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Are Speed Restriction Zones an effective management tool for minimising impacts of boats on dolphins in an Australian marine park?

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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 falls within the recently created Port Stephens—Great Lakes Marine Park. The effectiveness of Speed Restriction Zones (SRZs) as a management tool in this area was investigated during their second year of implementation by comparing dolphin usage and behaviour to adjacent Control Zones (CZs) of similar habitat. For this purpose, boat-based surveys and focal follows of dolphin groups were carried out in the zones between August 2008 and August 2009. Results showed that SRZs were more intensely used by dolphin-watching boats in summer. There was no change in dolphins' behaviour and group structure in the presence of dolphin-watching boats in SRZs when compared to dolphin groups within CZs in any season. Dolphin groups including calves used SRZs less during summer. The latter may indicate a shift in area utilisation for those groups during intense boat traffic by dolphin-watching operators. CZs were more important than SRZs as foraging grounds for dolphins in summer. This indicates that SRZs as specified are not effective at minimising boating impacts and that the location of these zones should in time be revised. This is important information for management of dolphin-watching within this marine park and an example of adaptive management in progress. Moreover these results are relevant for conservation of dolphins and the management of dolphin-watching industries elsewhere, particularly new industries, where management strategies may incorporate marine protected areas including zoning plans.

1. Introduction

Marine conservation is frequently based on the establishment of reserves or marine protected areas (MPAs) to provide protection to target species of concern [1]. With the development of MPAs, and their related conservation management strategies, marine mammals are often chosen as key indicators of ecosystem processes (e.g., [2–4]). In addressing any conservation issue it is important to utilise an appropriate philosophical framework. Jenkins et al. [5] suggest that there are five dimensions to every problem—a substantive, spatial, temporal, quantitative, and qualitative dimension (Fig. 1). These can be interpreted in the light of real conservation issues such as tourism's impacts upon dolphins. In Jenkins et al.'s framework [5], the substantive dimension describes whether or not an activity is harmful and therefore should cease, be modified, or mitigated, for example, boat traffic as a potential threat to dolphins. The spatial and temporal dimensions identify problem boundaries and whether issues are local or widespread and if they are existing, recent, or long term problems, respectively. The quantitative dimension illustrates whether the problem is further caused by single or multiple causes. It addresses whether there could be a cumulative effect, for example, if the presence of vessels is responsible for changes in dolphin behaviour and if speed of vessels further exacerbates effects. Finally, the qualitative dimension explains the cultural and value assessment of, in this case, marine systems and their inhabitants to the community at large.

Long-lived animals, such as dolphins, that exhibit a complex social structure may respond to interactions with boats in many different ways [6]. Indirect effects detectable as short term behavioural responses, may, if of sufficient severity and frequency, affect the health of individual animals, their reproductive success, and consequently population viability on a long term basis [7,8]. Many studies have shown changes in animals' behavioural states when disturbed (e.g., [9–11]). If these are persistent and frequent they may cause increased energy expenditure as a consequence of elevated metabolic rate due to heightened activity [12]. For social animals, changes in group structure (e.g., [13–15])and/or other avoidance tactics such as horizontal or vertical movements away from the source of disturbance may occur (e.g., [16–18]).

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Reduced inter-animal distance as a consequence of changes in group structure in the face of disturbance, as well as evasive movements, may be considered typical predator avoidance responses [19]. As these responses are shown by animals in the face of predation and during anthropogenic disturbance they may be considered to have, if not the same aetiology, at least the same consequences [20]. Both may potentially lead to individuals diverting time and energy from other fitness-enhancing activities such as feeding or parental care [21]. This may be inconsequential, but if animals are energetically constrained, survival and fecundity may ultimately be affected by human interactions and their resulting disturbance [22].

