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BENCHMARKING RECREATIONAL BOATING PRESSURE IN THE ROTTNEST ISLAND RESERVE, WESTERN AUSTRALIA

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Rottnest Island, off Western Australia, is a popular holiday destination with 0.5 million visitors annually, of which 150,000 arrive by private vessel. Management of these vessels is difficult as few data are available on their visitation patterns and associated recreational activities. An observational survey was conducted to provide baseline data. It clearly indicated higher vessel numbers during summer and on public holidays with some mooring areas exceeding 100% occupancy during these periods. Scuba diving and surfing were recorded at numerous locations around the island in the summer and winter months, respectively. Recreational fishing generally occurred throughout the year. The spatial and temporal patterns of boating and associated recreational usage can be used to assess the impact of management decisions and provide a benchmark for long-term monitoring.

Key words: Moorings; Fishing; Scuba diving; Zoning; Marine management

Introduction

Many small offshore islands around the world, particularly those adjacent to large population centers, are important tourism destinations popular for a wide variety of recreation and boating activities (Conlin & Baum, 1995; Henderson, 2001). In recent years, increased visitation to such destinations, due to easier access through better ferry or air transport and higher private ownership of boats, has increased the likelihood of environmental impacts from boating and associated activities. These impacts are well documented and many previous studies have focused on their quantification and minimization (Buerger, Hill, Herstine, & Taggart, 2000; Crawford, Stolpe, & Moore, 1994; Davenport & Davenport, 2006; Grigg, 1994; Medio, Ormond, & Pearson, 1997; Turner et al., 1997; Warnken & Leon, 2006). However, few studies have attempted to quantify the level of visitation and identify usage patterns of boaters in marine environments. The widespread application of Geographic Information Systems (GIS) in recent years has begun to support this type of research at fine-scale spatial resolutions (Pelot & Wu, 2007; Soiseth, Kroese, Liebermann, & Bookless, 2007).

The underrepresentation of boating data in research and monitoring programs increases the challenges facing resource managers who have the mandate of balancing sustainable use with protection of the natural environment, while also maintaining positive recreational experiences (Hall,

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1999; O'Conner, Zerger, & Itami, 2005). Informed decision making becomes more difficult without adequate knowledge of resource usage at appropriate spatial and temporal scales (Cessford & Muhar, 2003; English, Kocis, & Zarnock, 2004; Nickerson-Tietze, 2000). Tourism destination areas located offshore are also unique in that visitors who travel by private vessel are often not required to purchase tickets or follow set access routes, from which they can be monitored using traditional land-based options such as car counters. Furthermore, boaters may be self-sufficient and not utilize any landing facilities (if present), which increases the difficulty of collecting or conveying information to these users. However, access routes or vantage points located around the island, from which observations can be made of the surrounding marine area, would help facilitate monitoring efforts.

The increased availability of leisure time in developed countries such as Australia and the US allows more opportunities to pursue recreational activities (Pigram & Jenkins, 2001). These activities are frequently undertaken in natural areas, such as national parks, wilderness, and marine protected areas, which have also experienced significant growth in visitation in recent years (Newsome, Moore, & Dowling, 2007). This is particularly pertinent for marine areas, and the Great Barrier Reef Marine Park Authority (GBRMPA) has acknowledged marine tourism to be an important issue on the Great Barrier Reef (Harriott, 2004).

The issues associated with increased marine tourism, which includes those from boating and recreational activity, can be broadly categorized into ecological, cultural, and social facets (Harriott, 2002). Ecological impacts from boating can be specifically identified as anchor damage, pollution (e.g., waste discharge and antifouling paint) (Grigg, 1994; Turner et al., 1997), littering (Abu-Hilal & Al-Najjar, 2004; Department of Conservation and Land Management, 1996), increased turbidity (Crawford et al., 1994), erosion (Brouwer, Turner, & Voisey, 2001), and injury and behavioral effects on marine animals (Bejder, Samuels, Whitehead & Gales, 2006; Nowacek & Wells, 2001; Preen, 2001). Social facets of boating impacts include overcrowding, user conflicts, and safety concerns (Brouwer et al., 2001; Crawford et al., 1994; Falk & Gerner, 2002), while cultural impacts relate to effects of marine tourism on traditional land users (Harriott, 2004).

These impacts from boaters may result in the inability of managers to achieve their goals of a sustainable natural ecosystem (Cole, Hammond, & McCool, 1997). However, the effects can be controlled or mitigated through the use of direct and indirect management tools including zoning, use of moorings, speed restrictions, access restrictions (Bates, 1992; Soiseth et al., 2007), signage (Herstine, Jeffery, & Buerger, 2006), and compliance or education patrols. Zoning is an effective tool that can achieve multiple outcomes to reduce user conflict, separate incompatible activities, protect biodiversity, and maintain fisheries (Bohnsack, 1995; Day, 2002; Lynch et al., 2004). This is especially useful as the spatial distribution of activities, and their impacts, are not homogeneously spread throughout marine environments (Stelzenmuller, Rogers, & Mills, 2008) as users are influenced by various site choices based on previous experience, social and physical settings (McFarlane, Boxall, & Watson, 1998). This may be based on the availability of sheltered anchorages for snorkeling or good swell for surfing, and leads to the natural partitioning of these activities. However, some sites may be popular for a number of activities, resulting conflicts between those conducting the activities, and also with the ecological values of an area (Fox, 1996). These conflicts are more likely to occur with increasing demand for marine resources (Agardy, 1993; Burger & Leonard, 1999; Davis & Tisdell, 1995). However, it may still be possible to partition these activities using zoning, such as utilized in the Jervis Bay Marine Park to separate divers and anglers (Lynch et al., 2004). As well as spatial restrictions on activities, temporal limitations may also be applied: for example, daily and seasonal quotas for vessel access in the Glacier Bay National Park, Alaska (Soiseth et al., 2007).

Additional pressures on marine environments also occur from the impacts of recreational activities associated with boats such as scuba diving, snorkeling, and fishing. Damage from SCUBA diving is generally concentrated in heavily dived areas (Rouphael & Inglis, 2001; Schleyer & Tomalin, 2000) and is normally caused by a small percentage of divers (Rouphael & Inglis, 1995).

