http://dx.doi.org/10.1080/08920753.2012.692312

Smallwood, C.B., Beckley, L.E. and Moore, S.A. (2012) Influence of zoning and habitats on the spatial distribution of recreational activities in a multiple-use marine park. Coastal Management, 40 (4). pp. 381-400.

Influence of Zoning and Habitats on the Spatial Distribution of Recreational Activities in a Multiple-Use Marine Park

CLAIRE B. SMALLWOOD, LYNNATH E. BECKLEY, AND SUSAN A. MOORE

School of Environmental Science, Murdoch University, Murdoch, Western Australia

The spatial distribution of recreation is influenced by many factors, and also differs between activity types. Understanding these relationships is essential for planning and sustainable management of resource use, especially in coastal marine parks, which are often exposed to considerable anthropogenic pressure. However, such information is rarely available, especially at fine spatial scales. Ningaloo Marine Park, in north-western Australia, has a diversity of zoning and habitats, making it an ideal location to investigate the effect of these two attributes on recreational use. Spatially explicit data on a suite of recreational activities were obtained using 192 land-based roving surveys conducted over a 12-month period. Fishing was distributed widely throughout the Marine Park and was negatively associated with sanctuary (no-take) zones, whilst surfing and snorkeling had relatively high participation but were undertaken at localized sites, characterized by a rocky shoreline and sanctuary zones, respectively. Such data provides a greater understanding of patterns of recreational use with respect to zoning and habitat which can inform management and planning processes. This is especially pertinent for sanctuary zones, which, although they exclude recreational fishing and its associated effects, are popular with people participating in non-extractive activities (i.e., snorkeling) and may therefore still be vulnerable to environmental impacts.

Keywords coral reef, Geographic Information System, Ningaloo Reef, recreational fishing, snorkelling, surfing

Introduction

Coastal and nearshore environments are popular sites for recreation as they are easily accessible and contain a diversity of natural attributes. The impacts from recreational

This study was undertaken with the significant financial support of the Australian Government's CSIRO Wealth from Oceans Ningaloo Collaborative Cluster and Murdoch University. This project was completed under Murdoch University Human Research Ethics Committee Permit Number 2006/272. We acknowledge the assistance of Chris Jones, Dani Rob, and Renae Adamson during fieldwork as well as the support of the pastoralists along the Ningaloo coast, the Western Australian Department of Environment and Conservation, Western Australian Department of Fisheries and Commonwealth Department of Defence.

Address correspondence to Claire B. Smallwood, School of Environmental Science, Murdoch University, 90 South Street, Murdoch 6150, Western Australia. E-mail: c.smallwood@murdoch. edu.au

activities undertaken in these environments vary depending on several factors such as activity type and number of participants as well as the resilience of different species, habitats, substrates, and geomorphological features to anthropogenic pressure (Davenport and Davenport 2006; Leujak and Ormond 2007; Lloret et al. 2008a; Meyer and Holland 2008). The type of recreational activity can also have significant implications for the extent of any associated impacts, which can be localized or dispersed. Multiple use marine parks are often designated to help control environmental impacts by using management strategies which balance recreational, and also commercial, elements of human use with biodiversity conservation (Agardy et al. 2003).

Zoning is a spatial management tool that plays an integral part in achieving the objectives of multiple-use marine parks (Day 2008). Most non-extractive activities (i.e., snorkeling and diving) are permitted throughout such marine parks, but there are often zones in which extractive activities (such as recreational line fishing and spearfishing) are prohibited, as they can negatively impact on species and ecosystems (Lewin, Arlinghaus, and Mehner 2006). Although zoning levels and terminology vary widely around the world (Villa, Tunesi, and Agardy 2002; Read and West 2010), areas in which extractive activities are prohibited are commonly referred to as sanctuary (no-take) zones. Zoning can also be used to separate incompatible activities such as diving and fishing (Lynch et al. 2004) or jetskiing and swimming (Roe and Benson 2001).

Benefits of sanctuary zones include a higher abundance and biomass of fauna, when compared to areas in which extractive activities are still permitted (Russ et al. 2008; Claudet et al. 2010). Greater levels of enforcement can improve compliance and enhance these conservation benefits (Davis et al. 2004; Guidetti et al. 2008), while also affecting the spatial distribution of recreational fishers, as they are more likely to be located outside these zones (Smallwood and Beckley 2012). There are limited data, however, on how sanctuary zones, and other zone types, may affect other non-extractive recreational activities, such as snorkeling, diving, surfing or swimming. This small body of literature includes some broad patterns, with snorkelers and divers on charter boats in Florida located mostly within sanctuary areas (Shivlani and Suman 2000). These same activities were documented within Hawaiian sanctuary zones, and their heterogeneous spatial distribution was linked to broad habitat types (Meyer and Holland 2008). Mapping of human use in relation to various water use categories (i.e., conservation area, commercial harbor) has also been undertaken on Rhode Island, demonstrating different spatial distributions between various vessel types (Dalton et al. 2010).

Broad habitat classifications, which often comprise a mix of biological, substrate and geomorphic features, are often used as a surrogate for information on marine biodiversity during marine park design and planning processes (Abdulla et al. 2009; Ban et al. 2009; Dalleau et al. 2010). The use of habitat data in this process assists with selecting sites for a high level of protection that are representative of the broader diversity found in the marine environment (Roberts et al. 2003). Understanding how habitat affects the spatial distribution of different recreational activities is also important to consider, as this may impact on the effectiveness of these highly protected sanctuary zones in conserving biodiversity.

Previous research into the relationship between habitat type and recreational use has been limited to extractive activities (Parnell, Dayton, and Margiotta 2007; Lloret et al. 2008b; Parnell et al. 2010). Fish species have habitat preferences which can attract anglers to a particular site and result in a heterogeneous spatial distribution. For example, within an Australian marine park fishing for squid was strongly correlated with seagrass while trolling for larger pelagic teleost species occurred predominantly in deeper reef areas (Lynch 2006). Other research has provided a broad understanding of habitat preferences for some non-extractive activities, such as relaxing and swimming on sandy beaches (Valdemoro and Jimenez 2006; Schlacher and Thompson 2008; Sarda et al. 2009) or diving on coral reefs (Davenport and Davenport 2006), but this relationship is unknown for many other activities such as kitesurfing, wildlife watching (i.e., coral viewing, whale watching) or surfing.

An understanding of how zoning and habitat influence patterns of recreational use has widespread benefits. Decision support can be provided for the design and site selection of marine parks and sanctuary zones (Parnell et al., 2010). Being able to identify areas of potential environmental impact allows management strategies to be implemented which can mitigate these effects (Davenport and Davenport 2006; Lloret et al. 2008a; Meyer and Holland 2008). Sites of user conflict (Lynch et al. 2004) and overcrowding (Sarda et al., 2009) can be ascertained and this information used to address any management concerns while also maintaining and enhancing visitor satisfaction.

Access points and infrastructure, such as boat ramps, are also known to have a clustering effect on visitor distribution, and have been well researched across a range of recreational activities (Bruce and Eliot 2006; Coombes et al. 2009; Thompson and Dalton 2010; Smallwood, Beckley, and Moore 2012). Although the strong influence of access points and infrastructure is acknowledged, especially in transporting visitors to and from a marine park for recreation from boats and the shore, they were not the focus of this article as the spatial distribution of visitors may also be affected by other, less-understood, factors such as zoning and habitat.

The aim of this study was to examine the influence of zoning and habitat on participation and spatial distribution of recreational activities within a multiple-use marine park. Although the effects of sanctuary zones on recreational fishing have been explored from a biological perspective (Westera et al. 2003; Lester and Halpern 2008), little research has been conducted on the possible effects of zoning on non-extractive recreational activities. Moreover, the heterogeneous spatial distribution exhibited by recreational fishers in marine parks, which has been linked to biological factors such as habitat, has been explored for few other activity types. This article will address some of these knowledge gaps by analyzing a suite of recreational activities. The benefit of understanding the drivers of recreational use of multiple-use marine parks, in which a diversity of recreational activities are frequently undertaken, will also be discussed.