The small, genetically distinct, resident population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) inhabiting Port Stephens, New South Wales (NSW) [23–25], face a large volume of boat traffic. The population interacts with a large number of recreational vessels and is the focus of Australia's largest dolphin-watching industry. The latter focuses on the eastern community of dolphins that comprises about 70% of the total resident dolphin population [25,26]. National and international visitors come to this area predominantly for dolphin-watching cruises and tourist numbers have risen steadily in recent years with more than 270,000 in 2008 [27]. However, not only has the tourism industry expanded but also the use of the area by recreational vessels. Currently, there are more than 5400 registered recreational boats and 107 hire and drive licences within the region and the number of commercial vessels has risen and reached 304 in 2009 (pers. comm., T. Lymant, NSW Maritime).

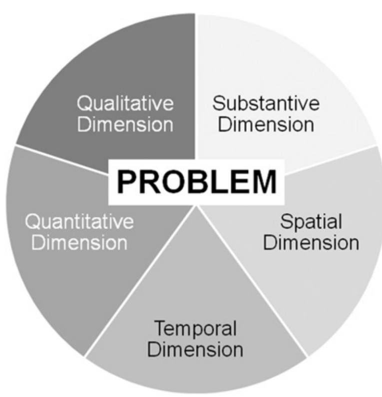

Fig. 1. Schema of Jenkins et al.'s five-dimensional approach to a problem.

The Port Stephens—Great Lakes Marine Park (PSGLMP) was implemented in December 2005 and a zoning plan was drafted by April 2007. The *Marine Parks Act 1997* [28] regulates the implementation of MPAs and related zoning plans in NSW. In terms of the latter, it may include provisions for the classification of areas, the uses permitted and prohibited within such areas, and their management [28]. In particular, it states the importance of conserving marine biodiversity and habitats, maintaining ecological processes, and providing opportunities for anthropogenic use through MPAs. Thus, marine park zoning plans follow strict criteria for site selection: (1) comprehensiveness to cover the full range of marine ecosystems, (2) adequacy to secure the level of reservation and to ensure ecological viability, and (3) representativeness to reflect the biodiversity of the marine ecosystems [29]. These criteria are accompanied not only by the assessment of the vulnerability and the ecological sustainable use of the site, but also economic, indigenous, and social interests [29].

The Marine Parks Authority NSW introduced four different zones to manage the PSGLMP—general use, habitat protection, sanctuary, and special purpose zones [30]. Each zone has specific management objectives that determine the human activities allowed in that particular zone. Most zones allow a wide range of uses such as fishing and boating; more than 80% of the marine park is zoned for extractive uses [30].

Two Speed Restriction Zones (SRZs) were implemented as part of a sanctuary zone that links two highly important conservation areas; Fly Point to the south-east and Corrie Island to the north (see Fig. 2). The 'PSGLMP—Basis for Zoning Sanctuary Zones' plan [29] identifies the former to cover important rocky reef habitat with an immense biodiversity of marine species and the latter to resemble a wide array of habitats, a declared Ramsar site (see [31]) and of international importance for migratory birds [32,33].

The SRZs were implemented in order to provide a trial for the protection of dolphins within the sanctuary zones and limit the speed of any watercraft to four knots (no wake). Previous studies on the dolphin population in the PSGLMP have shown that the presence of dolphin-watching boats, and the number and distance of those vessels to the groups affect dolphins' behaviour and group