Snorkelers are less likely to impact on the reef as they spend more time on the surface, but damage may occur in locations with water entry access points and shallow water where people are able to stand, especially at low tide (Allison, 1996; Harriott, 2004). The impacts from recreational fishing activities have been well documented (Cooke & Cowx, 2004; McPhee, Leadbitter, & Skilleter, 2002).

Although there are negative impacts from boating and recreational activities, these pursuits also provide economic benefits for communities (Dixon, Fallon Scura, & Van't Hof, 1995), with tourism being one of the world's leading industries (Lundberg, Krishnamoorthy, & Stavenga, 1995). The majority of people who visit marine and terrestrial areas for recreation derive pleasure from their experiences (Ban & Alder, 2008; Gray, Durwors, Villeneuve, Boyd, & Legg, 2003) and the preservation of these natural environments for future generations must also be considered when developing management approaches (International Council for the Exploration of the Sea [ICES], 2005). Therefore, a good understanding of the patterns of human usage is essential.

This study used an observational survey technique to provide a baseline from which the level of boating and marine recreational activity around Rottnest Island, Western Australia, could be quantified and applied in management. The longitudinal and geo-referenced survey approach allowed analysis to be structured on fine-scale spatial (i.e., bays) and temporal (i.e., day type and month) levels. Within this survey framework, information was collected on several aspects of recreational usage including the occupancy of moorings and anchorages, boat-based activities, and shore-based marine recreational activities. The effectiveness of this technique and the management implications of increasing boating pressure on marine resources at Rottnest Island, and within the wider context of other popular boating and tourism destinations, are explored.

The Study

Study Area

Rottnest Island is located only 18 km offshore from the Western Australian capital of Perth (with a population of approximately 1.3 million people) (32°00′S, 115°30′E) (Fig. 1). Covering an area of 19 km^2, the island coastline is highly variable and characterized by sandy bays, limestone reefs, cliffs, and intertidal platforms which range up to 200 m in width (Playford, 1983). The surrounding waters are generally <20 m deep, support a variety of habitat types and, because of the influence of the southward flowing Leeuwin current, has diverse marine biota (~ 420 fish species) including the southernmost coral reef in Western Australia (Hutchins, 1979, 1991). The island experiences a Mediterranean-type climate that is characterized by wet winters and dry summers. Summer winds are predictable with easterlies in the morning followed by fresh afternoon sea breezes from the southwest. Winter wind conditions are more variable and cold fronts generate gale force northwesterly to southwesterly winds (Pattiaratchi, Imberger, Zaker, & Svenson, 1995). The predominant swell direction is from the south-west in summer and the west in winter, and, as a result, the south and west corners of the island receive the greatest wave action (Hastings, Hesp, & Kendrick, 1995). However, during severe storms, the swell is refracted around the island and extensive wave action can occur in all areas except bays on the eastern end of the island (Hastings et al., 1995; Wells & Walker, 1991).

These diverse biological and environmental attributes, as well as its close proximity to Perth result in Rottnest Island being an extremely popular tourism destination with an estimated 0.5 million visitors each year. Approximately 150,000 visitors reach the island by private vessel while the remainder travel on commercial ferries (Rottnest Island Authority, 2003). The Rottnest Island Authority (RIA) is the Western Australian government statutory body responsible for the management of the island and surrounding waters (out to approximately 800 m). This area is a gazetted reserve and the RIA ensures that it is managed for the purpose of public recreation and the protection of flora, fauna, and the natural environment (Rottnest Island Authority, 2003). In the past, concerns were raised that despite the importance of the marine area within the reserve, insufficient resources had been allocated to its management (Government of Western Australia, 1995). This was particularly pertinent to management of private vessels, as

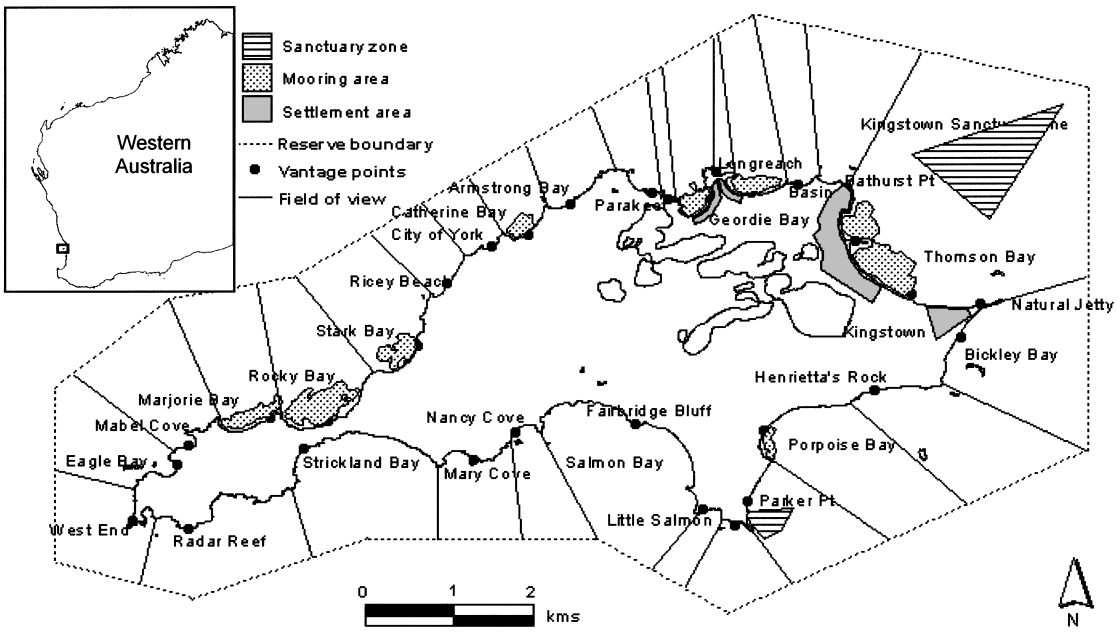

Figure 1. Rottnest Island, off the coast of southwestern Australia, with 2003 sanctuary zones, settlements, mooring areas, the reserve boundary, vantage points, and associated fields of view.

there is a finite number of moorings and anchorages available. To address these issues, a marine management strategy, including a marine reserve zoning plan incorporating 16% of the reserve waters across five sanctuary zones, was implemented in 2007 (Rottnest Island Authority, 2007a). This expanded on the previous management plan that was in place during the boating study, which incorporated two sanctuary areas (comprising 3% of the reserve waters) (Fig. 1), as well as zones for specific activities in high-use areas to avoid user conflicts in small embayments such as the Basin (Rottnest Island Authority, 1997, 2003).