Methods

Study Area

Ningaloo Marine Park comprises part of a world heritage area located adjacent to the remote north-western Australian coast and encompasses a unique 300 km long, fringing coral reef system (Figure 1). The Marine Park extends 5.6 km seaward to the edge of state waters while the landward boundary is located at the low water mark, or 40 m above the high water mark, depending on the adjacent land tenure (CALM and MPRA 2005). The fringing reef crest creates a shallow lagoon environment which provides a sheltered location for recreational activities from boats and the shore. Much of this recreational use is focused on the natural attributes of the reef, including the diverse array of fish and coral species as well as a number of iconic marine megafauna such as whale sharks, manta rays, humpback whales, and turtles (Preen et al. 1997). The remoteness of Ningaloo from major population centres has kept visitor numbers relatively low, at approximately 200,000 per annum (CALM and MPRA 2005), when compared to other iconic coral reef destinations, such as the Great

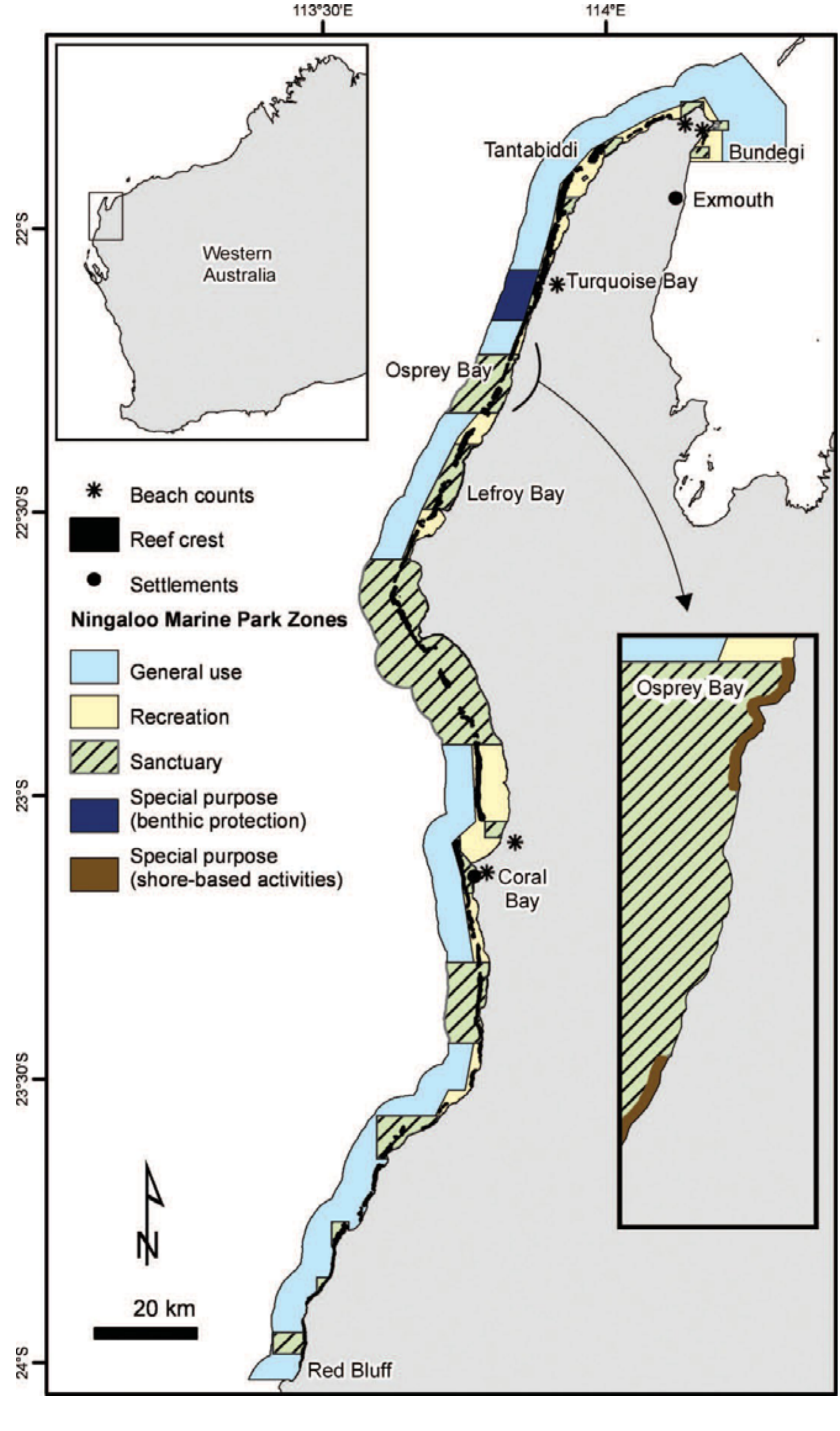

Figure 1. Ningaloo Marine Park, north-western Australia, indicating zoning scheme (color figure available online).

Barrier Reef in north-eastern Australia or Florida Keys in the southern United States. This number is expected to grow with increased visitation due to the recently conferred world heritage status and expected population growth in the region. Peak visitation occurs in the mild winter months from April to October (Smallwood et al. 2011), as the remaining months are characterized by very hot temperatures and risk of cyclonic activity (BOM 2011).

The strategic objectives of marine parks in Western Australia are to preserve representative ecosystems while also ensuring that the various uses of these areas are managed in an equitable, integrated and sustainable manner (CALM & MPRA 2005). To assist with achieving these objectives at Ningaloo Marine Park, there are five zone types, which allow for a range of activities to be undertaken (Figure 1; Table 1). Sanctuary (no-take) zones aim to conserve marine biodiversity by excluding extractive activities that are likely to have adverse environmental impacts. Recreation zones are managed for conservation and recreation, and permit recreational fishing and commercial tourism (while excluding commercial fishing). General use zones permit commercial and recreational fishing as well as aquaculture, provided they do not compromise ecological values (such as coral communities or water quality). Special purpose zones are unique to Western Australia, and have been developed for benthic protection (BP) and shore-based activities (SBA). Special purpose SBA zones were implemented to accommodate recreational line fishers, who are permitted to fish from the shore adjacent to 8 of the 17 sanctuary zones in the Marine Park (Figure 1; inset). The special purpose BP zone also accommodates recreational fishers by allowing targeting of pelagic species by trolling.

The marine and shoreline habitats of Ningaloo Marine Park were broadly characterized by Bancroft and Sheridan (2000) digitising information from aerial images and bathymetry. In this context, marine habitats also incorporate some geomorphic features and were broadly classified into coral reef, bare reef, macroalgae, sand and pelagic. Shoreline habitats (and geomorphology) were broadly categorized into sand, rocky shore, mangroves, and sand/rocky shore. Bare reef and sand comprised the largest percentages of marine and shoreline habitats, respectively, and were distributed across a variety of zone types (Figure 2).

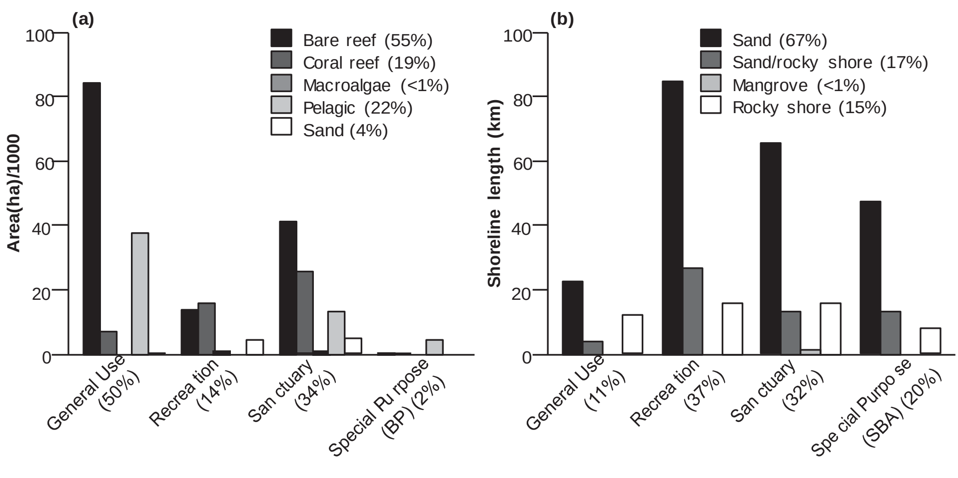

Figure 2. Extent of (a) marine and (b) shoreline habitats located within each zone type of Ningaloo Marine Park, represented as area (ha) and length (km), respectively, as well as percentage of the total [based on CALM & MPRA (2005)].

Ningaloo Marine Park was suited to this study due to its zoning scheme and diversity of habitat types, as well as the availability of geo-referenced data layers for both. This diversity of zones and habitat types caters for a range of recreational activities, and the collection of data on such activities allowed the influences of these two factors to be explored.