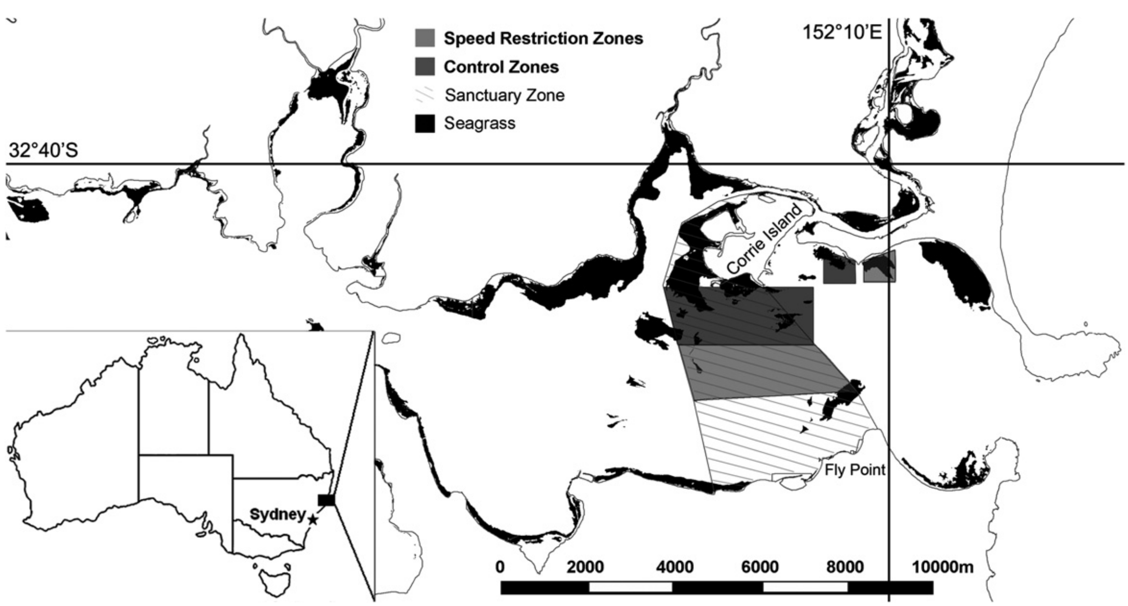

Fig. 2. Study area as part of the Port Stephens—Great Lakes Marine Park, New South Wales, Australia, indicating Speed Restriction Zones and Control Zones; depth contours not indicated.

organisation [11,15,34]. The objective of implementing SRZs was to minimise impacts of boats on resident Indo-Pacific bottlenose dolphins in the marine park. It was hypothesised that dolphins would be less likely to change their behaviour in SRZs in the presence of slow moving boats compared to areas where no speed restrictions were in place. This was expected to translate into smaller changes in the dolphins' behavioural states and group composition in SRZs compared to other areas without speed restrictions.

The aim of this study was to investigate the effectiveness of the SRZs as a management tool to minimise impacts of boats on the local dolphin population that inhabits the PSGLMP approximately two and a half years after the implementation of the marine park. The observations focus on the seasonal utilisation of the areas by boat traffic and the dolphins, particularly on the dolphins' behaviour, group composition, group dispersal, and direction of movement.

2. Methodology

2.1. Data collection

Interactions between boat traffic and dolphins were investigated by boat-based surveys in the eastern part of the inshore waters of the PSGLMP from August 2008 to August 2009. Fig. 2 shows the surveyed area including the two SRZs and adjacent Control Zones (CZs). The latter resemble adjacent areas to the SRZs of similar habitat and size (Fig. 2; Table 1). However, CZs comprise approximately double the amount of area covered by seagrass but were otherwise the most similar available.

The research area was searched for dolphins starting the survey randomly in one of the four zones (Fig. 2). When a group of dolphins was approached by the research boat, scan sampling of focal group follows was used to gain behavioural samples [6]. At the beginning of each encounter time, geographic coordinates using a global positioning system (GPS), estimated group size, group composition, sea state, wind direction, wind speed, and cloud cover were recorded. Observations were terminated in the event of precipitation, when sea state reached Beaufort three, or visibility deteriorated. Scan sampling was used to assess the predominant behavioural state of the dolphins in a group—resting, milling, feeding, socialising, and travelling (Table 2) in 5-min intervals (see [35]). Dispersal consisted of three categories; *more dispersed* (more than five body lengths between individual dolphins), *average* (one to five body lengths apart), and *less dispersed* (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. 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).

Table 1
Habitat composition in Speed Restriction Zones and Control Zones in the study area as part of the Port Stephens—Great Lakes Marine Park, New South Wales, Australia.

Habitat	Categories	Speed Restriction Zones (%)	Control Zones (%)
Sediment	Sand	82	68
	Seagrass	18	29
	Mud	0	3
Depth	0–5 m	98	95
	5–10 m	2	5

Table 2
Ethogram with definitions of behavioural states (modified from [38]).