As with many other tourism destinations worldwide, the number of visitors to Rottnest Island has been increasing in recent years and, as a result, the surrounding marine environment is subject to intense pressure, especially from private vessels. Vessel ownership in Western Australia is the highest per capita in Australia with 72,000 registered recreational boats, of which 47,000 are in the Perth metropolitan area (Department for Planning and Infrastructure, 2007). Many of these vessels are capable of making the crossing to Rottnest Island. Boats are permitted to anchor in the waters of the reserve and, to avoid damage to seagrass beds or limestone reefs, skippers are encouraged to anchor only in sandy areas (Hastings et al., 1995; Rottnest Island Authority, 2007b). Moreover, there are 897 swing moorings for boats installed in eight official locations around the reserve (Rottnest Island Authority, 2003) (Fig. 1). Thomson Bay has an additional 76 jetty and beach pen berths. With the exception of 33 RIA rental moorings, all moorings within the Rottnest Island Reserve are licensed to private boat owners. However, due to increased public demand for moorings and the limited geographical area available at Rottnest Island, a new system, whereby additional authorized users can occupy vacant moorings, has been recently implemented. Although the occupancy levels of moorings are unknown, evaluation has shown that the system is working effectively at improving access to authorized users (C. Wright, RIA, personal communication, 2006).

Recreation from private vessels, and the shore, is also popular as the diversity of the marine environment in the Rottnest Island Reserve lends itself

to a range of activities. There are a number of dive locations that can be easily reached from the shore, private vessels, and charter boats (which offer half- or full-day diving tours) (Beilby, 1988). Snorkeling from the shore is also an extremely well-liked activity by visitors (Hutchins, 1998) and annual surfing competitions are held on the island at Strickland Bay. Recreational fishing is widely practiced from both boats (Sumner & Williamson, 1999) and the shore (Smallwood, Beckley, & Sumner, 2006). Recreational rock lobster fishing (crayfishing) using pots is also a popular pastime in Western Australia and occurs in the reserve during the open season (Melville-Smith, Anderton, & Caputi, 2001). Although passengers on private vessels undertake various recreational pursuits while visiting the reserve, no data exist on the numbers or locations of boats providing platforms for these activities.

Methods

Direct observation of boating activity was undertaken concurrently with a shore-based recreational angling creel survey implemented from January until December 2003 (Smallwood et al., 2006). Surveys were conducted 8 days per month (for a total sample size of 96 surveys) and days were grouped into four randomly selected pairs of consecutive days to reduce travel costs to and from the island. Stratification of surveys was undertaken by both day type (weekday and weekend/public holidays) and time of day (morning/afternoon). Morning and afternoon shifts were 6 hours in length and were scheduled from 0700 to 1300 and 1300 to 1900, respectively. An equal number of samples for all strata were undertaken each month and surveys were randomized by starting point and travel direction.

The route for each survey encompassed one complete trip (30 km) around the island using a bicycle, visiting vantage and access points that allowed clear identification of boats, and their associated recreational activities, along the entire coastline within the reserve waters (which extend to about 800 m from the shore) (Fig. 1). In each designated mooring/anchoring area the numbers of each vessel type were recorded and assigned to categories as indicated in Table 1, which were similar to those used in other studies (Adams, Tippett, Nunn, & Archibald, 1992; Warnken & Leon, 2006; Widmer & Underwood, 2004). Outside of the designated mooring/anchorage areas, the various recreational activities (crayfishing with pots, scuba diving, fishing, and surfing) were identified and ascribed to the field of view indicated on Figure 1. These fields of view were also used to document the location of recreational activities undertaken from the shore (snorkeling, fishing, and surfing).

The data were stored and queried in a Microsoft Access database prior to analysis using the SPSS statistical package. Further to this, georeferenced data layers were utilized in the GIS program ArcView 3.2 to summarize and display information collected during field surveys.

Results

Distribution of Moored/Anchored Boats

In total, 16,853 boats were recorded as moored/anchored in the bays of Rottnest Island during the survey. On weekends, the most frequently recorded types of boats were motor cruisers (mean ± SE = 114 ± 18.26) which were approximately three times more abundant than on weekdays (Fig. 2). Similarly, the average counts of both open boats and sail boats on weekends were double those recorded on weekdays. Unattended tenders (small dinghies) attached to moorings were the dominant vessel type on weekdays. A distinct seasonal pat-

Table 1
Classification of Vessels in the Rottnest Island Reserve

Category	Description
Motor cruiser	Motor vessel with cabin accommodation
Sail boat	Vessel able to travel by wind power
Open boat	Motor vessel with no cabin accommodation
Tender	Small dinghy propelled by oars or small outboard motor used to carry passengers to the shore but often left secured to moorings in the absence of the parent vessel
Motoring/sailing	Any vessel type underway in the reserve

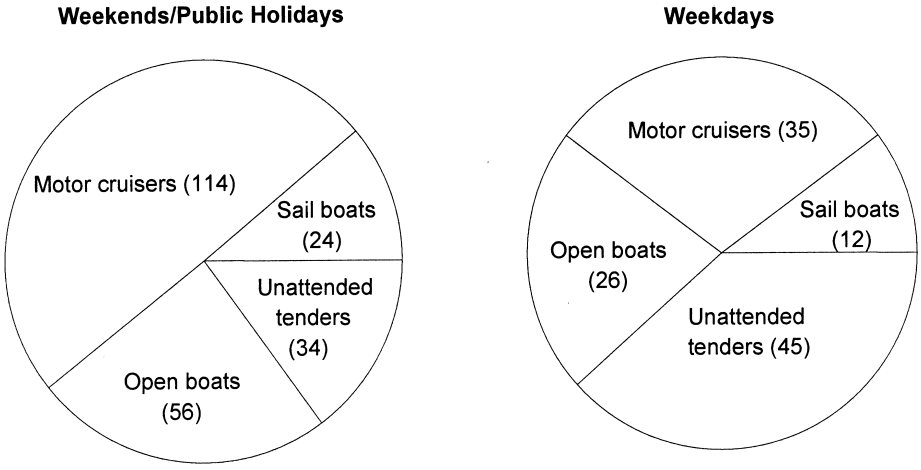

Figure 2. Average number of vessels of each type moored/ anchored in the Rottnest Island Reserve on weekends and weekdays during the boating survey in 2003.

tern was also evident with low numbers during the winter months between May and August (Fig. 3a). The highest numbers of boats recorded, excluding unattended tenders, were on weekends with public holidays: for example, Australia Day in January (738) and the Labor Day long weekend in March (748). The lowest count was four vessels on a weekday in August.

