012 for a period of three years.

4.4. Conclusions

This study provides important information for the conservation and management of dolphin-watching industries targeting small, resident populations of cetaceans. Those are not only regionally relevant but also globally significant as many discrete small populations contribute to overall global population numbers. However, many of these subpopulations are critically endangered and declining throughout their range (Currey et al., 2010). The aim of this study was to assist with the development of a local management plan to maintain the long-term viability of a small, resident dolphin population and the sustainability of the regional dolphin-watching industry located in Port Stephens, east coast of Australia. The results presented here have implications for the management of dolphin-watching industries elsewhere, particularly new industries. For the latter, we recommend following rather conservative regulations for dolphin-watching operators.

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