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; 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, and lacks the active components of the other behaviours described

This sampling assumed that the behaviour observed at the surface was representative of that underwater. A dolphin group was defined as a set of individuals within a 100 m radius of a central animal and engaged in similar behaviour for periods of minutes to hours [36]. Composition and size of the group were also recorded in 5-min intervals. The former was divided into adults and calves, the latter were defined as animals less than half the length of an adult, which is the same definition as in the National Parks and Wildlife Amendment (Marine Mammals) Regulation 2006 [37].

To minimise the research boat's potential effects on the dolphins' behaviour, the boat was manoeuvred carefully and slowly with limited gear changes and no wake. If the dolphins were stationary, milling, or moving slowly for a period of time the engine was turned off or placed in neutral. On occasions when individuals approached the research boat to bow-ride while travelling, the speed and course remained consistent. This allowed the dolphins to determine the length of time they would interact, rather than to initiate or maintain contact with the boat. Where possible, a distance of 50–100 m was maintained, but this varied with the groups' behavioural state.

2.2. Data analyses

Clustered bar charts were used to explore associations between area utilisation by boat types and dolphins' behavioural state, group composition, group dispersal, and direction of movement. When the seasonal utilisation of different areas by dolphins was tested, those samples with dolphin-watching boats within a 300 m radius of the dolphin group were not included in the analysis as it might alter the results. Research has shown that the presence of these vessels alter the behaviour of dolphins [11,15].

Associations between factors and outcomes were further analysed using the Pearson's chi-squared test. Chi-squared tests of association between the factors and each outcome were performed to evaluate those associations. As multiple tests were carried out on the same data significance was set at 0.1% (i.e., $\alpha = 0.001$). All statistical tests were performed using the software R [39,40]. The following graphs show the outcome variables on the x-axis with their observed counts on the y-axis. The black squares indicate expected values for each of the outcome variables.

3. Results

Behavioural data were collected during 35 random transects from August 2008 to August 2009. The data included 814 5-min time intervals of a total of 70 focal group follows.

3.1. Seasonal utilisation of zones by boats

Boat utilisation of zones varied significantly according to season ($\chi^2=33.82$; Table 3). Dolphin-watching boats used CZs significantly more during winter and other watercraft used CZs significantly more in summer ($\chi^2=28.91$; Fig. 3, Table 4). Dolphin-watching boats used SRZs significantly more in summer ($\chi^2=14.60$; Fig. 3, Table 4).

3.2. Seasonal utilisation of zones by dolphins

Dolphins' behavioural states varied significantly by zone and season ($\chi^2=29.87$; Table 3). Dolphins used CZs significantly more for feeding during summer ($\chi^2=14.44$; Fig. 4, Table 4).

SRZs and CZs were also compared as to whether they were used differently by age classes; i.e., if certain zones were more important for groups with only adults or for groups including calves. Dolphins' group composition varied significantly by zone and season ($\chi^2=18.67$; Table 3). Dolphin groups including calves used SRZs significantly less during summer ($\chi^2=16.01$; Fig. 5, Table 4).

Table 3
Summary of Pearson's chi-squared tests of outcome variable and area.

Outcome variable	χ^2	N
Seasonal utilisation by boat type	33.82*	225
Seasonal differences in dolphins' behavioural state	29.87*	630
Seasonal differences in dolphin's group composition	18.67*	630
Differences in dolphins' behavioural state in the presence of dolphin-watching boats	2.46	194
Differences in dolphins' group composition in the presence of dolphin-watching boats	5.26	194
Differences in dolphins' group dispersal in the presence of dolphin-watching boats	7.70	194
Differences in dolphins' direction of movement in the presence of dolphin-watching boats	4.38	194

$p \le 0.001$, *indicates significant differences.