Weekends were characterized by higher numbers of boats, and greater variability, in all survey months (Fig. 3a). There was a significant difference between the mean number of boats on weekdays and weekends [independent samples *t*-test assuming $\neq \sigma^2$, $t(61) = 3.93$, $p < 0.05$] and an interactive effect between month and day type [univariate analysis of variance, assuming $\neq \sigma^2$, $F(1, 11) = 2.23$, $p < 0.05$]. Unattended tenders left on moorings also showed a decline in numbers from summer to winter with an immediate drop after April (Fig. 3b). However, in general, there were more unattended tenders on weekdays than weekends, although this temporal variation was not significant [independent samples *t*-test assuming $= \sigma^2$, $t(95) = 1.12$, $p > 0.05$]. Vessels were also recorded as motoring/sailing through the Rottnest Island Reserve during surveys and these numbers also declined from summer to winter with an increase after September (Fig. 3c). In summer months the average number of motoring/sailing vessels on weekends was generally about double those on weekdays.

Occupancy of Moorings

The counts of vessels moored/anchored in the Rottnest Island Reserve showed that neither weekends nor weekdays produced full occupancy of the mooring areas, except on a few peak days in the summer months (Fig. 4). On these days, mooring areas exceeded 100% capacity as vessels also anchored in the bays: for example, Australia Day in Thomson Bay (104%), Longreach (114%), and Catherine Bay (106%), and the Labor Day long weekend in March at Longreach (136%), Geordie Bay (113%), and Catherine Bay (103%). Outside these peak days, only Longreach, Geordie, Catherine, and Marjorie Bays had an average occupancy greater than 70% on weekends. Rocky Bay never exceeded 40% capacity on survey days, even at peak times, while Porpoise Bay only achieved this level of occupancy during the Easter holiday weekend. Weekday averages were consistently lower in all bays and from May until October; no area exceeded 10% occupancy.

Even though no moorings are installed at Parker Point, vessels frequently anchored at this site as it is protected from prevailing swell and wind. On average, over 20 boats were moored in this

area during the summer months although, as with other areas, numbers dropped significantly after April (Fig. 5). However, during the winter months there were often one to two vessels anchored at Parker Point, whereas other areas such as Marjorie Bay and Stark Bay were unoccupied at this time.

Boat-Based Recreational Activities

The most popular recreational activity conducted from boats outside of mooring/anchorage areas around Rottnest Island during the summer months was scuba diving, while, in winter, surfing was the most frequently recorded activity (Fig. 6). Fishing and crayfishing were also popular, although the number of boats engaged in crayfishing dropped to zero between July and mid-November with the annual closure of the rock lobster season (Department of Fisheries, 2003).

Boats participating in these recreational activities were recorded in a number of areas. The most

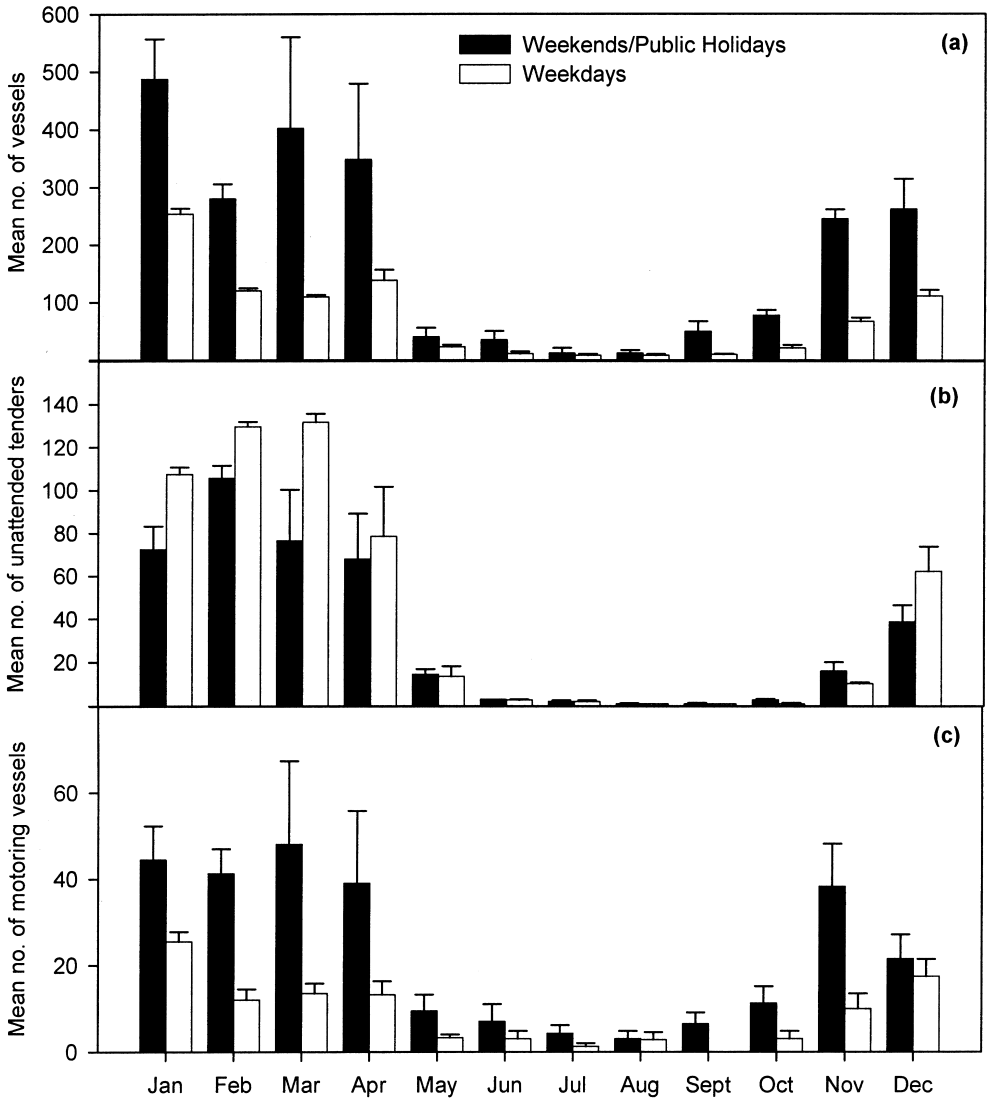

Figure 3. The mean number of (a) moored/anchored vessels (excluding unattended tenders), (b) unattended tenders, and (c) motoring/sailing vessels recorded in the Rottnest Island Reserve on weekends and weekdays each month during the 2003 boating survey (± SE).

