

Ningaloo Collaboration Cluster: Human use of Ningaloo Marine Park

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1. SUMMARY OF MAJOR FINDINGS AND THEIR IMPLICATIONS

1.1 Objectives

- Determine the spatial and temporal distribution of recreational fishing and other recreational activities (e.g., diving, snorkelling, kayaking, sailing, reef-walking etc) along the shore and within the reef lagoon system of Ningaloo Marine Park;
- Investigate the spatial distribution of recreational use in Ningaloo Marine Park in relation to biodiversity, habitats, physical conditions, park zoning, access roads and tracks, and accommodation nodes;
- Describe the demographics, frequency of visitation, choice of destination, socio-economics and catches of recreational fishers intercepted along the coast and at boat ramp access points;
- Develop an understanding of historical use patterns at Ningaloo from all other potential sources of data on reef utilisation such as Australian Customs surveillance, charter boat operators, dive operators and marine tour operators.

1.2 Outcomes

This project has provided a robust benchmark on the extent of human use of Ningaloo Marine Park during 2007. The data have high spatial and temporal resolution and are in a geo-referenced format which has allowed both assessment of spatio-temporal patterns as well as detailed understanding of recreational activities conducted in various areas of the park. The use of Ningaloo Marine Park is markedly seasonal with a clear increase in the number of users, and expansion of their spatial extent to cover most of the park, during the period April to October. In the off-season (November to March), people conducting activities in the park are fewer and largely concentrated in Coral Bay and around North West Cape. A wide range of extractive activities, such as recreational fishing, and non-extractive activities including snorkelling, surfing, sailing sports, relaxing on the beach and walking are conducted in the park. The demographic characteristics of people engaged in activities differed significantly between various areas and were related to road/track access, accommodation opportunities and tenure of the land adjacent to the park. Travel network analysis on how coastal roads, tracks and boat launching areas are utilised highlighted node-based patterns of use as well as rapid decay in use with distance from access points. The multivariate multiple regression model of environmental variables plus auto-correlative components explained about 54 % of the observed variation in recreational use with the major explanatory variables being sealed roads accessible by tourist buses and camping opportunities adjacent to the park. The results of the project provide a basis for enhanced management, readily measurable indicators for monitoring and are well-suited to systematic conservation planning for the next iteration of the Ningaloo Marine Park Management Plan.

1.3 Non-technical summary

The successful conservation of marine ecosystems relies on utilisation of both biodiversity and socio-economic information to develop appropriate and efficient management strategies. This project was primarily focussed on understanding how, when and where people use Ningaloo Marine Park, thereby enabling high resolution spatial and temporal data to become available as a benchmark for incorporating into the frameworks for management, monitoring and planning.

Aerial surveys of the entire Ningaloo Marine Park repeated throughout the year from January to December 2007 enabled the synoptic patterns in spatio-temporal distribution of people undertaking activities in the park to be established. Recreational use was greater and expanded over a wider spatial area during the peak months (April to October). Boat-based recreational activity was most frequently recorded in the lagoon and was concentrated around launching sites near Coral Bay and Tantabiddi. Turquoise Bay and Coral Bay were nodes of shore-based recreational activity throughout the year. Coastal camping was distributed over many sites adjacent to the marine park and, in peak months, highest densities were recorded at 3 Mile, 14 Mile, Red Bluff and Lefroy Bay. Parked vehicles, as well as boat trailers and small boats pulled up on the beach, also showed clear seasonality and could be useful indicators for monitoring use of the park.

Stratified, land-based surveys using vantage points along the coast complemented the aerial surveys and fine-scale patterns of recreational use were explored using the geo-referenced locations of observed boat-based and shore-based activities. Relaxing on the beach, walking, snorkelling, fishing and swimming were dominant activities along the shores of the marine park whilst wildlife interaction, fishing and diving were activities associated with boats. Snorkelling and diving were aligned with sanctuary zones and coral reef habitats while fishing was mainly associated with general use and recreation zones. Boating was restricted by the fringing reef crest and recreational fishing from small boats occurred predominantly inside the sheltered lagoon waters although activities such as wildlife interactions generally occurred in the open ocean.

Visitors usually access the 300 km coast of Ningaloo Marine Park via adjacent lands with a range of tenures (e.g. national park, government defence lands and pastoral leases) and different management arrangements. During the coastal surveys, face-to-face interviews were completed with 1 208 people participating in recreation along the shores of Ningaloo Marine Park to investigate recreational activity patterns and the influence of land tenures (and accompanying attributes) on visitor characteristics. Respondents conducting activities in the park adjacent to pastoral leases were found to be more likely from intrastate and stayed for longer than those conducting activities adjacent to Cape Range National Park or the settlement of Coral Bay, who stayed for shorter periods and included many international visitors. Repeat visitation and site fidelity were high, especially on pastoral leases. Snorkelling was popular off the national park and Coral Bay and there was higher participation in recreational fishing adjacent to pastoral leases.

Extractive activities within multiple-use marine protected areas have significant implications for conservation and resource management. From the geo-referenced, aerial and land-based, coastal surveys and interviews conducted throughout 2007 patterns of extractive recreational use and compliance with park zoning were established. In terms of overall use of the park,

extractive use represented ~12% of observed activity from boats and the shore, although the activity type could not be ascertained for 27% of boats. Line fishing was the dominant extractive use and occurred in higher densities and with wider spatial distribution in autumn and winter than other seasons. Clustering around infrastructure (e.g. boat launching locations, beach access points) was also evident. Non-compliance with zoning by fishing vessels was 12%, but this increased to 20% if vessels for which an activity type could not be determined were assumed to be fishing. The interviews with recreational fishers along the shore indicated that the overall catch per unit effort was low (<1 fish/person/hour) and spangled emperor (*Lethrinus nebulosus*) was the most common out of the >30 fish species caught. Respondents displayed a high level of knowledge about the location of sanctuary zones and the majority stated that the current zoning had not affected their fishing activity. Note that this work complements the concurrent WA Department of Fisheries creel survey to ascertain catch and effort in the Gascoyne region, which was largely focussed at boat ramps and other access points.

This study also quantified the distance travelled by people to participate in recreation in Ningaloo Marine Park and showed that there was spatial variability in the distances travelled by interviewees along the road/track network in the various parts of the park. These patterns were influenced by attributes such as demographics, length of stay and repeat visitation. Visitors were highly clustered around beach access points, clearly identifying areas which are more likely to be exposed to high levels of shore-based recreational pressure such as at Lighthouse Bay, Turquoise Bay and Coral Bay. Similar areas could also be identified for boat-based recreation which, although more dispersed throughout the Marine Park, had its highest concentrations around North-West Cape and Coral Bay. The distribution of these motorised vessels was linked with attributes such as boat length and the location of the fringing reef crest with smaller vessels usually restricted to sheltered lagoon areas.

Data on shore-based recreational usage of the Ningaloo Marine Park determined from the aerial and coastal surveys were modelled against a range of explanatory variables containing information on infrastructure, accessibility by road/track, geomorphology, accommodation availability and the management zoning scheme as well as temporal variables of date and time. Principal Coordinate Analysis of Neighbourhood Matrices revealed significant spatial and temporal structures in the recreational usage. A multivariate multiple regression model of the environmental variables plus auto-correlative components explained about 55 % of the observed variation in recreational use. Notably, 28 % of this was explained by whether the beach was accessible to charter buses (i.e. serviced by a sealed road) or whether coastal camping was possible in close proximity. As a case study, the model was used to explore the effects of reducing the travel impedance to Gnaraloo Bay by upgrading the road to allow easy and fast access by 2WD vehicles from Carnarvon, and thus predict increase in recreational usage of the area.

Overall, the research objectives were met and the high-resolution spatio-temporal data on human usage has provided a clear benchmark as to how, when and where people engage in activities both from boats and the shore of the Ningaloo Marine Park. These data are appropriate for management and monitoring and well-suited to systematic conservation planning for the next iteration of the Ningaloo Marine Park Management Plan.

1.4 Implications for Management

The findings of the human use of Ningaloo project have clear applications to most of the generic marine park management strategies of the WA Department of Environment and Conservation.