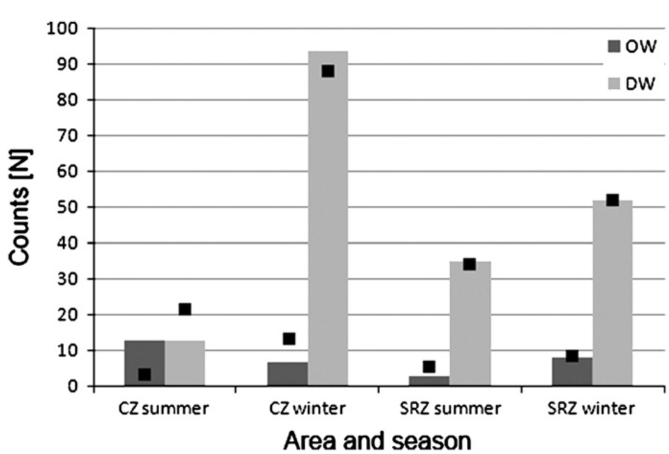

Fig. 3. Utilisation of different zones as part of the Port Stephens—Great Lakes Marine Park, New South Wales, Australia, by boat type; DW=dolphin-watching boats, OW=other watercraft, SRZs=Speed Restriction Zones, CZs=Control Zones, black squares indicate expected values.

Table 4
Summary of chi-squared tests of association between outcome variables and seasonal utilisation of the areas.

Outcome variable		Association outcome variable/area	χ^2	N
Boat type		SRZs summer/winter	0.69	98
		CZs summer/winter	28.91*	127
		CZs/SRZs summer	14.60*	64
		CZs/SRZs winter	1.83	161
Dolphin behaviour	Feeding	SRZs summer/winter	0.08	186
		CZs summer/winter	14.44*	444
		CZs/SRZs summer	7.27	233
		CZs/SRZs winter	0.06	397
	Resting	SRZs summer/winter	9.42	186
		CZs summer/winter	5.08	444
		CZs/SRZs summer	2.25	233
		CZs/SRZs winter	0.60	397
	Others	SRZs summer/winter	3.82	186
		CZs summer/winter	5.30	444
		CZs/SRZs summer	9.46	233
		CZs/SRZs winter	0.51	397
Group composition		SRZs summer/winter	16.01*	186
		CZs summer/winter	2.28	444
		CZs/SRZs summer	0.15	125
		CZs/SRZs winter	6.38	505

$p \le 0.001$, *indicates significant differences.

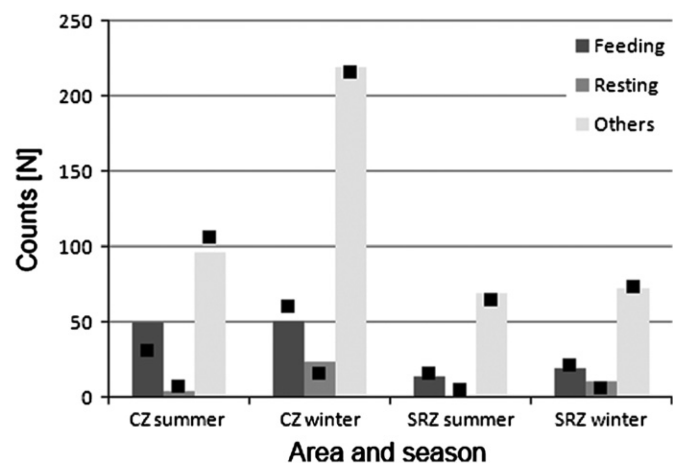

Fig. 4. Seasonal differences in behaviour of Indo-Pacific bottlenose dolphins by zones as part of the Port Stephens—Great Lakes Marine Park, New South Wales, Australia; SRZs=Speed Restriction Zones, CZs=Control Zones, black squares indicate expected values.

3.3. Effects of dolphin-watching boats by zone

We investigated whether dolphin-watching boats had different effects on behavioural state, group composition, group dispersal, and direction of movement of dolphins in SRZs versus the CZs. Neither behavioural state ($\chi^2=2.46$; Table 3), group composition ($\chi^2=5.26$; Table 3), group dispersal ($\chi^2=7.70$; Table 3), nor direction of movement ($\chi^2=4.38$; Table 3) were associated with the presence of dolphin-watching boats in different zones.