Survey Design and Sampling Regime

Land-based coastal surveys were used to collect spatially explicit data on recreational activity occurring from boats and the shore throughout Ningaloo Marine Park. This approach was adapted from well-known roving creel techniques often used to survey recreational fishing (Pollock, Jones, and Brown 1994), and involves researchers travelling in a vehicle to vantage (observation) points situated along a pre-determined route throughout the study area where they undertake counts and/or interviews. Such surveys have been effective at measuring recreational use occurring at small, confined spatial scales such as islands (Smallwood and Beckley 2008) and coastal embayments (Widmer and Underwood 2004). Expanding this technique to a large (~300 km long) study area required splitting Ningaloo Marine Park coastline into three survey routes, each of which covered about 100 km of coastline and could be completed in a single day (Figure 1). Thus, it was possible to survey the entire length of the Marine Park in three days. The two survey routes between Exmouth and Coral Bay were completed six times per month while Coral Bay to Red Bluff was completed four times per month due to logistical challenges and time constraints in accessing this isolated section of coast. The survey was undertaken over a 12-month period from January–December 2007.

The selection of 167 vantage points, each with an unobstructed (and overlapping) view of the shoreline and marine environment, was fundamental to the survey design. Coastal areas, such as that adjacent to Ningaloo Marine Park, are well suited to this type of survey as there are often tourist lookouts and beach access tracks. Travel by vehicle can be slow, especially along parts of the coast with corrugated sand tracks. Observations from vantage points were therefore made progressively over a period of several hours. Such progressive counting may introduce errors from multiple sightings of the same object (i.e., boat or shore-based group). As the aim of this study was to obtain information on participation and spatial extent of activities [similar to Reed-Anderson et al. (2000) and Dalton, Thompson, and Jin (2010)], if a boat was first observed motoring (or transiting), but was later sighted during the same survey while undertaking a recreational activity, then details of the second observation were recorded and the first sighting deleted.

Randomization and stratification ensures that data are representative of the entire population and is often incorporated in survey designs (Pollock, Jones, and Brown 1994). Surveys were stratified by month to ensure equal sampling effort across the study period and days were randomly selected without replacement. Although all day types (weekends, weekdays, and public holidays) were surveyed, this level of stratification was not incorporated into the design due to the small permanent populations located adjacent to the Marine Park (about 2,000 people) which is likely to decrease the effect of day type. The practical limitations of surveying the large, and linear, shape of Ningaloo Marine Park made it difficult to randomize starting location. To mitigate the effect of this, start times were varied between 7:30 am–11 am, and finish times between 1:30 pm–6 pm. Trip direction was also alternated, so sites were visited in both the morning and afternoon.

A handheld global positioning system (GPS) was used to geo-reference the location from which each observation was made and, by using distance and bearing information obtained from a rangefinder (Newcon LRB 4000), it was possible to calculate the actual location of boats or people on the shore. Distances of 2,000 m were consistently achieved, and thus allowed coverage of most of the sheltered lagoon environment. Beyond this, a handheld compass was used to determine bearing, and distance was estimated relative to the reef crest indicated on nautical charts. Each of these observations had associated information on platform (shore or boat), number of people and recreational activity type. A total of 28 activity types was recorded throughout the study period, and the 15 most frequently observed were the focus of this analysis (Table 1). Number of people was often difficult to identify for boat-based activities, especially if a cabin obscured the view of researchers, therefore, these data were analyzed using boats as the unit of measurement while shore-based activities were measured using number of people. At some specific high-use beaches (i.e., Turquoise Bay) (Figure 1), it was not possible to distinguish separate groups, and counts were aggregated to a central location.

All data points were imported into ArcGIS and the spatial distribution of shore and boat-based activities over the 12-month study period was summarized using the point density tool in Spatial Analyst. This tool calculated the density of point features (i.e., vessel or person) associated with each 1 km^2 grid cell located within a continuous network overlaid over the entire study area. Grid cells of this scale were selected after examining the clustering of data points using second-order Euclidean distance, similar to Hengl (2006). For shore-based activity, the number of people associated with each data point was used to weight these calculations (i.e., larger groups had a greater value) while this was not necessary for boat-based activity as each data point was equal to one vessel.

Spatial extent of recreational activities was determined using a second network of 1 km^2 grid cells which, although similar for boats, differed for shore-based activities as the grid-based approach did not sit uniformly over the coastline. To address this, 1 km long coastal segments (which extended 0.5 km inland and 0.5 km seaward of the mean high water mark) were created using the horizontal boundaries of the boating grid network. Using these two networks, spatial extent was calculated by counting the number of cells or segments in which an activity occurred, and contrasted against the level of participation to provide a ratio which standardized these two measures, which more clearly highlighted the differences across activity types. Grid-based analyses also allowed identification of areas where the greatest diversity of shore and boat-based activities occurred. Diversity was measured by counting the number of activity types undertaken in each grid or coastal segment and can provide an understanding of areas of potential user conflict.

In ArcGIS, each data point was identified according to the zone and habitat type on which it was located. Chi squared (χ^2) tests were then used to show the differences in association between the variables of activity type (Table 1), zone and habitat (Figure 2) while log-linear models were used to test for interactive effects. Log-linear modelling is a form of generalised linear modelling in which the expected cell frequencies for each activity type were modelled against the variables (zone and habitat) to indicate association between variables (Agresti 1996). The goodness-of-fit was determined using the residual deviance to calculate a Chi squared statistic comparing each model, with a significant result indicating an interactive effect. The interactions between these two variables were important to consider as habitat type is often used as a surrogate for biodiversity, and can therefore be linked to the placement of sanctuary or other zone types. So as not to violate the assumptions of statistical analysis based on contingency tables (in which no more than 20% of cells should have frequencies greater than five), it was necessary to combine, or exclude, some levels within each variable (Agresti 1996). Only 52 boats were observed in macro-algal and pelagic habitats, and they were combined for this analysis. Moreover, only two people were recorded in mangrove habitats, and these were excluded from analysis.

Table 1

Description of main shore and boat-based activity types, and the zone types in which they are permitted, adapted from CALM & MPRA (2005)

		Zone type				
Activity (platform)	Description	General use	Recreation	Sanctuary	Special purpose SBA	Special purpose BP
Beach games (shore)	Sporting activities conducted on the beach (i.e., frisbee).	√	√	√	√	√
Diving (boat)	Use of compressed air (SCUBA).	√	√	√	√	√
Fishing (boat/shore)	Extraction of marine organisms using a hook and line.	√	√	×[a]	√	×[b]
Kayaking (boat)	Vessel powered by paddles.	√	√	√	√	√
Motoring (boat)	Vessel transiting at high speed.	√	√	√	√	√
Relaxing (shore)	Sunbaking, sitting or resting along the shoreline.	√	√	√	√	√
Sailing sports (boat)	Wind driven sport such as kitesurfing.	√	√	√	√	√
Snorkelling (shore)	Viewing of marine organisms using a face mask.	√	√	√	√	√
Spectating/sightseeing (shore)	Looking at features of interest in the natural environment (including people participating in recreational activities).	√	√	√	√	√
Surfing (shore)	Use of a board to ride waves.	√	√	√	√	√
Swimming (shore)	Partial or full immersion in water.	√	√	√	√	√
Walking (shore)	People travelling on foot along the shoreline.	√	√	√	√	√
Wildlife interaction (boat)	People view wildlife from close proximity (i.e., swimming with manta rays or whale sharks).	√	√	√	√	√
Wildlife viewing (boat)	People view wildlife from a distance (i.e., whale watching and coral viewing from glass bottom boats).	√	√	√	√	√
Unknown (boat)	Activity of vessel could not be ascertained.	√	√	√	√	√

[a]Shore fishing permitted, boat fishing prohibited.
[b]Trolling only.

Sampling Error

The spatial accuracy of each data point was also calculated. Known landmarks, such as a carpark or boat ramp, were used to locate 20% of data points while an additional 15% were obtained by the researcher standing at the exact location. These points therefore had no associated sampling error. Observations that were up to 2,000 m distant comprised 39% of co-ordinates and could be reliably located using the rangefinder, which had an standard error of ±1 m (Newcon Optik 2005). GPS units also have inherent biases and these were assumed to be about 25 m for each data point. Combined with the mean horizontal positional error (obtained from the GPS), these data points had a mean sampling error of 35 m (*SD* = 1 m). The remaining 13% of co-ordinates were located more than 2,000 m distant and, the error associated with these co-ordinates was difficult to quantify.