- **Management intervention**

The study identified areas of high use that may require management intervention to protect sensitive biodiversity. The spatio-temporal data can be used to identify areas and/or times of high activity where active management is needed (e.g., Turquoise Bay during holiday periods). Visit characteristics can be used to identify where additional facilities may be needed and to plan/manage/design them appropriately.

- **Management frameworks**

The findings can assist with assessing potential commercial tourism activities and suitable sites that will avoid conflicts with other and incompatible uses. For future recreation and tourism planning (e.g., need for infrastructure or visitor risk assessment) the results can be used to identify areas and intensity of human use. Similarly, they can be utilised to assist in minimising management-related impacts on livelihoods and lifestyles. The patterns of human use will inform recreation/tourism planning and policy by identifying expected outcomes/pressures from management actions (e.g., putting in a boat ramp will result in high use and focus visitors in its proximity).

- **Research**

The results provide benchmark information on human use patterns relative to the current (2005-2015) park management scheme. They provide an important input for systematic conservation planning and Management Strategy Evaluation or other models which assist in predicting likely consequences of future coastal development and/or changes in management strategies. The information on extractive use can be used to validate results from creel or access point recreational fishing surveys.

- **Monitoring and evaluation**

The 2007 usage data can be used by managers as a benchmark from which to monitor future park usage focussing on target areas of high use, high biodiversity and high value. Various surrogates for human use such as camp site occupancy, number of cars in car parks and number of boat trailers at boat ramps were identified and calibrated. The data also provide a basis by which to evaluate management effectiveness in terms of changes to human use patterns relative to management actions.

- **Education**

The identification of times/sites of high use can assist in planning education campaigns to target a wider audience as well as identifying places that need provision of interpretive material. The results allow identification of inappropriate uses that education programmes can target and provide information on visitor and visit characteristics that can be used to develop targeted education campaigns.

- Surveillance and enforcement

The usage patterns identified in the study can be utilised to design appropriate and efficient enforcement programmes as well as assess effectiveness of sanctuary zone compliance.

1.4.1 Tools, technologies and information for improved ecosystem management

Appropriate use of GPS and GIS technologies is extremely important in implementing geo-referenced surveys or monitoring of human use. The laser range finder used during the coastal surveys was particularly useful in geo-referencing location of activities from coastal vantage points. Aerial surveys were found to be cost-effective for synoptic information for the entire park though coastal surveys enabled higher resolution data on specific types of recreational activities to be collected.

1.5 Problems encountered

Despite the remote survey area, this project encountered remarkably few problems and most were of a minor nature like punctures, locked gates, heat and flies. Reconnaissance work which included traversing all routes prior to the study was important in being able to confidently formulate a comprehensive survey protocol. Further, a safety network comprising the Exmouth office of DEC and pastoral lessees provided peace of mind that in event of problems, assistance would have been available to the field team. Competent and enthusiastic field workers, skilled in off-road driving, were a major advantage in this project.

1.6 Further developments

It is anticipated that the skills, survey methods and analysis techniques developed during this project will be transferable to other areas of Australia, in particular, remote areas such as the Kimberley coast.

1.7 Acknowledgements

This study was completed with the significant financial support of the CSIRO Wealth from Oceans Ningaloo Collaborative Cluster and Murdoch University. We would like to acknowledge the competent and enthusiastic assistance of Chris Jones and Dani Rob during the fieldwork component of the project and Renae Adamson for diligent data entry. The WA Department of Environment and Conservation in Exmouth is thanked for logistical support and the excellent service provided by Norwest Airwork Pty Ltd is gratefully acknowledged. The Commonwealth Department of Defence and the pastoral lease holders are thanked for allowing access to coastal areas adjacent to the Ningaloo Marine Park.

2. COMMUNICATION OF PROJECT RESULTS AND DATA

2.1 Planned publications

- A systematic evaluation of the incremental protection of broad-scale habitats at Ningaloo Reef, Western Australia
- Spatio-temporal distribution of recreational usage in Ningaloo Marine Park, north-western Australia: A synoptic overview
- Fine-scale patterns of recreational use in Ningaloo Marine Park: a land-based coastal survey approach
- Recreational use in a marine park in north-western Australia: Effects of adjacent land tenure
- Spatial extent, seasonal variability and zoning compliance of recreational fishing in an Australian multiple-use marine park
- Travel networks related to recreational use of Ningaloo Marine Park, north-western Australia
- A model of shore-based recreational use of Ningaloo Marine Park, north-western Australia, relative to spatial, temporal and environmental variables

2.2 Communications

Throughout the duration of the Ningaloo human use project, communication was maintained with the WA Department of Environment and Conservation, particularly the on-ground staff in the Exmouth office. In addition, contact was maintained with pastoral station lessees, WA Department of Fisheries and WA Department for Planning and Infrastructure. Numerous presentations were given at local and international scientific meetings, workshops and conferences and there was collaboration with the other project participants in the cluster, particularly in the modelling and habitat mapping components. Two students completed higher degrees under the auspices of the project.

2.2.1 Presentations

Beckley, L.E (2007). Who, what, where and when? Collecting human usage information for better Marine Protected Area planning. *Parks and Protected Areas Forum*, Fremantle, Australia.

Beckley, L.E. (2009). Adding up the numbers: quantifying human usage along the Western Australian coast. *South West Marine Conference*, Busselton, Australia.

Beckley, L.E. (2009). Staking a claim with beach towels: recreational usage of the Western Australian coast. *5th Western Australian State Coastal Conference 2009, Whose coast is it?* Fremantle, Australia.

Beckley, L. E. & Lombard, A.T. (2009). Surely, 34% is enough? A systematic evaluation of the incremental protection of broad-scale habitats at Ningaloo Reef, Western Australia. *46th Australian Marine Sciences Association Conference*, Adelaide, Australia.

Beckley, L.E., Smallwood, C.B., Lombard, A.T., Moore, S.A., Kobryn, H.T. & Neiman, J. (2008). Incorporating human usage into conservation planning and management of coral reefs: New spatial and temporal mapping of use at Ningaloo Reef, North-Western Australia. *11th International Coral Reef Symposium*, Fort Lauderdale, USA.

Beckley, L.E., Smallwood, C.B., Moore, S.A. & Kobryn, H.T. (2009). High resolution mapping of reef utilisation by humans in Ningaloo Marine Park. *3rd Ningaloo Symposium*, Exmouth, Australia.

Beckley, L.E., Smallwood, C.B., Moore, S.A. & Kobryn, H.T. (2009). What do people do at Ningaloo? Spatial and temporal mapping of tourist usage in a large marine park, north-western Australia. *6th International Coastal and Marine Tourism Conference*, Port Elizabeth, South Africa.

Beckley, L.E., Smallwood, C.B., Moore, S.A. & Kobryn, H.T. (2009). What's the use? High resolution mapping of reef utilisation and applications to monitoring in Ningaloo Marine Park. *Australian Coral Reef Society Conference*, Darwin, Australia.

Beckley, L.E., Smallwood, C.B., Moore, S.A., Kobryn, H. T., Jones, C.M. & Nieman, J.L. (2007). What do people do at Ningaloo? High resolution spatial and temporal mapping of human use in Ningaloo Marine Park, Western Australia. *Australian Coral Reef Society Conference*, Fremantle, Australia.

Beckley, L.E., Smallwood, C.B., Moore, S.A., Kobryn, H., Jones, C.M., Nieman, J. & Lombard, A.T. (2007). High resolution mapping of reef utilization by humans in Ningaloo Marine Park. *1st Ningaloo Research Symposium*, Perth, Australia.

Beckley, L.E., Smallwood, C.B., Moore, S.A., Kobryn, H. & Lombard, A.T. (2008). High resolution mapping of reef utilization by humans in Ningaloo Marine Park. *2nd Ningaloo Research Symposium*, Perth, Australia.

Smallwood, C.B., Beckley, L.E. & Moore, S.A. (2007). A spatial and temporal framework for historical human usage data in the Ningaloo Marine Park. *Australian Coral Reef Society Conference*, Fremantle, Australia.