4. Discussion

Jenkins et al.'s five-dimensional approach ([5]; Fig. 1) is used to explain the different aspects of the problem. The first dimension,

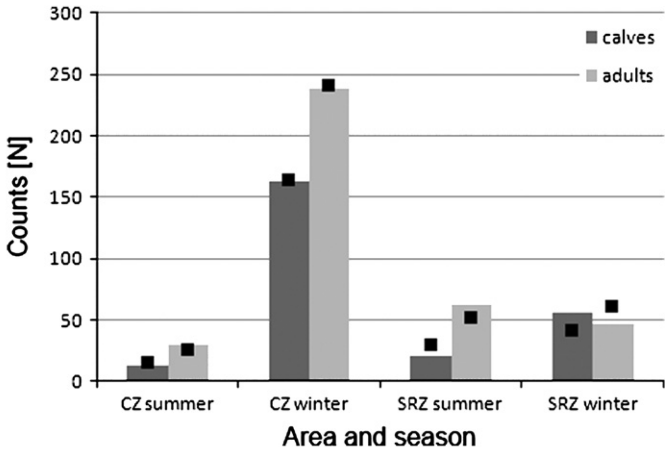

Fig. 5. Seasonal differences in group composition of Indo-Pacific bottlenose dolphins by zones as part of the Port Stephens—Great Lakes Marine Park, New South Wales, Australia; SRZs = Speed Restriction Zones, CZs = Control Zones, black squares indicate expected values.

the substantive level, describes whether or not an activity is harmful and should cease, be modified, or mitigated. Comparisons between SRZs and CZs showed that SRZs as currently designated have not provided areas where impacts of boats on dolphins were minimised (see Section 3.3). This was the case regardless of dolphins' behavioural state, group composition, group dispersal, and direction of movement (see Section 3.3). Nevertheless, findings showed that there are seasonal differences in the utilisation of zones by boats and dolphins and this is further addressed below. However, previous research has shown that important dolphin behaviour and group structure are affected by dolphin-watching boats in the PSGLMP [11,15,34]. Thus, boat traffic as a potential threat (e.g., [7,10,14,41]), at least that generated by commercial dolphin-watching vessels, has to be considered as an ongoing potential disturbance in the PSGLMP [11,15,34].

The spatial dimension identifies the extension of a problem. In our study this was a local problem restricted to a proportion of the resident population of dolphins, with the dolphin-watching industry concentrated on the eastern part of the inshore waters of the PSGLMP and focused on the sub-divided eastern dolphin community [25,26]. However, a local problem provides a microcosm of what may be a spatial management issue at varying scales. The results of this study may be more broadly applicable to dolphin-watching industries elsewhere, some of which face similar challenges albeit at much larger scales, for example, 22,000 km^2 in Shark Bay, Western Australia, or 2500 km^2 in Golfo Nuevo, Argentina (e.g., [9,42]). The PSGLMP management of dolphin-watching is focused on an area of much smaller scale within the 980 km^2 of the marine park [30]. The dolphins' main home range is concentrated on the inshore areas of the PSGLMP, an area that covers only about 166 km^2 [25] and the dolphin-watching industry itself is concentrated in only half this area, focusing on the eastern dolphin community [25,26]. The small spatial scale combined with the fact that it is a small, resident dolphin population, suggests that potential impacts may be intensified.