Results

During the 12-month study, the locations of 2,576 boats and 23,204 people undertaking boat and shore-based recreational activities were geo-referenced, respectively. Of these, 82% of boats and 98% of people were participating in the 15 main activity types (Table 1). Boats were distributed throughout the waters of the Marine Park, with the highest density occurring within the sheltered lagoon area, especially around Tantabiddi, Lefroy Bay, and Coral Bay (Figure 3). People participating in shore-based activities were also widely distributed and had highest densities around North West Cape, Turquoise Bay, and Coral Bay.

Boat-Based Recreational Activities

Boats were most frequently observed while motoring and engaged in unknown activities (Table 2). These same activities also had the greatest spatial extent, being located in more than 9% of grid cells. Motoring vessels travelled at high speed and were mostly likely being observed at the completion, or prior to the commencement of, a specific activity. A specific activity could not be ascertained for some vessels, and they were designated as unknown. Of the remaining boats for which an activity type was ascertained, fishing had both the

Table 2
Level of participation, spatial extent, and ratio of boat-based recreational activities observed during coastal surveys, where n = number of boats

Activity (n)	Participation (% vessels)	Spatial extent (% grid cells)	Ratio (P/S)
Motoring (679)	29.8	9.1	3.3
Wildlife interaction (73)	2.9	1.3	2.2
Diving (78)	3.1	0.7	4.4
Fishing (242)	9.9	3.6	2.8
Wildlife viewing (54)	2.1	0.5	4.2
Sailing sports (122)	5.1	1.6	3.2
Kayaking (117)	4.5	1.4	3.2
Other (290)	7.8	2.8	2.8
Unknown (821)	34.8	11.3	3.1

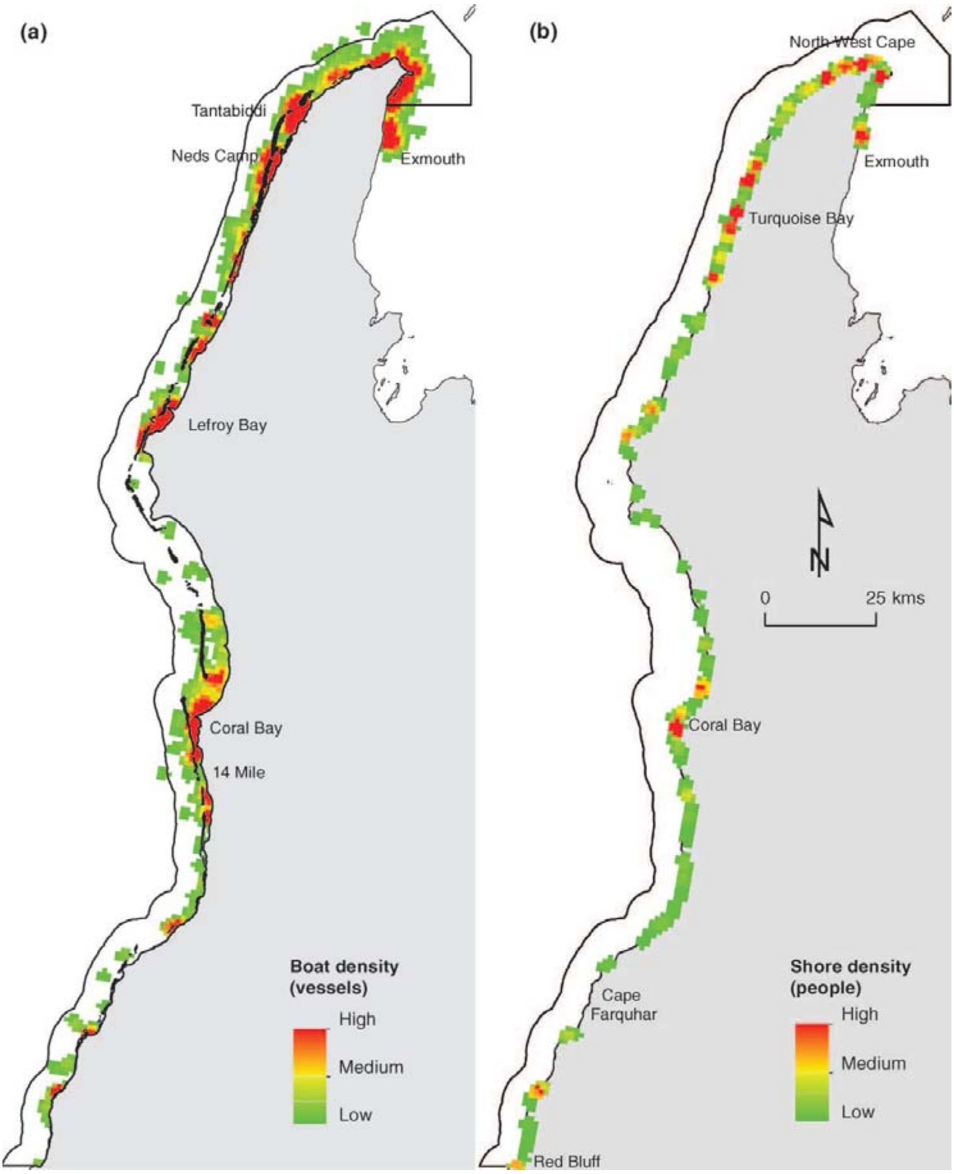

Figure 3. Relative density of (a) boat-based and (b) shore-based activity in Ningaloo Marine Park obtained from coastal surveys (color figure available online).

greatest spatial extent and spatial distribution, while wildlife viewing had the lowest. The participation to spatial extent ratio standardized these two measures across activity types. Diving and wildlife viewing had the highest ratio, indicating they had high participation relative to spatial distribution. Conversely, wildlife interaction and fishing had the lowest ratio, indicating low participation but wide spatial distribution.

Boat-based recreational activities were unevenly distributed across the various zones and habitat types (Figure 4a, b). Chi squared tests found significant differences for both

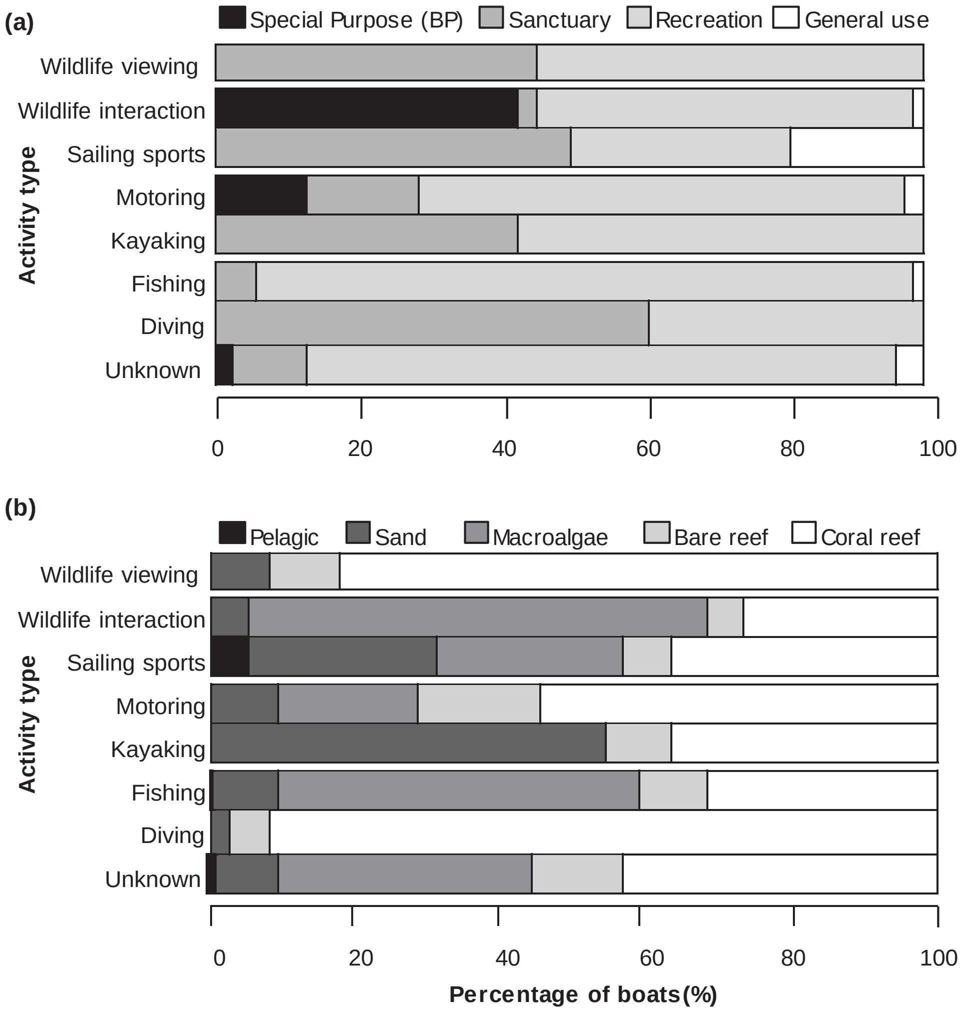

Figure 4. Percentage of boats observed undertaking boat-based recreational activities in Ningaloo Marine Park within each (a) zone type and (b) habitat when standardized by area (number of boats = 2,109).