Smallwood, C.B., Beckley, L.E. & Moore, S.A. (2008). Spatial footprint and temporal variability of recreational usage at a remote fringing reef in North-Western Australia. *11th International Coral Reef Symposium*, Fort Lauderdale, USA.

Smallwood, C.B., Beckley, L.E. & Moore, S.A. (2008). A spatial and temporal framework for historical human usage data in the Ningaloo Marine Park. *2nd Ningaloo Research Symposium*, Perth, Australia.

Smallwood, C.B., Beckley, L.E. & Moore, S.A. (2009). Using spatial surveys of visitors to better understand and manage recreational fishing in the Ningaloo Marine Park, north-western Australia. *8th Indo-Pacific Fish Conference*, Fremantle, Australia.

Smallwood, C.B., Beckley, L.E. & Moore, S.A. (2009). Connecting visitors to the environment: a study of travel networks in the Ningaloo Marine Park, north-western Australia. *46th Australian Marine Sciences Association Conference*, Adelaide, Australia.

Smallwood, C.B., Beckley, L.E. and Moore, S.A. (2009) Getting out and about at Ningaloo: understanding visitor travel networks for better management of a fringing coral reef. *Australian Coral Reef Society Conference*, Darwin, Australia.

2.2.2 Student Projects

Nieman, J.L. (2007). Diurnal variability in beach use patterns at three beaches in the Ningaloo Marine Park, Western Australia. MSc thesis, Murdoch University, Australia. 42pp.

Smallwood, C.B. (2009). Spatial and temporal patterns of recreational use at Ningaloo Reef, north-western Australia. PhD thesis, Murdoch University, Australia, 316 pp.

2.3 Data accessibility

The Ningaloo human use data are stored in a MS Access database with several relational and lookup tables for storing data collected during aerial observation surveys, land-based observation surveys and face-to-face interviews in 2007.

2.3.1 Meta data description

A file containing a full description of the metadata associated with the database has been prepared. It is available through the project leader.

2.3.2 Who is the custodian of the data

The custodian of the data is currently the project leader, Associate Professor Lynnath Beckley, at Murdoch University, Western Australia. It is anticipated that the data will be co-located with other data from the Ningaloo Cluster, probably at iVEC or CSIRO, once all the projects are complete.

2.3.3 Raw data and data products description

The raw data comprise geo-referenced records of observed human use in Ningaloo Marine Park during the year 2007 with information on type of activity conducted and number of people involved (Figure 2-1). It also includes data on observations at fixed locations adjacent to the Ningaloo Marine Park such as boat ramps, camp sites and parking areas of indicators of use such as number of vehicles, boats, trailers etc. In addition, data from the interviews conducted with recreational participants in Ningaloo Marine Park are included.

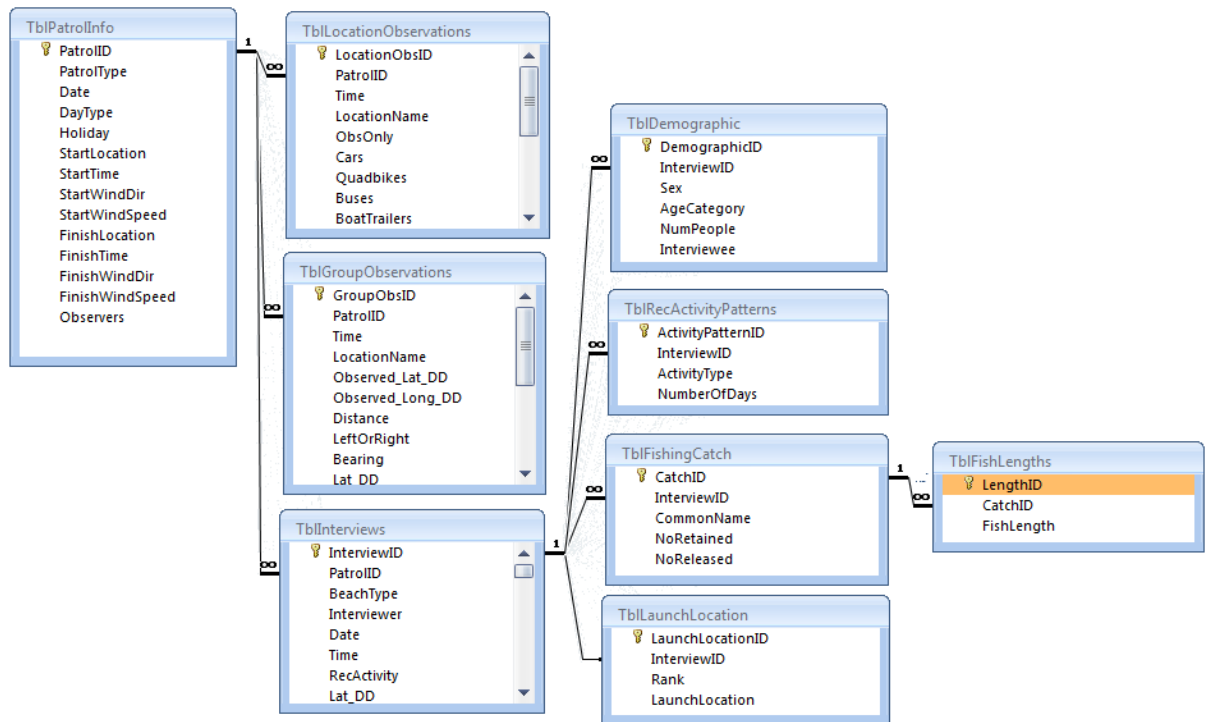


Figure 2-1. Relational tables (and their relationships) in the Ningaloo human use database

3. A SYSTEMATIC EVALUATION OF THE INCREMENTAL PROTECTION OF BROAD-SCALE HABITATS AT NINGALOO REEF, WESTERN AUSTRALIA

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3.1 Summary

Ningaloo Reef, in north-western Australia, is protected by the Ningaloo Marine Park (State Waters) which, in 2004, was expanded incrementally so that 34% of the park now comprises no-take sanctuary zones. Does this imply that all habitats at Ningaloo are actually protected at this level? To examine this, a systematic conservation planning exercise using existing broad-scale benthic habitat data (as a surrogate for overall biodiversity) and C-Plan software was conducted. Though subtidal and intertidal coral communities were found to be adequately protected, other habitats, particularly those in deeper waters seaward of the reef did not attain the 34% target level. Efficient incremental additions to the sanctuary zones to allow increased representation of these under-represented habitats were explored. It is recommended that systematic conservation planning incorporating new biodiversity and social information (e.g. high resolution human usage data) be undertaken for the next iteration of the Ningaloo Marine Park management plan.

3.2 Introduction

Ningaloo Reef is a fringing reef that extends for 300 km along the coast of north-western Australia. It supports a high diversity of corals (Veron & Marsh, 1988), fishes (Fox & Beckley, 2005) and other biota including seasonal migrants such as whale sharks, turtles and humpback whales (Sleeman et al., 2007). In addition to its biodiversity value, the Ningaloo region has high social importance, particularly for its Aboriginal history, recreational opportunities and nature-based tourism (Department of Conservation and Land Management, and Marine Parks and Reserves Authority, 2005).

The fringing reef was initially protected in 1987 through establishment of the Ningaloo Marine Park (State Waters) (hereafter NMP) extending offshore to the legal limit of Western Australian coastal waters (3 nautical miles) of which 10% was designated as no-take sanctuary zones. Simultaneously, the federal government of Australia proclaimed the Ningaloo Marine Park (Commonwealth Waters) in the adjacent, deeper territorial waters. Remarkably, in 2004, after lengthy public consultation, negotiations with stakeholders and a complex political process, the NMP was extended south to cover the full length of the reef (263 343 ha).