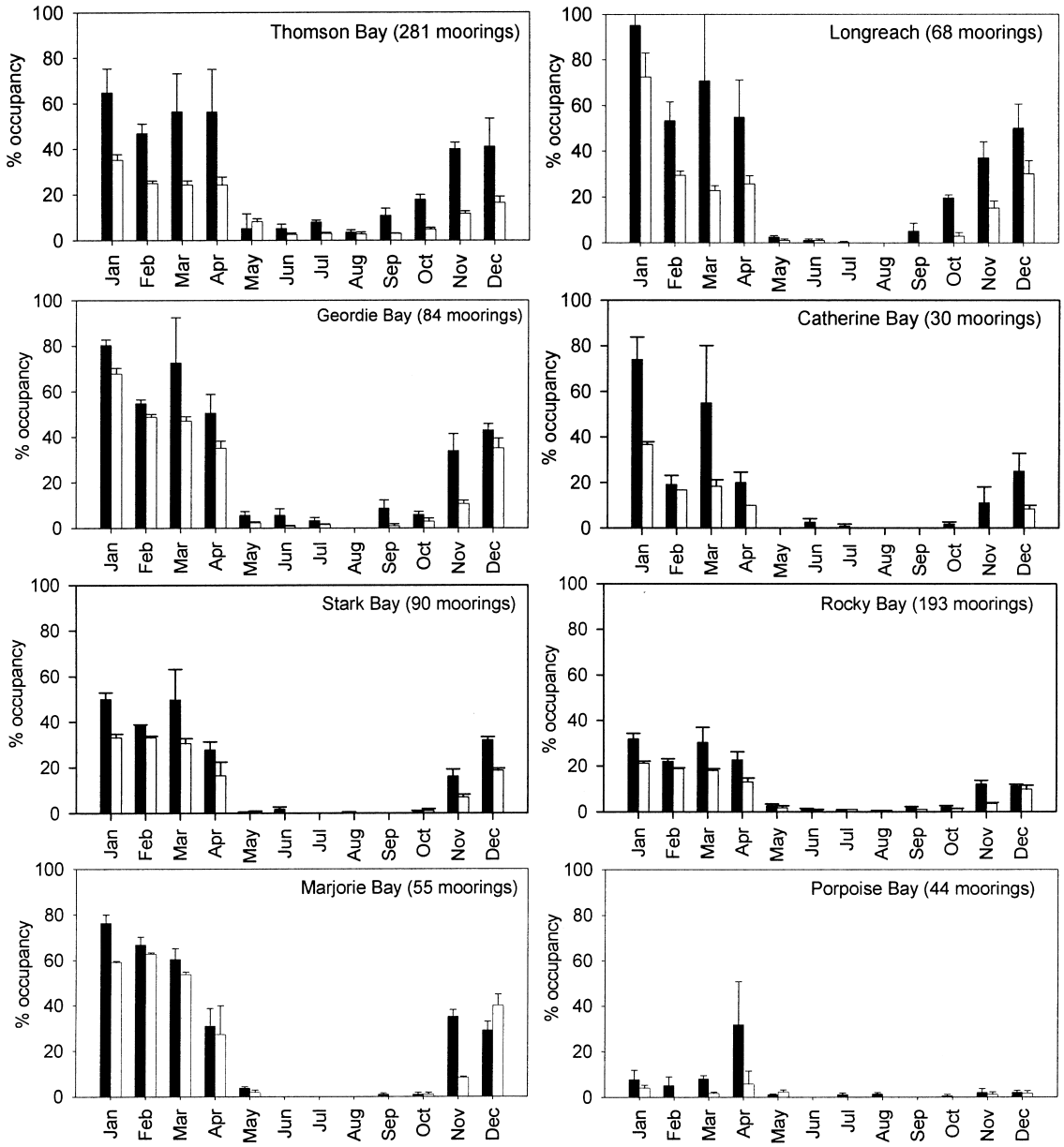

Figure 4. The mean percentage occupancy of moorings in anchorage areas in the Rottnest Island Reserve for each month during the 2003 survey. Note: values also include beach anchored vessels and vessels in pens. (filled columns = weekends/ public holidays, open columns = weekdays, ± SE).

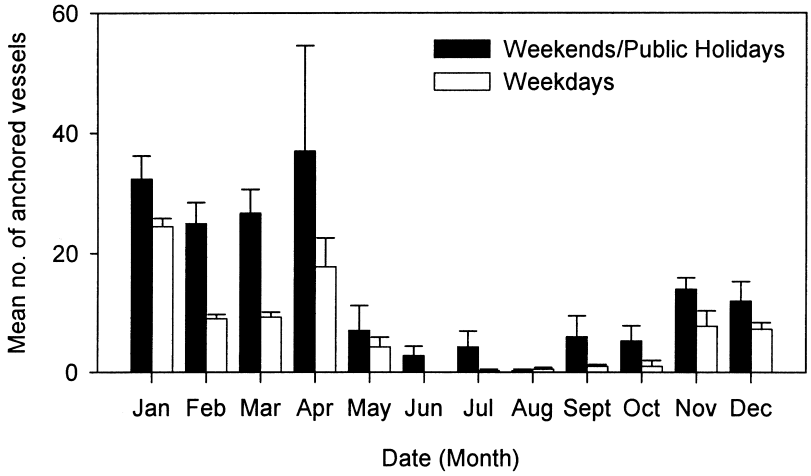

Figure 5. The mean number of vessels anchored at Parker Point during each month of the 2003 boating activity survey (± SE).

popular of these were Strickland Bay, West End, Salmon Bay, Bathurst Point, and Henrietta's Rocks, with >30 boats recorded at each of these sites during the 96 surveys (Figs. 1 and 7). The most popular activity engaged in from boats on the western and southern sides of Rottnest Island was surfing, especially at Strickland Bay, Eagle Bay, West End, and Salmon Bay. Scuba diving was the most popular activity from boats on the northern side and eastern end of the island, from Parker Point around to Armstrong Point. Fishing from boats was recorded at many sites around the island, with the highest numbers recorded off the West End, Henrietta's Rocks, and Bickley Bay.