factors with results of χ^2 (21) = 462, ρ < .05 and χ^2 (21) = 200, ρ < .05, respectively. For zoning, these differences were the result of the higher than expected association of diving and wildlife viewing with sanctuary zones. Other positive attractions were evident between sailing sports and general use zones as well as wildlife interaction and the special purpose BP zone. The strongest negative association was between fishing and sanctuary zones, although 12% of boats were observed while being non-compliant with these zone boundaries. For habitat, coral reef had a strong positive attraction for both diving and wildlife viewing (which includes glass bottom boat tours) while kayaking and sailing sports were strongly associated with sand. The strongest negative associations occurred between kayaking and bare reef habitat as well as diving and sand.

Log-linear analysis was used to test each activity type for interactions between zone and habitat. Significant interactive effects were found for diving (df = 2, deviance =

9, $p < .05$), wildlife viewing (df = 2, deviance = 23, $p < .05$) and kayaking (df = 2, deviance = 16, $p < .05$). Low deviance values indicate a good fit for these models. Diving and wildlife viewing were associated with coral reef habitat located in sanctuary zones, while kayaking was associated with sand habitat in recreation zones. As only three activities (wildlife interaction, motoring and unknown), comprising 18 observations, were recorded in the special purpose BP zone they were excluded from further analysis. Furthermore, many activities are not likely to be undertaken in this zone as it is located offshore, and therefore too far to paddle in a kayak, and in deep water, so unlikely to be popular for diving.

Areas with a high diversity of boat-based activities were identified within the Marine Park. Of all the 1 km^2 grid cells in which boats were observed, more than 50% contained only one type of activity (Figure 5). Conversely, more than five activities were recorded in 2% of 1 km^2 grid cells; these comprised a number of frequently observed activities (Table 1) as well as others which were less common, such as jetskiing and waterskiing. Grid cells with the highest diversity of activities were located at in the northern extent of the Marine Park around Tantabiddi, and further south, at Coral Bay (Figure 1).

Shore-Based Recreational Activities

People were most frequently observed along the shoreline of the Marine Park while relaxing and walking (Table 3). These activities also had the largest spatial distributions and are likely to have been conducted in conjunction with other activity types. Spectating/sightseeing had the smallest participation level while surfing had the smallest spatial distribution. When participation and spatial extent were standardized across activities, relaxing and snorkeling had the highest ratio, indicating high participation levels and relatively small spatial extent, focused on a few sites. Fishing and sightseeing/spectating had the lowest ratios, revealing low participation but wide spatial extent.

Shore-based recreational activities were unevenly distributed across different zones and habitat types (Figure 6a, b). Chi squared tests found significant differences for both

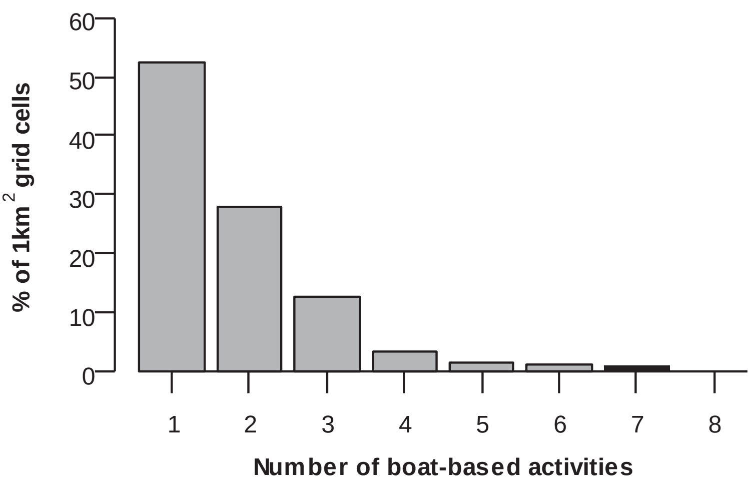

Figure 5. Number of boat-based recreational activity types occurring within 1 km^2 grid cells in Ningaloo Marine Park.

Table 3
Level of participation, spatial extent, and ratio of shore-based recreational activities observed during coastal surveys, where n = number of people

Activity	Participation (% people)	Spatial extent (% segments)	Ratio (P/S)
Relaxing (8,775)	37.8	36.9	1.0
Walking (4,375)	18.8	45.3	0.4
Snorkeling (2,722)	11.7	19.3	0.6
Fishing (2,078)	9.0	41.2	0.2
Swimming (1,775)	7.6	20.1	0.4
Beach games (1,327)	5.7	19.7	0.3
Surfing (752)	3.4	6.6	0.5
Spectating/sightseeing (452)	1.9	18.9	0.1
Other (911)	3.9	45.6	0.1

factors with results of χ^2 (21) = 8,258, $\rho < .05$ and χ^2 (14) = 3,305, $\rho < .05$, respectively. For zoning, these differences were the result of the higher than expected association of surfing and sightseeing/spectating and general use zones and between snorkeling and sanctuary zones. Fishing had a strong negative association with sanctuary zones, and was largely undertaken in special purpose SBA zones. For habitat, surfing and sightseeing/spectating had the strongest association with a rocky shoreline while relaxing and swimming were undertaken predominantly on sand beaches. Although snorkeling also appears to be conducted predominantly on sand habitats, coral reef is often located within close proximity to the sandy shore (<100 m) and is the likely focus of people conducting this activity. Negative associations were found between relaxing and swimming and rocky shorelines.

Log-linear analysis was used to test each shore-based activity type for interactions between zone and habitat. Significant interactive effects were found for all activities ($p <$ .05) although large deviances indicated that these models were not a good fit for explaining the variation in number of people associated with these two factors. Models with the best fits were obtained for swimming (df = 3, deviance = 33, $p < .05$) and beach games (df = 4, deviance = 84, $p < .05$). Both these activities were most strongly associated with sandy beaches in sanctuary zones.

Areas with the highest diversity of shore-based recreational activities were also identified, with a maximum of 15 different types occurring within a single coastal segment (Figure 7), which was located at Coral Bay. Only 20% of coastal segments were associated with a single activity, while more than five activities including fishing, snorkeling, swimming, surfing, and walking were recorded within 32% of coastal segments. Areas of coastline with the greatest diversity of activities were located around Coral Bay, Lefroy Bay, and Turquoise Bay (Figure 1).

Discussion

The spatial distribution and level of participation varied among all the recreational activities surveyed within Ningaloo Marine Park. Boats motoring and people relaxing on the beach had the greatest spatial extent and participation, although when standardized across these two measures, this participation was found to be concentrated within a relatively small area