The NMP is managed using a comprehensive plan that outlines objectives and strategies to facilitate the conservation of marine biodiversity for the period 2005-2015 (Department of Conservation and Land Management, and Marine Parks and Reserves Authority, 2005). This plan incorporated a new system of zoning that incrementally built on the earlier sanctuary zones (hereafter sanctuaries) and added several new ones. This resulted in 34% of the area of the NMP being apportioned into 18 sanctuaries spread throughout the length of the park (Figure 3-1a). They vary in size from the tiny Lakeside sanctuary (8 ha) to the substantial Cloates sanctuary (44 752 ha). Other zones include general use, recreation and special purpose. Special purpose zones (shore-based activities) are 100 m wide to accommodate shore-based recreational fishing and are located along the shorelines of eight of the sanctuaries. The single special purpose zone (benthic protection) is located seaward of the fringing reef in the Mandu sanctuary to accommodate recreational game-fishing for pelagic species.

Internationally, it has been recommended that 20-40% of marine habitats be protected in no-take areas (Gell & Roberts, 2003). However, although 34% of the NMP is now designated as no-take sanctuaries, this does not guarantee that all habitats are actually protected at this level. Ubiquitous habitats may be disproportionately represented thereby placing those habitats with smaller geographical extents at risk of being under-protected. A systematic conservation planning approach (Margules & Pressey, 2000) was used to evaluate the sanctuaries in terms of their overall contribution to protecting each of the different broad-scale habitats occurring at Ningaloo Reef.

The objective of systematic conservation planning is to efficiently conserve representative samples of a region's biodiversity. The approach relies on the designation of conservation targets which define how much of biodiversity patterns and processes should be given full protection. This study was restricted to the evaluation of pattern data only, i.e. broad-scale benthic habitats (as surrogates for overall biodiversity) and their representation within the 2004 sanctuaries for the NMP. A target of 34% of each habitat to be protected was set as this is the overall level of no-take area achieved by the current zoning scheme. Further, if the habitat representation within the current zones is not quantified, the counter-argument "Surely, 34% is enough?" could curtail any further expansion of sanctuaries in future iterations of the management plan.

Cognisant of criticism by Knight et al. (2006) of published conservation planning studies consisting of "ever-more precise information on, and efficient techniques for, prioritising elements of nature" while ignoring social components, the inclusion of social information (e.g. high resolution human usage data) into future iterations of the management plan for conserving Ningaloo Reef was also explored.

3.3 Materials and methods

Spatial data for the 11 broad-scale marine habitats at Ningaloo, derived from interpretation of aerial photographs, bathymetry and ground truthing (see Bancroft, 2003), and both the 1987 and 2004 zonation schemes, were obtained in Geographic Information System (GIS) format from the Western Australian Department of Environment and Conservation (Figure 3-1). Analyses were restricted to the NMP but excluded the 40m-wide coastal strip above the

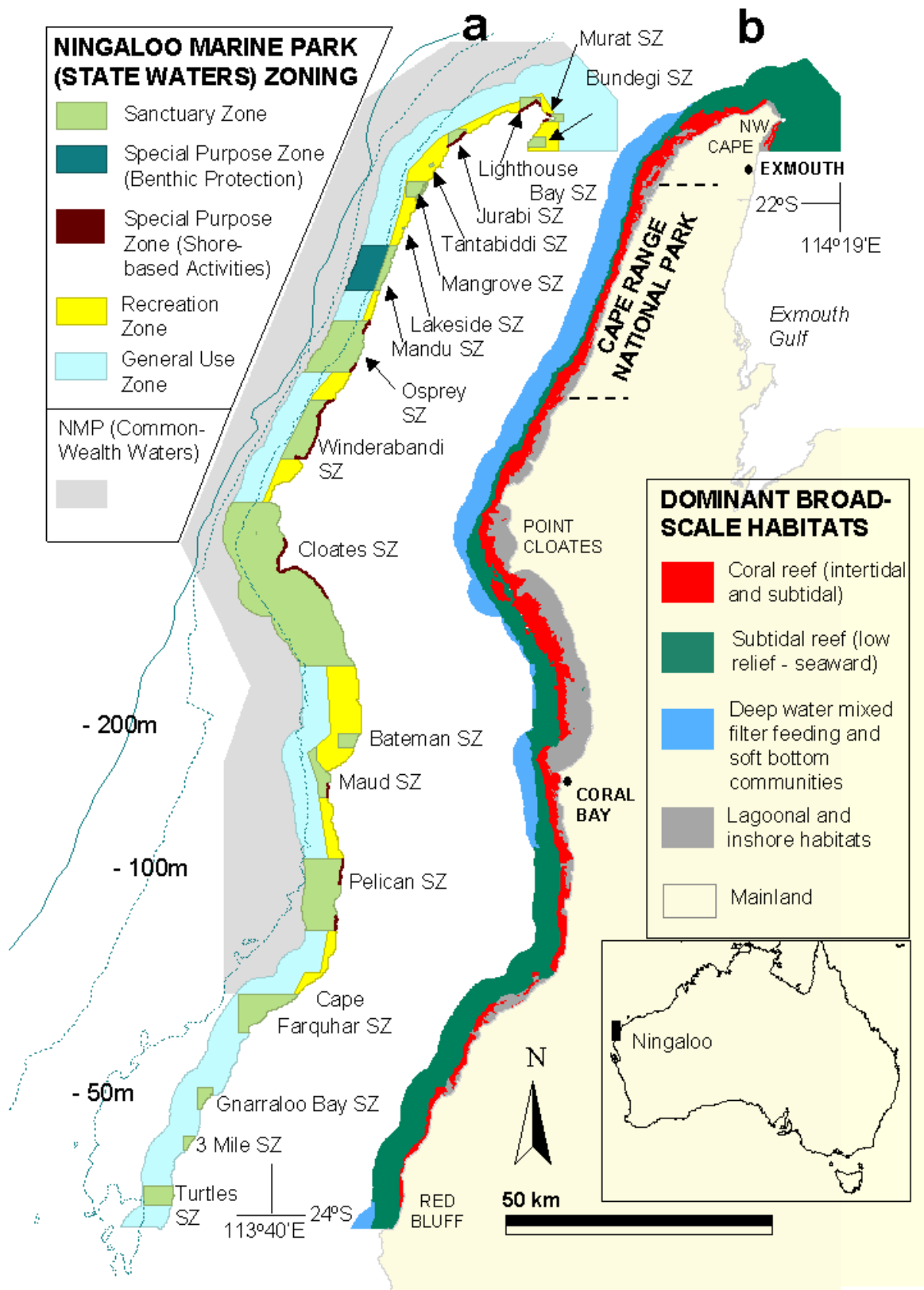


Figure 3-1. Ningaloo Marine Park (State Waters) showing (a) the 2004 zoning scheme and (b) dominant broad-scale benthic habitats. All information summarised from Department of Conservation and Land Management and Marine Parks and Reserves Authority (2005).

high water mark. Spatially explicit information on recreational fishing from a survey conducted in 1998-99 at boat ramps at Ningaloo Reef (Sumner et al., 2002) was also incorporated into the GIS. The study area was divided into a series of planning units (1 km² or 100 ha) which could be smaller along the edges and shoreline of the study area in order to match these boundaries exactly (minimum planning unit size was 5 ha). The 18 sanctuaries were not allowed to be subdivided by planning units and, consequently, each sanctuary constituted a single planning unit. The 2 281 final planning units were overlaid on the habitat map in the GIS in order to determine the amount of each habitat in each planning unit. As described above, a target of 34% of each habitat to be protected in sanctuaries was set.

Using C-Plan software (Pressey, 1999), the irreplaceability of each planning unit was calculated. Irreplaceability is the likelihood that the planning unit will be needed to meet the conservation target (Ferrier et al., 2000). The target was not met for some habitats and, using C-Plan, spatial options for attaining the target were explored by building incrementally onto existing sanctuary areas, while avoiding areas with high boat-based recreational fishing effort.

3.4 Results and Discussion

3.4.1 Habitat representation in zones

The fringing reef with its subtidal and intertidal coral communities comprises 19% of the total area of the NMP (Figure 3-2). Low relief, subtidal reef seaward of the fringing reef is the dominant habitat type (44%) and subtidal lagoonal reef comprises 10% of the park. Deep-water mixed filter feeding and soft bottom communities comprise 22% of the area, and shoreline reef, sand, macro-algal beds and a small area of mangals with associated mudflat and saltmarsh constitute the remaining 5%.