The temporal scale as the third dimension has three different aspects. Firstly, dolphin-watching boats used the CZs significantly more during winter and other watercraft used the CZs significantly more in summer (Fig. 3). Boat traffic is generally high in the research area, with more than 5400 registered recreational boats and an additional 107 hire and drive licences per year (pers. comm., T. Lymant, NSW Maritime), but visitor numbers peak during the summer months. Secondly, the CZs also appeared to be within important feeding areas for the dolphins at least in summer (Fig. 4) and dolphin groups including calves use SRZs less in summer (Fig. 5). On one hand, this may be due to the fact that CZs comprise a larger area covered by seagrass (Table 1), which may in turn be preferred feeding areas for the dolphins ([43,44], A. Steckenreuter, unpubl. data). On the other hand, the intensified utilisation of SRZs by dolphin-watching boats in summer may be a direct cause for dolphin groups shifting their foraging grounds into other areas including CZs at the same time. This shift in utilisation by different group compositions might also be the case for dolphin groups including calves to avoid these areas during that time. Regardless of the ultimate cause, from an ecological perspective, there was a seasonal shift in certain important behavioural activities, i.e., feeding. In many cetaceans feeding depends on prey availability and distribution, which in turn may be strongly correlated with water temperature and therefore subject to seasonal fluctuations. For example, water temperature is an informative indicator of the distribution and foraging activity of bottlenose dolphins (*Tursiops truncatus*) in the northern Gulf of Mexico [45] and southern resident killer whales (*Orcinus orca*) prefer to forage on Chinook salmon (*Oncorhynchus tshawytscha*) during summer months [46]. Thirdly, there is the temporal scale of management implications. The PSGLMP zoning plan was initiated in April 2007 [30] and will be reviewed in April 2012. Thus, management of the marine park including the SRZs as a management tool to minimise impacts of boats is a recent change and should be addressed accordingly.

The quantitative dimension identifies whether the causes are singular, multiple, and/or cumulative. Recent research on the dolphin population in the PSGLMP has shown that the presence of dolphin-watching boats, the number and the distance of those vessels affect dolphins' behaviour and group organisation [11,15,34]. Whether boat speed or cumulative effects are responsible for changes in dolphin behaviour has still to be determined.

The last and fifth dimension, the qualitative aspect, addresses cultural and value assessments. In the case of the PSGLMP, this is the significance of the marine protected area and its benefits to the community at large. This area is used by people in many different ways including all kinds of recreational activities such as recreational fishing, boating, swimming, surfing, etc. However, the usage is not limited to recreation. There are also a variety of commercial activities that benefit from use of the marine park such as commercial fishing, oyster farms, and tourism.

Investigating the implementation of the SRZs as an efficient management tool in the PSGLMP revealed a few major findings, in particular with regard to the spatial and temporal dimensions of the zones. First, due to the home ranges of the majority (ca. 74%) of resident dolphins [26] overlapping with the area of most intensive boat traffic, boat traffic is an ongoing potential threat. This is the same area targeted by the commercial dolphin-watching industry that is known to affect dolphin behaviour and group organisation [11,15,34]. Secondly, the temporal dimension indicates that SRZs were more intensely used by dolphin-watching boats in summer, but that there was no change in dolphins' behaviour and group structure in the presence of dolphin-watching boats when compared to CZs throughout the seasons. However, the fact that dolphin groups including calves used SRZs less during summer may indicate a shift in area utilisation for those groups during intense boat traffic by dolphin-watching operators. Additionally, CZs were important foraging grounds for dolphins in summer. This indicates that SRZs as specified are not effective at minimising boating impacts and that if these effects are constant that in time the location of these zones should be revised. However, whether dolphins are in the process of adapting or responding to the implementation of SRZs cannot yet be conclusively answered, since their implementation in April 2007 is relatively recent. It is entirely possible that if dolphins respond to changed boat behaviour that medium to long term change may still occur. We recommend monitoring of both SRZs and the CZs over at least a 5-year period. Based on continued long term monitoring it may be possible to modify the zoning plan for the PSGLMP to incorporate changes to SRZs locations, size, or accompanied regulations, and also the potential of introducing additional zones, such as Total Exclusion Zones for all boat traffic. The latter could address seasonal, e.g., only summer, or permanent closures of specific areas that are particularly important for the dolphin population in ecological terms. This is important information for development of a local management plan for dolphin-watching within this marine park and an example of adaptive management in progress. The information may be used by management authorities, such as the NSW Department of Environment and Climate Change and the Marine Park Authority NSW, to modify management plans as information comes to hand in order to use the best evidence available to ensure long term viability of the small, resident dolphin population and sustainable use of the PSGLMP. These results have implications for the conservation of dolphins and the management of MPAs elsewhere, particularly newly introduced ones, where management strategies may also incorporate regulations for dolphin-watching industries.

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