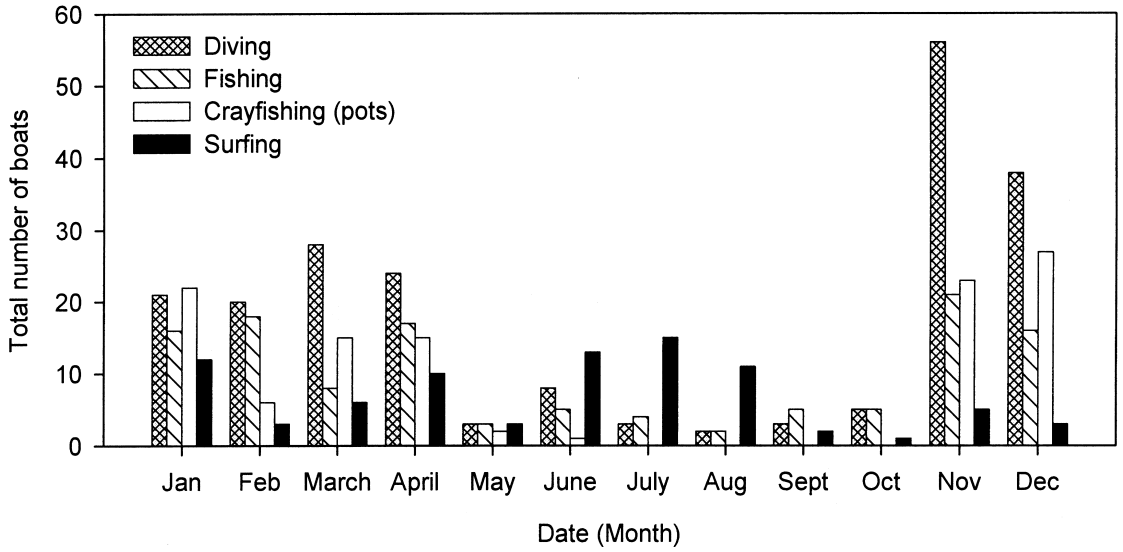

Figure 6. The total number of boats outside of designated mooring areas recorded each month participating in recreational activities within the Rottnest Island Reserve ($n = 408$).

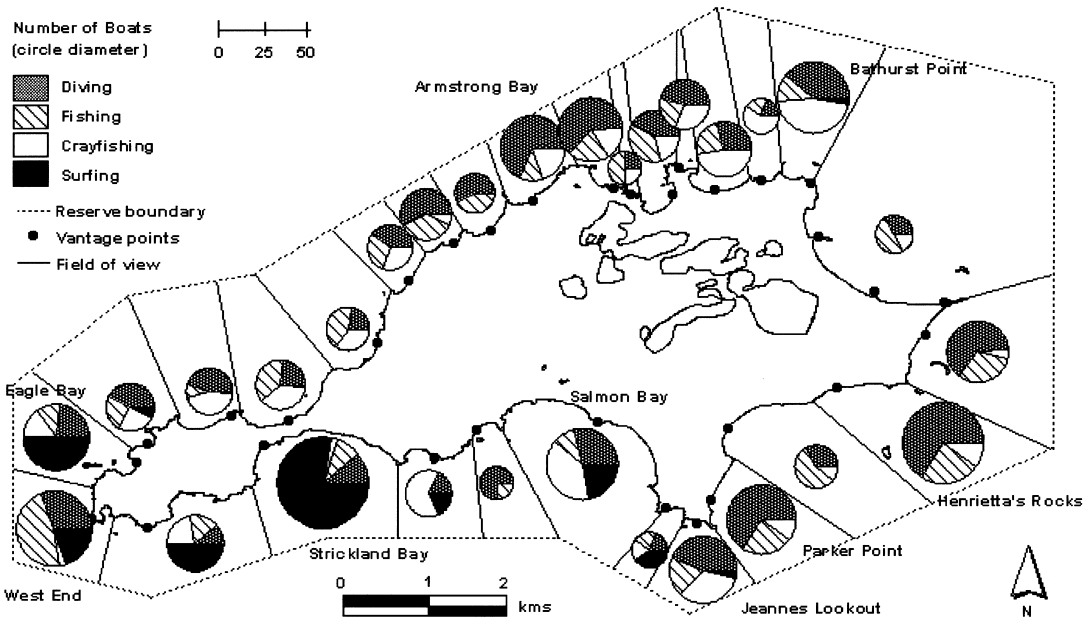

Figure 7. The total number of vessels and associated recreational activities recorded at sites in the Rottnest Island Reserve during the 2003 boating activity survey ($n = 408$).

Crayfishing with pots was most frequently recorded in Salmon Bay, offshore from both Jeanne's Lookout and Bathurst Point.

Shore-Based Marine Recreational Activities

Fishing was the most frequently recorded shore-based activity (at 31 locations) and occurred throughout the year. The most popular locations were Thomson Bay at the Army Jetty (60% of survey days), Ferry Jetty (54% of survey days), Bathurst Point (29% of survey days), and Geordie Bay (20% of survey days) (Fig. 8). Shore-based snorkeling was recorded at 25 locations around Rottnest Island and the most popular sites were generally at the northeastern part of the island: for example, the Basin (29% of survey days), Little Parakeet Bay (20% of survey days), and Armstrong Bay (18% of survey days) (Fig. 8). Parker Point (23% of survey days), on the southern side of the island, was also popular for snorkeling. Snorkelers were recorded from January to May and October to December with none observed during the winter months. Shore-based surfing was recorded at fewer locations than snorkeling with the most popular sites at Strickland Bay (27% of survey days), followed by Salmon Bay (11% of survey days), and Mary Cove (4% of survey days) (Figs. 1 and 8). The majority of shore-based surfing sites were located on the southern side of Rottnest Island. In contrast to snorkeling, surfing was recorded mostly between the months of April and August.