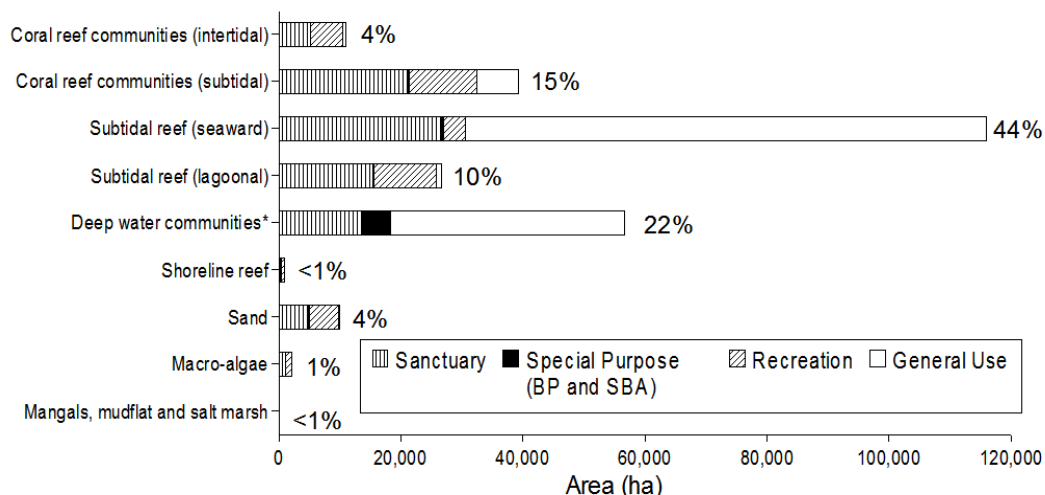


Figure 3-2. Extent of broad-scale benthic habitats and representation in the zones demarcated in Ningaloo Marine Park (State Waters). Proportion of each habitat in the park is given as a percentage.
* Deep water mixed filter feeder and soft bottom communities.

Greater than 20% of the total area of each broad-scale habitat is protected in the 2004 sanctuaries (Figure 2-1), considerably improving on the 1987 zonation scheme. Both subtidal and intertidal coral reef communities are well represented and, as with macro-algae, sand and

subtidal lagoonal reef, each attains the target of 34%. The small area associated with mangals is entirely encompassed by Mangrove sanctuary. However, although from 1987 to 2004 there were huge improvements in the amount of subtidal reef (seaward) and deep water mixed filter feeding and soft bottom communities in sanctuaries (from 0-23% and 0-24%, respectively), both these habitats, and shoreline reef, are still represented at less than the 34% target.

Subtidal reef (seaward) is proportionally the least protected habitat in the NMP (Figure 3-2). The largest areas of this low coral cover habitat occur in the northern and southern portions of the park where the fringing reef abuts the shoreline and lagoonal areas are scarce (Figure 3-1b). Various options for target achievement were explored in the south because of the known high intensity of boat-based recreational fishing in the north (Sumner et al., 2002). For example, extending all three sanctuaries in the south (Cape Farquhar, Gnarraloo, 3 Mile) to the seaward boundary of the NMP did not meet the target but if, in addition to these extensions, the entire area between 3 Mile sanctuary and Red Bluff was upgraded to sanctuary level protection, the target could be met.

Deep water mixed filter feeder and soft bottom communities dominate in the north of the park (Point Cloates to North West Cape) because of the narrow and steep nature of the continental shelf (Figure 3-1b). Achievement of the target for this habitat would require extending sanctuaries offshore. For example, widening the Winderabandi sanctuary seaward to the NMP boundary or changing the designation of Mandu special purpose zone (benthic protection) to sanctuary both provided efficient options to achieve the target. Note that this Mandu Special Purpose zone was a compromise solution allowing both protection and fishing although such partial fishing closures have been shown to be ineffective as conservation tools (Denny & Babcock, 2004).

The reason that shoreline reef does not meet the 34% target is largely a result of the inclusion of much of this limited habitat in recreation or special purpose (shore-based activities) zones. Instead of creating new, narrow sanctuaries to accommodate this geographically specific habitat, the most efficient way to increase its protection would be to rezone special purpose zones (shore-based activities) inshore of sanctuaries. If, for example, the special purpose zone inshore of the Winderabandi sanctuary was designated as sanctuary, the target for shoreline reef conservation could be achieved (Figure 3-1a).

3.4.2 Incremental increase in protection

The incremental increase in the proportional area of sanctuaries in the NMP is similar to that achieved by expansion of the Great Barrier Reef Marine Park (Fernandez et al., 2005) although, at Ningaloo, a formal systematic conservation planning approach was not used. Stewart et al. (2007) have cautioned that there is a loss of efficiency when a reserve system that was not initially systematically designed is incrementally increased, and this may be evident at Ningaloo. However, if conservation targets are increased in response to changing goals, threats or new information, this will probably be the case for the vast majority of older, existing marine protected areas implemented before systematic conservation planning methods became widely used. This analysis at Ningaloo Reef could thus serve as a useful example of a *post-hoc* systematic approach to guide conservation implementation.

3.4.3 Improving habitat data

Although the NMP is essentially located in one meso-scale bioregion that extends from North West Cape to Red Bluff (Commonwealth of Australia, 2006), improving the resolution of biodiversity data may reveal further gaps in the protection of habitats by the current zoning scheme. Greater resolution may also actually show subtle changes in *beta* diversity associated with gradients in the physical environment over three degrees of latitude. Indeed, a bioregional subdivision of habitats in the Great Barrier Reef Marine Park was necessary to achieve adequate representation in the recent re-zoning of this very large, iconic, marine protected area (Fernandez et al., 2005).

3.4.4 Improving human usage data

Information on use of marine resources is essential for efficient planning of marine protected areas (Stewart et al., 2003), and is especially so at Ningaloo Reef where recreational pursuits and nature-based tourism are widely renowned. The recreational fishery survey at the major boat ramps in the region clearly indicated the high usage in proximity to the Exmouth, Tantabiddi and Coral Bay access points (Sumner et al., 2002). In contrast, diffuse access to the lagoon by anglers using small, beach-launched boats or fishing from the shore, particularly by campers who frequent the Cape Range National Park and the coastline of pastoral stations adjacent to the NMP, was not well quantified or spatially explicit (Sumner et al., 2002). It is likely that the incremental increase in the area of sanctuaries subsequent to the 1998-99 survey has resulted in some displaced fishing effort and relocation to areas outside of sanctuaries.

Little published spatial information exists with respect to other recreational and tourist usage of the NMP. For example, although many snorkelling and diving sites are known, actual use of the park for these activities has not been enumerated. Similarly, information on the intensity of nature-based tourism (e.g., whale shark, manta ray, turtle and whale watching) by commercial tour operators has not been spatially explicit in the past.

Successful implementation of systematic conservation planning outcomes relies on building high resolution human use data into the planning framework as a “cost” to the conservation of biodiversity (Stewart & Possingham, 2005; Possingham et al., 2006). This allows spatial conservation initiatives in areas of least conflict thereby maximising their likelihood of success. Further, the importance of high resolution social and biodiversity data in the development of effective conservation plans has been highlighted in the operational framework for implementing conservation action developed by Knight et al. (2006).

Improvements to the resolution of both biodiversity and marine resource usage data sets at Ningaloo Reef are currently underway through numerous research projects being conducted by Australian state government departments, federal agencies and universities. It is recommended that, for future iterations of the NMP management plan, systematic conservation planning that incorporates this new biodiversity and social information (e.g. high resolution human usage data) be undertaken. Embedding the conservation planning process in an operational framework (*sensu* Knight et al., 2006) would also allow progress along the conservation continuum from mere habitat representation to actual persistence of Ningaloo Reef.