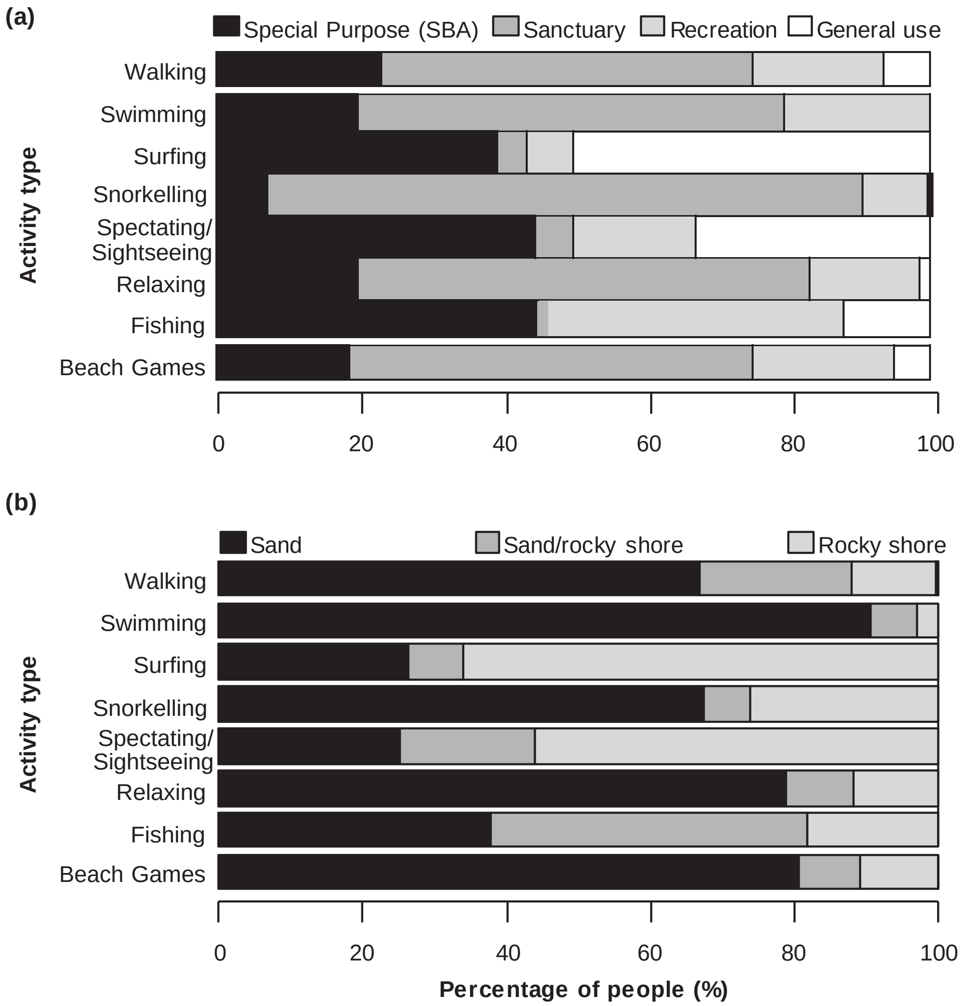

Figure 6. Percentage of people observed undertaking shore-based recreational activities from the shore at Ningaloo Marine Park within each (a) zone type and (b) coastal habitat standardized by length of shoreline (number of people = 22,726).

when compared to other activity types. Motoring is also an interesting activity in that it is likely to precede (or be undertaken after) other specific activity types such as fishing or diving. Fishing was widely dispersed throughout the Marine Park and was negatively associated with sanctuary zones. Surfing and snorkeling were undertaken in more localized areas, characterized by a rocky shoreline and sanctuary zones, respectively. These findings provide a rare insight into patterns of use for a suite of recreational activities occurring across an entire marine park, thereby providing a basis for discussing the implications and benefits for marine parks in terms of zoning and habitat.

Zoning is the centrepiece of many marine park management plans, including iconic locations such the Great Barrier Reef (Kenchington and Day 2011) and Galapagos Islands (Baine et al. 2007). Outside of scientific reference zones, which prohibit all activities, sanctuary (no-take) zones generally offer the highest level of resource protection by

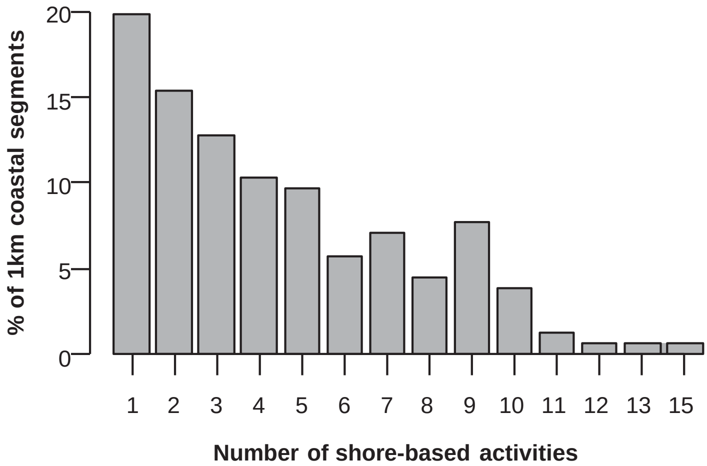

Figure 7. Number of shore-based recreational activity types occurring within 1 km coastal segments at Ningaloo Marine Park.

excluding extractive activities. The aim of these zones is to provide a refuge that assists with maintaining ecosystem function, allows for the replenishment of targeted species and enhancing resilience to natural and human-induced disturbance (Hughes et al. 2003; Russ et al. 2008).

Unsurprisingly, recreational fishing from boats and the shore had a negative association with sanctuary zones. Not only does this suggest good compliance with sanctuary zoning but also an increased likelihood of achieving their conservation objectives, which in Ningaloo Marine Park, are defined as no loss of diversity, biomass, or abundance for key species and habitats (CALM and MPRA 2005). Similar high levels of compliance have been found in several marine parks (Meyer 2007), especially in areas with high levels of enforcement activity (Davis et al. 2004; Guidetti et al. 2008).

More than 40% of people engaged in shore-based fishing at Ningaloo were in special purpose SBA zones. This zone type is unique to Western Australia and was developed during stakeholder engagement for the current 2005–2015 management plan, to excise some parts of the shoreline from sanctuary zones so that fishing could continue at favored sites along the coastline. High participation in fishing within some of these areas suggests these zones are decreasing the level of displacement that may have otherwise resulted from the expansion of sanctuary zones. Displacement of fishing effort is difficult to ascertain without understanding the spatial distribution of an activity before and after the implementation of zoning. Such data are rarely available, and the collection of baseline data is required if such analysis is to be undertaken in the future (Parnell et al. 2010). This survey has demonstrated how this much-needed baseline information can be obtained.

Conversely, sanctuary zoning had a strong association with several non-extractive activities such as snorkeling, diving, and wildlife viewing (i.e., glass bottom boat tours). Although a similar pattern was observed for diving and snorkeling from charter boats in a Florida marine park (Shivlani and Suman 2000), it has not been documented for other activity types. People are attracted to sanctuary zones because they are seen as areas which contain examples of vulnerable, and representative, species or habitats, which can be viewed in an undisturbed state. The attractiveness of sanctuary zones for non-extractive activities such as snorkeling has implications for achieving conservation objectives, as such activities can potentially result in environmental impacts, especially if participation is high. Physical damage is the greatest concern, especially in coral reefs habitats that contain fragile branching coral species in shallow waters (Hawkins et al. 2005; Meyer and Holland 2008). Such impacts result not only from people, but also vessels, as anchoring may also result in damage to many habitat types, including corals and seagrass (Davenport and Davenport 2006; Lloret et al. 2008a).

For habitat, diving was most strongly associated with coral reef, especially if located within a sanctuary zone. This habitat type is known to be attractive to divers, who are drawn to the high levels of biodiversity and multitude of fish species as well as interesting topographies (Rouphael and Inglis 1997; Davenport and Davenport 2006; Roman, Dearden, and Rollins 2007). For shore-based activities, snorkeling appears to be conducted largely off sand beaches, which is an artefact of both using broad a broad habitat classification and also the close proximity (<100 m) of coral reef to the shoreline at Ningaloo Marine Park. Therefore, although snorkelers depart from a sand beach, they are only required to swim a small distance to reach coral reef, which means these areas are quite vulnerable to human impact.

Other non-extractive recreational activity types that have rarely been investigated include swimming, relaxing, and beach games, and they were undertaken predominantly on sand beaches. Sand beaches are known worldwide to be premier locations for recreation, often with high concentrations of people participating in swimming and sunbaking (Valdemoro and Jimenez 2006; Sarda et al. 2009). Research in the United Kingdom has also shown that beach users have preferences for those with greater width and a more shallow gradient (Coombes et al. 2009). Although spatial information on beach slope and gradient were not available for this study at Ningaloo Marine Park, many of the beaches have a gentle gradient due to the shallow lagoon area situated on their seaward side (Collins et al. 2003).

Surfing was most strongly associated with rocky shorelines, particularly at sites located within general use or general use zones. Australia has numerous sites suitable for surfing around its extensive coastline (Farmer and Short 2007), and these can occur on both rocky and sandy shores (Phillips and Mead 2008; Wiegal 2008). Although both these habitats types were distributed widely along the Ningaloo coast, surfing was recorded at a few localized sites, reflecting the strong influence of other environmental factors such as exposure to swell on the presence of surfers (Davenport and Davenport 2006; Lazarow 2009). Although surfing itself has little impact on the marine environment, it does require the support of infrastructure such as roads and beach access for both the surfers and spectators (Davenport and Davenport 2006).