Discussion

There was a pronounced seasonal trend in boating activity at Rottnest Island, with significantly higher numbers of vessels in summer months. Weekends, school holidays, and annual sporting events (such as the annual swimming contest from the mainland to Rottnest Island) also resulted in a higher number of vessels in the reserve. However, it was only on public holidays that 100% capacity was reached (and exceeded) in some mooring areas. Low occupancy was recorded in Porpoise Bay and Rocky Bay as these are less attractive mooring locations due to shallow water (which limits access by larger vessels) and exposure to prevailing southwesterly sea breezes, respectively.

The inverse relationship of unattended tenders

with other boat types was unique and indicated that they were being left on moorings during weekdays until the parent vessel returned for weekend trips. The *Rottnest Island Regulations (1988)* state that a person shall not permit an unattended vessel to remain secured to a mooring for a period longer than 24 hours and infringement can result in penalties. There was a low level of compliance with, and enforcement of, this regulation. The large number of unattended tenders on moorings restricts possible access by other users and is a safety issue and marine hazard if they come adrift.

The distribution of vessels participating in recreational activities was also affected by weather conditions. Winter months, characterized by large swells from a westerly direction, resulted in surfing being the most popular activity on the southern and western sides of the island. During summer, conditions were more suited to scuba diving, which was common on the northern and eastern sides of the island, which offer protection from afternoon sea breezes. Early morning easterlies in summer also provide good conditions for diving along the southern side of the island. Shore-based snorkeling followed a similar pattern and, although situated on the southern side of Rottnest Island, and exposed to afternoon seabreezes, Parker Point and Little Salmon Bay were popular locations. These locations are protected by fringing reef, which reduces their exposure to wave action, and are also advertised by the RIA as locations that provide good coral viewing opportunities.

Fishing regulations also influenced recreational activities and the absence of crayfishing with pots during the July to mid-November closed season was clearly identified in the results. However, in Western Australia capture of crayfish by scuba divers is permitted and this accounts for the marked increase in divers when the new crayfishing season opened during November.

The number of vessels recorded participating in boat-based recreational activities was only a small proportion of the total number of boats observed in the Rottnest Island Reserve. Surfing and scuba diving (alpha flag flying from the boat) were easy to ascertain but boat-based fishing, especially if using handlines or trolling, was more difficult. This problem has also been experienced in other on-site studies, such as at the Great Barrier Reef

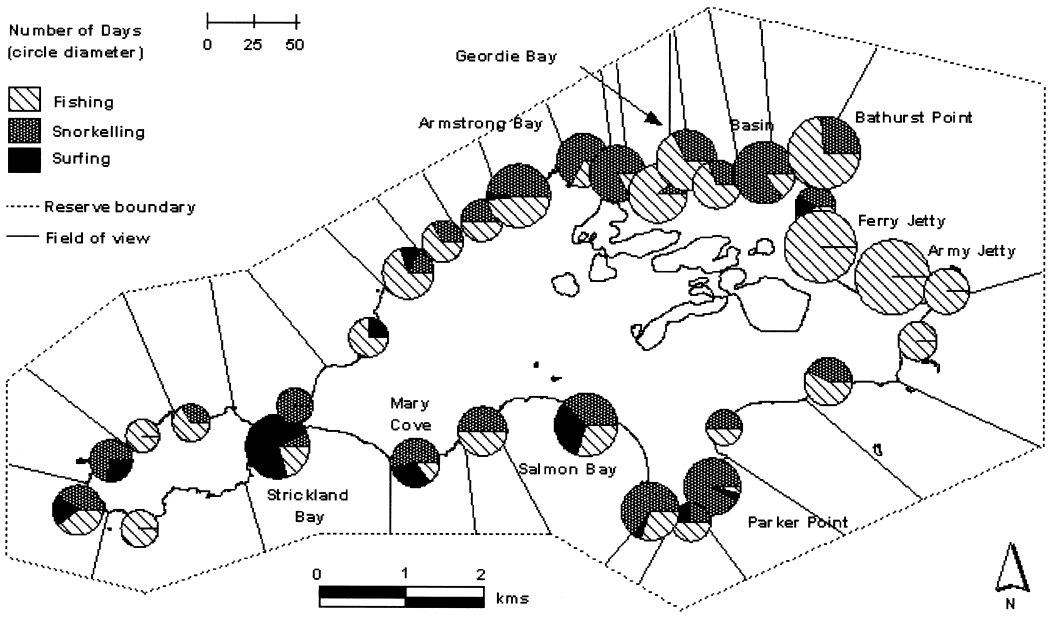

Figure 8. The number of survey days when shore-based recreational activities were recorded at each location around Rottnest Island in 2003 ($n = 96$).

(Mapstone et al., 2004). Also, it must be considered that as vessels enter and depart the reserve throughout the day, turnover could substantially increase the total number of vessels involved in boat-based recreational activities. The only other prior study from which information on recreational activity could be gained was a recreational fishing survey by Sumner and Williamson (1999), where it was estimated that between 500 and 2,000 boats utilized the area around Rottnest Island for this activity. However, the survey was of low spatial resolution and four of their 5×5 nautical mile survey blocks intercepted the Rottnest Island Reserve.

Management Implications

The rapid growth in numbers of recreational boats in Australia has resulted in high demand for moorings, launching sites, and a need for regulation (Kenchington, 1990). The current Rottnest Island Management Plan (2003–2008) indicates concern that there are no established indicators or monitoring programs in place to determine if boating activity is impacting on the Rottnest Island Reserve. As highlighted earlier, there are many impacts associated with intense boating activity, and particular concerns for Rottnest Island are overcrowding, pollution, and user conflict (Rottnest Island Authority, 2003). Steps that have been taken within the marine reserve to reduce the impacts of boating include change to the design of moorings to reduce scouring of the seabed, which were found to be negatively impacting on seagrass beds (Hastings et al., 1995; Lukatelich, Bastyan, Walker, & McComb, 1987). Furthermore, regular water quality monitoring is undertaken in popular swimming areas to address concerns that waste discharged from recreational vessels is affecting water quality in the reserve. However, at Rottnest Island physical factors such as flushing of bays by wind-induced currents minimize the likelihood of safe health limits being exceeded (Department of Environmental Protection, 1996).