3.5 Acknowledgements

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4. SPATIO-TEMPORAL DISTRIBUTION OF RECREATIONAL USAGE IN NINGALOO MARINE PARK, NORTH-WESTERN AUSTRALIA: A SYNOPTIC OVERVIEW

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4.1 Summary

Geo-referenced data collected during 34 temporally stratified aerial surveys throughout 2007 provided a synoptic overview of the spatial extent of recreational activity over the entire Ningaloo Marine Park (State Waters). The density of recreational use was higher in peak months from April – October when compared to off-peak months. The highest density of boating activity was found adjacent to the townsite of Coral Bay and boat launching sites such as Tantabiddi. Shore-based recreational activity was concentrated at Coral Bay and Turquoise Bay and, as with boating, the spatial extent of activities expanded along the coast in peak months. This period also corresponded to an increase in the number of vehicles, camps and boats on the beach adjacent to the Marine Park. Aerial surveys proved to be an effective technique for obtaining data with high spatial accuracy on recreational use at Ningaloo with the methodologies developed and applied here potentially useful for surveying marine parks elsewhere. The geo-referenced data are also advantageous as various scales of analysis and integration with other datasets become possible in order to meet management needs.

4.2 Introduction

The Australian coast is highly valued for the range of recreational opportunities it offers to both residents and tourists (James, 2000). Recreational activities within marine environments include those in which participants are located in or on the water, such as swimming or boating, as well as activities which may be undertaken on land, but are inextricably linked to the sea, such as fishing from the shore or sunbaking on the beach (Orams, 1999). These activities operate over various spatial and temporal scales and, to understand how they may influence an ecosystem, the intensity of the activity as well as its geographical extent must be known (Ban and Alder, 2008; Halpern et al., 2008). In marine environments it is often more difficult to identify the sphere of influence because of the dynamic and ephemeral nature of many activities as well as dispersed travel networks (Ban and Alder, 2008).

Ningaloo Reef, located 1 200 km north of Perth in the Gascoyne region of Western Australia, is one of the largest fringing coral reef systems in the world. It supports a diverse array of marine life including large charismatic species such as humpback whales, whale sharks, manta rays and turtles. Ningaloo Marine Park extends for about 300 km along the coast to protect the biodiversity of the region and annually attracts about 200 000 visitors (CALM and MPRA, 2005).

Although data derived from ticket sales, entry or camping fees and vehicle counters provide an indication of the visitation to some popular parts of the Marine Park, there are only a few studies which identify spatial patterns of recreational use over its geographical extent. Recreational fishing at Ningaloo was investigated over a 12-month period in 1998/99 and spatial distribution of boat-based fishing was reported in 5 x 5 nautical blocks (~80 km²) based on self-reporting by fishers interviewed at boat ramps (Sumner et al., 2002). Charter vessels involved in whale shark tours at Ningaloo report the geographical location of interactions with the animals (Mau, 2008). Bi-annual counts of coastal camping have been undertaken but spatial resolution of these data are poor (DEC, unpublished data).

The overall objective of this study was to determine the spatial and temporal patterns of recreational use in the lagoon environment of the Ningaloo Marine Park (State waters) (hereafter NMP) and adjacent coastal strip. To this end, a comprehensive fieldwork program was designed which incorporated aerial observation surveys. This is a well-established method for collecting data on recreational fishing activity (Pollock et al., 1994) and direct observation is also a well-documented technique for broader recreation and tourism activities (Keirle, 2002; Cessford and Muhar, 2003; Arnberger et al., 2005).

4.3 Materials and methods

4.3.1 Sampling design and methods

Aerial survey is an off-site technique which is a cost-effective method for estimating abundance of targets over large tracts of land or ocean (Caughley, 1974; Ridpath et al., 1983). Traditionally, this technique has been used to conduct animal census and population estimates (Short and Hone, 1988; Forney et al., 1995) although it has been adapted to numerous other fields including mapping fishing effort (Brouwer et al., 1997), surveying beach use (Wardell, 2002; Brunt, 2003; Blackweir and Beckley, 2004; Coombes et al., 2009), assessing camping impacts (Hockings and Twyford, 1997) and monitoring boating activity (Deuell, 1982; Reed-Anderson, 2000; Sidman, 2001; Falk, 2002; Mapstone, 2004; Warnken, 2006; Soiseth, 2007). The extended coastline and linear nature of the NMP make aerial flights an appropriate method for surveying the entire coastline and lagoon area.

A 12-month fieldwork program of aerial observation surveys was undertaken between January and December 2007. This consisted of sampling on 2-4 days per month, with higher sampling intensity in the peak tourist season (April to October) and school holidays (April, July and October). The December/January school holidays were excluded from this higher sampling intensity as they occurred in the very hot season (November – March). Sampling dates were selected using a stratified random survey design which is a statistically robust technique frequently used to construct surveys of recreational anglers (Robson, 1960; Pollock et al., 1994) and also has widespread applications in the social sciences (Frankfort-Nachmias and Nachmias, 1992; Watson et al., 2000; Neuman, 2006).

Using a 4-seat fixed (high) wing Cessna 172 aircraft, two observers flew a line transect that encompassed the width of the lagoon area and length of the NMP (~300 km) from Exmouth to Red Bluff, and return. All recreational activity observed occurring from boats and along the

shore was documented during this period. The aircraft flew at 500 ft (151.5 m) at an average speed of 100 knots and, depending on weather conditions, it took about four hours for a return trip to cover the study area. In locations where a large number of activities were occurring, speed was decreased, or a circuit was flown, so that data could be recorded by the observers. Digital cameras (Canon Powershot A710 IS) were also used to photograph vessels as well as high-use shore areas. The outward, southbound (08h00 - 10h00) and return, northbound (10h00 - 12h00) flights were considered to be two separate counts of recreational activity in the Marine Park with the turning time at Red Bluff (the southern end of the NMP) designated as the start time of the return flight.

The departure time for all flights was set at 08h00 to allow the best opportunities for viewing recreational use in the Marine Park. This standardisation of start times was an approach adopted by Reed-Anderson et al. (2000) and Warnken and Leon (2006) during aerial surveys of boating in lakes in North America and Queensland, respectively. Factors such as glare and wind speed, which can affect the observer's ability to identify activities (Bayliss, 1986; Marsh and Sinclair, 1989), and the likelihood of recreational activities being undertaken, were also considered when planning flights. Wind patterns along the Ningaloo coast generally consist of easterly breezes in the morning and onshore sea breezes in the afternoon (BOM, 2009). These morning conditions are more suitable for boating and many beach-related activities as the breeze is predominantly offshore and wind speeds are generally lower than in the afternoon. The scheduling of all flights in the morning therefore increased the likelihood of the observers identifying vessels, snorkellers and swimmers due to the reduced wind action on the water surface. The sun was also generally at an angle which reduced glare off the water thus improving visibility for observers.

During the flight, all recreational activities in the lagoon were identified and recorded as specifically as possible, although they were later grouped into more general categories for analysis. The observer in the front seat was responsible for identifying boat-based activity because of the improved field of view from this position in the plane. The focus of the study was on vessels located in the lagoon area, but those outside were also recorded. A long-recognised problem with aerial surveys is low sighting frequency of objects close to the aircraft because of the obstruction of downward visibility (Leatherwood et al., 1982; Quang and Becker, 1997). This issue was addressed by the observer looking forward along the flight line to assess upcoming observations. The pilot also assisted with locating boats or people which could have been obscured from the view of the observers. The rear observer was responsible for collecting data on recreational activity being undertaken on the shore as well as undertaking counts of coastal camps, boat trailers at boat ramps, vehicles in car parks or at access points, boats on the beach not being used for recreation at the time and boats on moorings or in marina pens. Prior to the aerial surveys, these places had been geo-referenced, and their facilities documented, so that counts were standardised across the survey period. The definition of a camp site was adapted from Hockings and Twyford (1997) and Hughes and Mau (2006), to be one (or more) tents, caravans or camper trailers which share a communal space in an identifiable area.

Real-time data were collected during aerial flights using a Garmin 72 GPS to obtain information on time (hours, minutes and seconds), position (latitude, longitude), heading and altitude via National Marine Electronic Association 0183 (NMEA) data strings which were extracted to a Palm Pilot for storage. Observers were able to improve the rate at which they

recorded information by writing only the time of observation, rather than position, as this could be linked when the data strings were extracted at the completion of the flight. It was also impractical to record positional information directly from the GPS due to the high speed of the aircraft.