Zoning and habitat both influenced the distribution of shore and boat-based recreational activities in Ningaloo Marine Park. This is a complex relationship and other factors are also likely to play a role in this distribution, especially access points and infrastructure, which affect how people reach recreation sites (Coombes et al. 2009; Thompson and Dalton 2010; Smallwood, Beckley, and Moore 2012). The heterogeneous distribution of recreational activity throughout the Marine Park indicates that high numbers of people are found in localized areas. Areas that experience the highest levels of recreational use, and are more likely to be exposed to the impacts associated with these activities, are generally located in close proximity to the road network and beach access points (i.e., Turquoise Bay and Coral Bay). Similar conclusions were drawn in Florida, whereby dive sites in sanctuary areas located in closest proximity to charter boat departure points were visited more frequently (Shivlani and Suman 2000).

A high diversity of activities, particularly those associated with the shoreline, was undertaken in some localised areas of the Marine Park, and this could lead to potential conflict between users, and also overcrowding, which has implications for safety and visitor satisfaction. Zoning is one mechanism for mitigating recreational conflict by spatially separating incompatible activities (Wang and Dawson, 2005; Day, 2008). Spatial separation of activities may also occur naturally, with different habitat preferences influencing the locations of choice for various activities, as demonstrated in this study. However, social conflict between users may still occur even with limited direct contact, due to differences in core values, which may need to be addressed using other strategies such as education and communication (Vaske et al., 2007; Gray et al., 2010). Spatial separation of activities is already occurring at Ningaloo due to zoning, which excludes extractive activities from sanctuary zones. Additionally, restricted access and speed restrictions for recreational boaters have been implemented in some areas popular with snorkellers and swimmers to increase visitor safety (i.e., in Coral Bay). Similar mechanisms may need to be implemented elsewhere in the Marine Park if visitation continues to increase in areas which were identified as hosting a suite of activities.

Conclusion

This study builds on the emerging body of literature identifying the need for spatially explicit data on recreational activities in order to better inform managers of coastal environments and marine parks, in particular. The findings revealed the diversity of recreational activities which can occur within a multiple-use marine park and highlighted the variability in participation and spatial distribution, which has not previously been explored for many activity types. Some of this variability was associated with zoning and habitat, although the influence of other factors, such as access points and infrastructure, are also important to consider. The benefits of these findings are widespread, as they provide a much needed understanding of patterns of recreational use that can be broadly applied to marine parks, particularly for supporting decisions relating to development and zoning as well as mitigation of environmental impacts and user conflict.

References

Abdulla, A., M. Gomei, D. Hyrenbach, G. Notarbartolo-di-Sciara, and T. Agardy. 2009. Challenges facing a network of representative marine protected areas in the Mediterranean: Prioritizing the protection of underrepresented habitats. *ICES Journal of Marine Science* 66: 22–28.

Agardy, M. T., P. Bridgewater, M. P. Crosby, J. C. Day, P. K. Dayton, R. Kenchington, D. Laffoley, et al. 2003. Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems* 13:353–367.

Agresti, A. 1996. *An introduction to categorical data analysis*. New York, NY: John Wiley and Sons. 290 pp.

Baine, M., M. Howard, S. Kerr, G. Edgar, and V. Toral. 2007. Coastal and marine resource management in the Galapagos Islands and the Archipelago of San Andres: Issues, problems and opportunities. *Ocean and Coastal Management* 50:148–173.

Ban, N. C., G. J. A. Hansen, M. Jones, and A. C. J. Vincent. 2009. Systematic marine conservation planning in data-poor regions: Socioeconomic data is essential. *Marine Policy* 33:794–800. Bancroft, K. P., and M. W. Sheridan. 2000. *The major habitats of Ningaloo Marine Park and the proposed southern extensions* (MMS/PI/NMP&NSW-26/2000). Perth, Western Australia: Department of Conservation and Land Management. 33 pp.

BOM. 2011. *Climate of Learmonth*. Australian Bureau of Meteorology. http://www.bom.gov.au/weather/wa/learmonth/climate.shtml (accessed May 2011).

Bruce, E. M. and I. Eliot. 2006. A spatial model for marine park zoning. *Coastal Management* 34:17–38.

CALM and MPRA (Department of Conservation and Land Management and Marine Parks and Reserves Authority). 2005. *Management plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area: 2005–2015* (Management Plan No. 52). Perth, Western Australia: Department of Conservation and Land Management and Marine Parks and Reserves Authority. 112 pp.

Claudet, J., C. W. Osenberg, P. Domenici, F. Badalamenti, M. Milazzo, J. M. Falcón, I. Bertocci, et al. 2010. Marine reserves: Fish life history and ecological traits matter. *Ecological Applications* 20:830–839.

Collins, L. B., Z. R. Zhu, K. Wyrwoll, and A. Eisenhauer. 2003. Late quaternary structure and development of the northern Ningaloo Reef, Australia. *Sedimentary Geology* 159:81–94.

Confer, J. J., B. Thapa, and J. L. Mendelsohn. 2005. Exploring a typology of recreation conflict in outdoor environments. *World Leisure* 1:12–23.

Coombes, E. G., A. P. Jones, I. J. Bateman, J. A. Tratalos, J. A. Gill, D. A. Showler, A. R. Watkinson, and W. J. Sutherland. 2009. Spatial and temporal modeling of beach use: A case study of East Anglia, UK. *Coastal Management* 37:94–115.

Dalleau, M., S. Andrefouet, C. C. C. Wabnitz, C. Payri, L. Wantiez, M. Pichon, K. I. M. Friedman, L. Vigliola, and F. Benzoni. 2010. Use of habitats as surrogates of biodiversity for efficient coral reef conservation planning in Pacific Ocean Islands. *Conservation Biology* 24:541–552.

Dalton, T. M., R. Thompson, and D. Jin. 2010. Mapping human dimensions in marine spatial planning and management: An example from Narragansett Bay, Rhode Island. *Marine Policy* 34:309–319.

Davenport, J., and J. L. Davenport. 2006. The impact of tourism and personal leisure transport on coastal environments: A review. *Estuarine Coastal and Shelf Science* 67:280–292.

Davis, K. L., G. R. Russ, D. H. Williamson, and R. D. Evan. 2004. Surveillance and poaching on inshore reefs of the Great Barrier Reef Marine Park. *Coastal Management* 32:373–387.

Day, J. C. 2008. The need and practice of monitoring, evaluating and adapting marine planning and management - Lessons from the Great Barrier Reef. *Marine Policy* 32:823–831.

Dinsdale, E. A. and V. J. Harriott. 2004. Assessing anchor damage on coral reefs: A case study in selection of environmental indicators. *Environmental Management* 33:126–139.

Farmer, B. and A. D. Short. 2007. Australian surfing reserves: Rationale and process for recognising iconic surfing locations. *Journal of Coastal Research* SI 50:99–103.

Gray, D. L., R. Canessa, R. Rollins, C. P. Keller, and P. Dearden. 2010. Incorporating recreational users into marine protected area planning: A study of recreational boating in British Columbia, Canada. *Environmental Management* 46:167–180.

Guidetti, P., M. Milazzo, S. Bussotti, A. Molinari, M. Murenu, A. Pais, N. L. Spano, et al. 2008. Italian marine reserve effectiveness: Does enforcement matter? *Biological Conservation* 141:699–709.

Hawkins, J. P., C. M. Roberts, D. Kooistra, K. Buchan, and S. White. 2005. Sustainability of scuba diving tourism on coral reefs of Saba. *Coastal Management* 33:373–387.

Hengl, T. 2006. Finding the right pixel size. *Computers and Geosciences* 32:1283–1298.

Hughes, T. P., A. H. Baird, D. R. Bellwood, M. Card, S. R. Connolly, C. Folke, R. Grosberg, et al. 2003. Climate change, human impacts and the resilience of coral reefs. *Science* 301:929–933.

Kenchington, R. A., and J. C. Day. 2011. Zoning, a fundamental conerstone of effective marine spatial planning: Lessons learnt from the Great Barrier Reef, Australia. *Journal of Coastal Conservation* 15:271–278.

Klein, C. J., C. Steinback, M. Watts, A. J. Scholz, and H. P. Possingham 2010. Spatial marine zoning for fisheries and conservation. *Frontiers in Ecology and the Environment* 8:349–353.