Other potential impacts of boating that may occur within the Rottnest Island Reserve include the effect on marine animals, especially dolphins, whales, and sea lions, which are likely to be influenced by boating through noise and collisions which may result in injury, stress, and behavioral changes. These impacts were found to be an issue at the Shark Bay World Heritage Area in northwestern Australia (Bejder et al., 2006). However, the magnitude of these effects (if any) has not yet been determined for Rottnest Island.

The management plan also recommended that research be undertaken to determine the boating capacity of the marine reserve, based on social, ecological, and infrastructure constraints (Rottnest Island Authority, 2003). Boating capacity can be defined as the maximum number of units (i.e., boats) that can be accommodated in an area without exceeding acceptable levels specified by evaluative standards (Newsome et al., 2007; Pilgram, 1983; Stewart, 1993). The results of this study suggest that the maximum capacity at Rottnest Island may not be a concern at the current time as moorings are only exceeding occupancy on a limited number of peak days every year. Intervening time between these peak days may be sufficient for the marine environment to recover from these effects, such as found at Kawau Island, New Zealand (Backhurst & Cole, 2000). However, the increasing usage of Rottnest Island and other marine tourism destinations by recreational vessels should be considered by managers, as these maximum limits, if not already reached, may be attained in the future.

This study provides a starting point to determine the boating capacity of Rottnest Island by providing a benchmark on the level of boating activity in 2003. It has identified times of the year when the highest numbers of boats occur and can be expected to have the most environmental impact. This dataset can be further strengthened by integrating data collection into the standard procedures of the RIA and therefore providing a framework for ongoing monitoring. For example, counts of moored/anchored vessels could be undertaken by rangers during their daily patrols or by increasing the frequency and geographic extent of the water quality monitoring program. This would provide a cost-effective and standardized survey method with information stored in a database with georeferenced locations linking to a spatial (GIS) program. Analysis could be tailored to meet manage-

ment needs by highlighting fine-scale spatial (i.e., bays) and temporal (i.e., daily, seasonal) variations to assess the displacement of activities caused by changes in management and planning regimes, such as the implementation of marine sanctuary zones.

Internationally, a wide range of other techniques such as telephone and/or mail surveys of boat owners (Penaloza, 1991), on-site questionnaires (Jennings, 1998), on-site boat counts (Adams et al., 1992; Widmer & Underwood, 2004), aerial surveys (Sidman & Fik, 2005; Soiseth et al., 2007; Warnken & Leon, 2006), and ticket sales for boat trailer parking (Wardell, 2002), have been used to determine patterns and effects of boating activity. In recent years, applications of GIS have also facilitated the use of geo-referenced data on boating and recreational activities for decision support in planning and management (Pelot & Wu, 2007; Sidman & Fik, 2005; Soiseth et al., 2007). Due to the dispersed nature of boating activity and difficulty in contacting these users, an on-site survey method (using roving counts) is most appropriate for environments such as Rottnest Island. Although expensive to conduct on a regular basis, aerial surveys may also be appropriate, with the added benefit of being able to travel at a higher speed than most vessels and therefore avoiding the possibility of duplicate counts (Warnken & Leon, 2006).

In terms of the impacts of marine recreational activities that can be expected to occur at Rottnest Island, the trampling of intertidal reef platforms, changes to fish communities from fishing, and damage to reefs from scuba divers and snorkelers are the most likely. Research in the Red Sea (Hawkins & Roberts, 1997) and Caribbean (Hawkins et al., 1998) identified the carrying capacity to be approximately 5,000 divers per dive site each year. Establishing the carrying capacity for Rottnest Island requires additional research, and this current survey has identified popular locations for diving (and other activities) that could be used as a basis for this.

The RIA has indicated that they wish to implement an education program to promote environmentally friendly diving techniques to scuba divers and snorkelers who visit the reserve (Rottnest Island Authority, 2003). Briefings to divers prior to entering the water have been shown to be an effective method of reducing damage to reefs (Medio et al., 1997). This is particularly pertinent to charter boats, which frequently visit the reserve for dive tours, and whose on-board staff can be encouraged to provide briefings prior to diving. These charter (and private) vessels also frequently anchor in reef areas, which can result in significant damage to the benthos. Permanent moorings at these dive locations, such as already installed in Armstrong Bay, reduce this impact and have been found to be effective in the other localities (Dinesen & Oliver, 1997). However, this concentrates divers in a particular location and may increase the likelihood of diver damage around the mooring area (Harriott, 2004). Signage has also been identified as an effective method of managing human activity (Herstine et al., 2006; Oliver, Roggenbuck, & Watson, 1985). However, visitors on private vessels may not utilize the landing facilities where signage is located and inserting clearly marked sanctuary zone boundaries (using buoys with appropriate labeling) may be more effective in this situation.

Zoning is a valuable management tool, although the boundaries and the restrictions placed on these areas must be clearly explained and well publicized to encourage compliance and environmentally friendly behavior by visitors. The RIA has sufficient powers to declare areas for specific purposes, and this was exercised over small areas of the island in the previous 1997–2002 management plan, but further expansion of sanctuary areas was hampered by a lack of scientific data to support the decision-making process (Rottnest Island Authority, 2007a). However, during the development of the recently implemented marine management strategy, data from this current study, and also that on shore-based recreational fishing (Smallwood et al., 2006), provided a greater understanding of the spatial distribution of activities in the reserve. Five sanctuary areas now encompass 16% of the marine reserve area, and through the use of this 2003 benchmark, further monitoring could now be undertaken to investigate the displacement of boating and recreational activity (caused mainly by spatial restrictions to extractive

activities) as a result of the implementation of these sanctuary areas.

Conclusions

The RIA is challenged with tackling the issues associated with increasing boating pressure at Rottnest Island while balancing sustainable use and maintaining equitable access to marine resources. This study has provided baseline data about boating pressure in the reserve and highlighted the seasonal and spatially variable nature of usage around the island. The effect of management initiatives, such as changes to mooring regulations or zoning, can thus now be determined against this 2003 benchmark. This is especially pertinent as the current Rottnest Island management plan is due for review in the near future. Management should consider the ongoing collection of quantifiable and geo-referenced information on boating and associated activities in order to monitor trends, establish boating capacity, and determine the extent of environmental impacts from marine recreational activities around the island.

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