Time and positional information identified the location of the plane when the observation was made. A bearing and offset distance (i.e. distance the object was from the observation point) was then required to calculate the actual location of the object using Vincenty's formula (Vincenty, 1975). All observations were made using a reference line taped on the window and wing strut to ensure that they were made perpendicular (90°) to the plane's heading. Bearing to the object could then be calculated by adding or subtracting 90° (depending on the location of the observed object) from the plane's heading, which was extracted from the NMEA strings. This has been used in previous studies of marine mammals (Laake et al., 1997; Logan and Smith, 1997; Lercak and Hobbs, 1998) and turtles (Cardona et al., 2005) and results in improved data quality.

Offset distance was obtained by using calibration markers on the wing struts of the plane. This technique has been applied previously in wildlife research to define the observable strip width and, subsequently, the area sampled (Johnson et al., 1989; Grigg et al., 1999; Ottichilio and Khaemba, 2001). In this study, each strip represented a point 100, 300, 1000 and 1500 m out from the plane, and the observer could use them to improve their distance estimation to an object.

Once the time and offset distance had been recorded by the observers, they recorded (in order of priority) the platform (i.e. shore or boat), type of activity and number of people in the group. The front observer also obtained additional information on boats, which included (in order of priority) the vessel type (Table 4-1), vessel status (anchored, motoring, drifting, moored, unknown), substrate type over which the vessel was located (reef, sand, unknown) and whether the boat was inside or outside the lagoon environment. If the vessel was motoring, the direction of travel was also recorded.

Digital photographs were taken of most vessels and high-use areas for later validation of observations. This was particularly useful at high-use beaches such as Bundegi Beach, Turquoise Bay and Coral Bay where density of people engaged in recreational activity did not allow separation into groups. The photographs were downloaded from the digital cameras at the completion of each flight and all people participating in recreational activity on the beach were counted from these images.

NMEA data strings were downloaded from the Palm Pilot and imported into a MS Access database and linked with the information recorded by the observers. This database was linked with ArcGIS 9.3 for analysis. At the completion of the flights, hourly weather data (wind speed, wind direction and temperature) were downloaded from the Bureau of Meteorology and Australian Institute of Marine Science websites.

All maps were based on the geographic WGS84 datum, which is commonly used for marine applications as well as by Western Australian government agencies. A number of nested grids were created (1 km, 3 km and 9 km) and used to standardise analysis of activities undertaken from boats. The boundary of the grid was defined by the survey area (from Exmouth Marina in

the north to Red Bluff in the south) and current boundaries of the NMP (state and Commonwealth waters out to ~9 nm offshore). The linear nature of the coast (at Mean High Water Mark) makes it a suitable feature from which to create the buffer (of standard distance both inland and seaward) that was the foundation for the analysis of shore activities. After trailing a number of buffer widths, a 500 m width was selected as it contained >99% of observations of shore activity and <10% of boat activity. The small (<1%) number of observations for shore activities outside this buffer were associated with a popular surf break located near North-West Cape and the buffer was edited at this location so that 100% of shore observations were included. Coastal segment lengths of 3 km were used for spatial analysis of shore-based recreational activity.

Table 4-1. Categories of vessel types recorded during aerial and coastal observation surveys [adapted from Adams et al. (1992), Widmer and Underwood (2004) and Warnken and Leon (2006)].

<i>Vessel type</i>	<i>Description</i>
<i>Motorised vessels</i>	
Cabin cruiser	Vessel with sleeping accommodation and an in-board engine.
Charter	Vessel with paid passengers undertaking recreational activities; where possible, the vessel was identified by name.
Commercial	Vessel, such as tug or fishing vessel, used for commercial purposes (includes research and government vessels).
Open >5 m	Vessel without sleeping accommodation with an out-board engine, >5 m in length (includes centre consol and rubber inflatables).
Open <5 m	Vessel without sleeping accommodation with an out-board engine, <5 m in length (includes centre consol and rubber inflatables).
Tinnie	Small aluminium vessel with an out-board engine (excludes centre consol and rubber inflatables), generally <5 m in length.
Jetski	Jet propelled craft with high powered engine, also known as Personal Water Craft (PWC).
Tender	Small open vessel which is powered either by oars or motor and used to transport people to or from a larger vessel.
<i>Non-motorised vessels</i>	
Yacht	Vessel >7 m in length powered by sail. If motoring, then still identified as a sailing vessel.
Dinghy	Vessel <7 m in length, no fixed keel and powered by sail.
Kayak	Vessel powered by paddles, capable of carrying one or two passengers (includes canoes and waveskis).
Windsurfer	One person vessel consisting of a board and single sail.
Kitesurfer	Small surfboard with kite-like sail used to harness wind power and pull a person across the water.

The effects of temporal factors on recreational use were investigated using multivariate analysis to determine which grouping would provide the most distinct patterns. These temporal factors included months and four seasonal quarters appropriate for Ningaloo namely, summer (January to March), autumn (April to June), winter (July to September) and spring (October to December). In addition, periods of tourist activity identified using historical visitor data (i.e. DEC vehicle counters) were defined as peak (April to October and including school holidays in April, July and October) and off-peak (November to March).

Statistical approaches used to determine the significance of spatial and temporal effects on recreation included one and two-way Analysis of Variance (ANOVA). Multivariate analysis was undertaken using the PRIMER and R statistical packages. Data were standardised across samples to correct for differences in absolute abundances, square root transformed to adjust for the effect of dominant activity types and a Bray-Curtis similarity measure was used to create a data matrix on which the analyses were performed. Analysis of similarity (ANOSIM) was applied to detect any statistical differences between groups in this classification while similarity percentages (SIMPER) determined which activities were responsible for the similarity within groups and the dissimilarity between groups (Clarke, 1993). ANOSIM generates a value of R that falls between -1 and +1, with a value of zero representing no difference between samples, and an associated p which indicates significance at 0.05 level.

4.4 Results

4.4.1 Spatial and temporal patterns of usage

Data collected during the 34 aerial surveys conducted throughout 2007 were split into southbound (Exmouth Marina to Red Bluff) and northbound (Red Bluff to Exmouth Marina) flights. Although flights were scheduled at standard times, there was some variation on the time of observation at each location due to small digressions in departure times and effect of weather conditions (i.e. headwinds or tailwinds) (Figure 4-1)

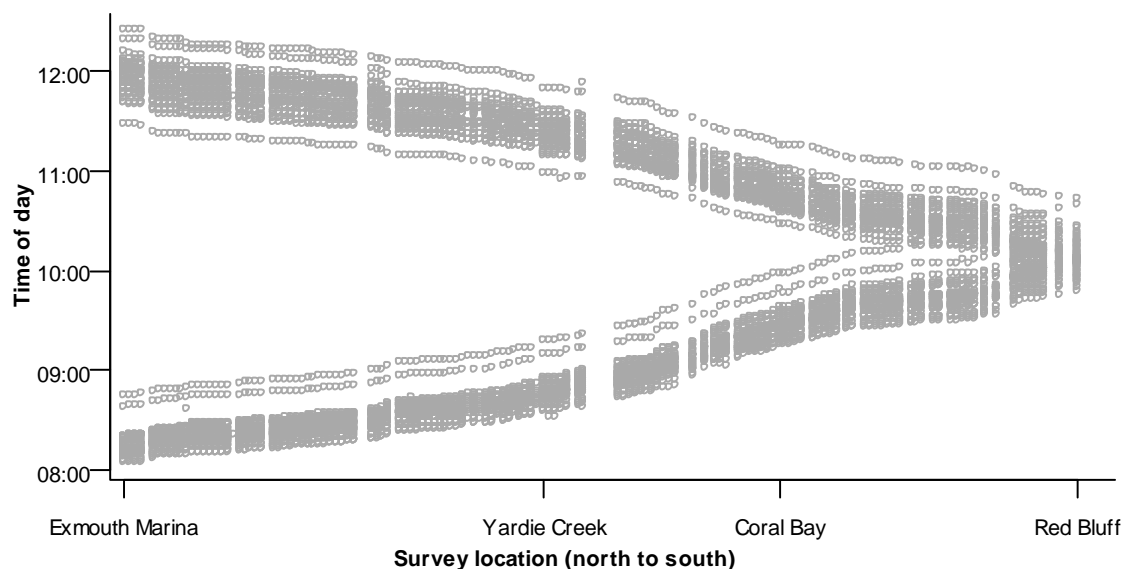


Figure 4-1. Time of observation at each location surveyed during every return flight over Ningaloo Marine Park during 2007 (number of surveys = 34).