Lazarow, N. 2009. Using observed market expenditure to estimate the value of recreational surfing to the Gold Coast. *Journal of Coastal Research* SI 56:1130–1134.

Lester, S. E., and B. S. Halpern. 2008. Biological responses to marine no-take reserves versus partially protected areas. *Marine Ecology Progress Series* 367:49–56.
Leujak, W. and R. F. G. Ormond. 2007. Visitor perceptions and the shifting social carrying capacity of south Sinai's coral reefs. *Environmental Management* 39:472–489.
Lewin, W. C., R. Arlinghaus, and T. Mehner. 2006. Documented and potential biological impact of recreational fishing: Insight for management and conservation. *Reviews in Fisheries Science* 14:305–367.
Lloret, J., N. Zaragoza, D. Caballero, and V. Riera. 2008a. Impacts of recreational boating on the marine environment of Cap de Creus (Mediterranean Sea). *Ocean and Coastal Management* 51:749–754.
Lloret, J., N. Zaragoza, D. Callabero, T. Font, M. Casadevall, and V. Riera. 2008b. Spearfishing pressure on fish communities in rocky coastal habitats in a Mediterranean marine protected area. *Fisheries Research* 94:84–91.
Lynch, T. P. 2006. Incorporation of recreational fishing effort into design of marine protected areas. *Biological Conservation* 20:1466–1476.
Lynch, T. P., E. Wilkinson, L. Melling, R. Hamilton, A. MacReady, and S. Feary. 2004. Conflict and impacts of divers and anglers in a marine park. *Environmental Management* 33:196–211.
Mathieu, L. F., I. H. Langford, and W. Kenyon. 2003. Valuaing marine parks in a developing country: A case study of the Seychelles. *Environment and Development Economics* 8:373–381.
Medio, D., R. F. G. Ormond, and M. Pearson. 1997. Effect of briefings on rates of damage to corals by scuba divers. *Biological Conservation* 79:91–95.
Meyer, C. G. 2007. The impacts of spear and other recreational fishers on a small permanent marine protected area and adjacent pulse fished area. *Fisheries Research* 84:301–307.
Meyer, C. G., and K. N. Holland. 2008. Spatial dynamics and substrate impacts of recreational snorkelers and SCUBA divers in Hawaiian Marine Protected Areas. *Journal of Coastal Conservation* 12:209–216.
Parnell, P. E., P. K. Dayton, R. A. Fisher, C. C. Loarie, and R. D. Darrow. 2010. Spatial patterns of fishing effort off San Diego: Implications for zonal management and ecosystem function. *Ecological Applications* 20:2203–2222.
Parnell, P. E., P. K. Dayton, and F. Margiotta. 2007. Spatial and temporal patterns of lobster trap fishing: a survey of fishing effort and habitat structure. *Bulletin of Southern California Academy of Science* 106:27–37.
Phillips, D., and S. Mead. 2008. Investigation of a large offshore sandbar at Raglan, New Zealand: Impacts on surfing amenity. *Shore and Beach* 76:53–62.
Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. *Angler survey methods and their applications in fisheries management*. Special Publication 25. Maryland, USA: American Fisheries Society. 465 pp.
Preen, A. R., H. Marsh, I. R. Lawler, R. I. T. Prince, and R. Shepherd. 1997. Distribution and abundance of dugongs, turtles, dolphins and other megafauna in Shark Bay, Ningaloo Reef and Exmouth Gulf, Western Australia. *Wildlife Research* 24:185–208.
Read, A. D., and R. J. West. 2010. Qualitative risk assessment of multiple-use marine park effectiveness - A case study from NSW, Australia. *Ocean and Coastal Management* 53: 636–644.
Reed-Anderson, T., E. M. Bennett, B. S. Jorgensen, G. Lauster, B. Lewis, D. Nowacek, J. L. Riera, B. L. Sanderson, and R. Stedman. 2000. Distribution of recreational boating across lakes: do landscape variables affect recreational use? *Freshwater Biology* 43:439–448.
Rees, S. E., L. D. Rodwell, M. J. Attrill, M. C. Austen, and S. C. Mangi. 2010. The value of marine biodiversity to the leisure and recreation industry and its application to marine spatial planning. *Marine Policy* 34:868–875.
Roberts, C. M., G. Branch, R. H. Bustamante, J. C. Castilla, J. Dugan, B. S. Halpern, K. D. Lafferty, et al. (2003). Application of ecological criteria in selecting marine reserves and developing reserve networks. *Ecological Applications* 13:215–228.

Roe, M., and J. F. Benson. 2001. Planning for conflict resolution: Jet-ski use on the Northumberland Coast. *Coastal Management* 29:19–39.

Roman, G. S. J., P. Dearden, and R. Rollins. 2007. Application of zoning and “limits of acceptable change” to manage snorkeling tourism. *Environmental Management* 39:919–830.

Rouphael, A. B., and G. J. Inglis. 1997. Impacts of recreational scuba diving at sites with different reef topographies. *Biological Conservation* 82:329–336.

Russ, G. R., A. J. Cheal, A. M. Dolman, M. J. Emslie, R. D. Evans, I. Miller, H. Sweatman, and D. H. Williamson. 2008. Rapid increase in fish numbers follows creation of world’s largest marine reserve network. *Current Biology* 18:R514–R515.

Sarda, R., J. Mora, E. Ariza, C. Avila, and J. A. Jimenez. 2009. Decadal shifts in beach user sand availability on the Costa Brava (Northwestern Mediterranean Coast). *Tourism Management* 30:158–168.

Schlacher, T. A., and L. M. C. Thompson. 2008. Physical impacts caused by off-road vehicles to sandy beaches: spatial quantification of car tracks on a Australian barrier island. *Journal of Coastal Research* 24:234–242.

Shivlani, M. P., and D. O. Suman. 2000. Dive operator use patterns in the designated no-take zones of the Florida Keys National Marine Sanctuary (FKNMS). *Environmental Management* 25:647–659.

Smallwood, C. B., and L. E. Beckley. 2008. Benchmarking recreational boating pressure in the Rottnest Island reserve, Western Australia. *Tourism in Marine Environments* 5:301–317.

Smallwood, C. B., L. E. Beckley, and S. A. Moore. 2012. An analysis of visitor movement patterns using travel networks in a large marine park, north-western Australia. *Tourism Management* 33:517–528.

Smallwood, C. B., and L. E. Beckley. 2012. Spatial distribution and zoning compliance of recreational fishing in Ningaloo Marine Park, north-western Australia. *Fisheries Research* 125–126:40–50.

Smallwood, C. B., L. E. Beckley, S. A. Moore, and H. T. Kobryn. 2011. Assessing patterns of recreational use in large marine parks: A case study from Ningaloo Marine Park, Australia. *Ocean and Coastal Management* 54:330–340.

Stamieszkin, K., J. Wielgus, and L. R. Gerber. 2009. Management of a marine protected area for sustainability and conflict resolution: Lessons from Loreto Bay National Park (Baja California Sur, Mexico). *Ocean and Coastal Management* 52:449–458.

Thompson, R., and T. M. Dalton. 2010. Measuring public access to the shoreline: The boat-based offset survey method. *Coastal Management* 38:378–398.

Valdemoro, H. I., and J. A. Jimenez. 2006. The influence of shoreline dynamics on the use and exploitation of Mediterranean tourist beaches. *Coastal Management* 34:405–423.

Villa, F., L. Tunesi, and T. Agardy. 2002. Zoning marine protected areas through spatial multiple-criteria analysis: The case of the Asinara Island National Marine Reserve of Italy. *Conservation Biology* 16:515–526.

Ward, T. J., M. Vanderklift, A. O. Nicholls, and R. Kenchington. 1999. Selecting marine reserves using habitats and species assemblages as surrogrates for biological diversity. *Ecological Applications* 9:691–698.

Westera, M., P. Lavery., and G. Hyndes. 2003. Differences in recreationally targeted fishes between protected and fished areas of a coral reef marine park. *Journal of Experimental Marine Biology and Ecology* 294:145–168.

Widmer, W. M. and A. J. Underwood. 2004. Factors affecting traffic and anchoring patterns of recreational boats in Sydney Harbour, Australia. *Landscape and Urban Planning* 66:173–183.

Wiegal, R. L. 2008. Waikiki Beach, Oahu, Hawaii: History of its transformation from a natural to an urban shore. *Shore and Beach* 76:3–30.