There was a total of 7 247 aerial observations of recreational activity along the shore or from boats made throughout the study. The number of observations was significantly higher on the northbound flights when compared to southbound flights ($F_{(1, 66)} = 15.88, p < 0.05$) (Figure 4-2). There was also significant temporal variation, with higher numbers of observations recorded in peak months between April and October on both southbound and northbound flights ($F_{(1, 66)} =$

33.42, $\rho < 0.05$). However, there was no significant interaction between these two factors of flight direction and off-peak/peak periods ($F_{(1, 64)} = 1.00, \rho > 0.05$).

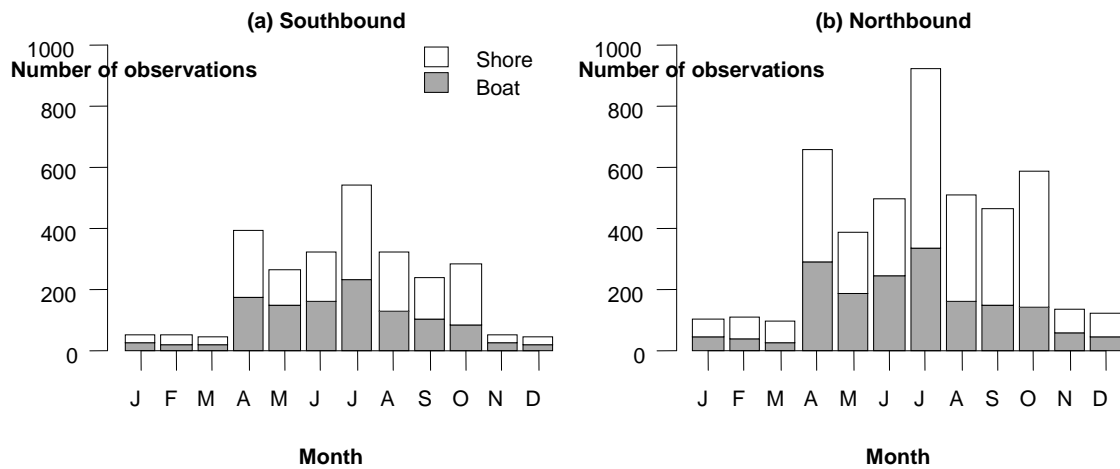


Figure 4-2. Total number of shore and boat observations for each month of (a) southbound and (b) northbound aerial surveys along Ningaloo (number of surveys = 34).

4.4.2 Boat-based activities

Boat-based activity was recorded most frequently inside the lagoon (54.7%) with 29.6% outside and the remaining 15.7% adjacent to parts of the coast with no fringing reef crest (at the northern and southern extents). There were 13 different boat types, which were dominated by tinnies (small aluminium vessels) (26.8%), open boats >5 m in length (20.3%) and charter vessels (16.5%) (Figure 4-3). The largest boats (charter vessels and open boats >5 m in length) were observed in higher numbers outside the lagoon whereas the smaller motorised vessels, comprising tinnies as well as non-motorised vessels such as kayaks, kitesurfers and windsurfers, were found almost exclusively inside the lagoon.

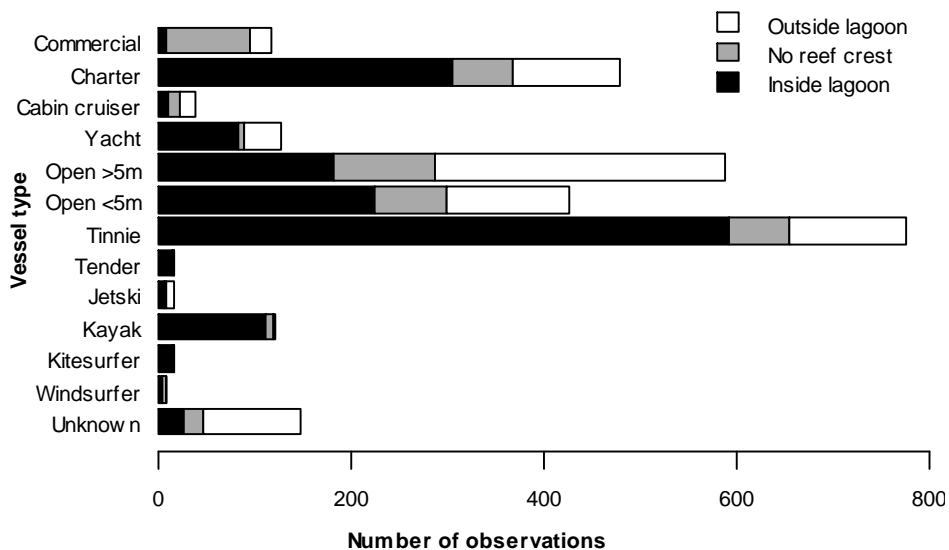


Figure 4-3. Total number of observations for each boat type recorded inside and outside the lagoon as well as adjacent to areas with no fringing reef crest during all aerial flights at Ningaloo in 2007 (number of observations = 2 894).

Although every attempt was made to ascertain the number of persons aboard each boat observed during the surveys, for 67% of observations the number of people was unable to be determined. This was particularly the case for larger boats such as charter vessels where views were obscured by cabins and shade canopies.

The effects of temporal factors on boat activities were investigated and showed significant differences between season and off-peak/peak months in terms of participation in activities; however, there was no significant difference for school holiday versus non-school holiday periods (Table 4-2). To determine which activities were responsible for these differences, a SIMPER analysis was performed which highlighted low levels of dissimilarity (23.8 – 39.0%) based on activity type and number of boats. It was therefore difficult to differentiate between temporal factors based on activity type as wildlife viewing, motoring and fishing occurred year round. However, analysis showed that off-peak/peak periods provided the strongest differentiation of activities and number of boats (i.e. highest Global R).

On northbound flights recreation activity was recorded as occurring in 4.2% more 9 km² grid cells as well as there being a greater number of cells with higher densities of boats, especially at Lighthouse Bay and around Tantabiddi. An ANOSIM test showed significant differences in the number of boats and composition of recreational activities undertaken on different flight directions ($R = 0.256, \rho < 0.05$). A SIMPER analysis to determine the activities responsible for these differences in northbound and southbound flights still had a low level of dissimilarity (36.2%), based on activity type and level of participation, although there was a large number of motoring vessels during southbound flights. Based on the higher densities of boats and greater spatial extent of activities obtained on the northbound flights (conducted at the later flight time of 10h00 – 12h00), these data were select for further analysis of boating activity.

Table 4-2. Results of 2-way crossed ANOSIM tests (based on Bray-Curtis similarities with square root transformed data) using total number of boats observed across all aerial flights to investigate temporal factors (season, off-peak/peak, school holidays) and types of recreational activity. Note: * denotes significant result.

<i>Factor</i>	<i>Global R</i>	<i>ρ</i>		
Off-peak/peak	0.363	<0.05*		
Season	0.268	<0.05*		
	<i>Pairwise comparisons</i>		<i>R</i>	<i>ρ</i>
			0.353	<0.05*
			0.454	<0.05*
			0.037	>0.05
			0.056	>0.05
			0.367	<0.05*
			0.382	<0.05*
School holidays	0.034	>0.05		

Recreational activity from boats was concentrated adjacent to the coast and inside the lagoon environment (Figure 4-4). The highest mean densities of boats were in the blocks adjacent to Coral Bay. The seasonal effect on the density and spatial extent of boat-based activities can be clearly identified with expansion along the coast and outside the fringing reef crest in peak months. During the peak months, the increase in observations around Tantabiddi was obvious.

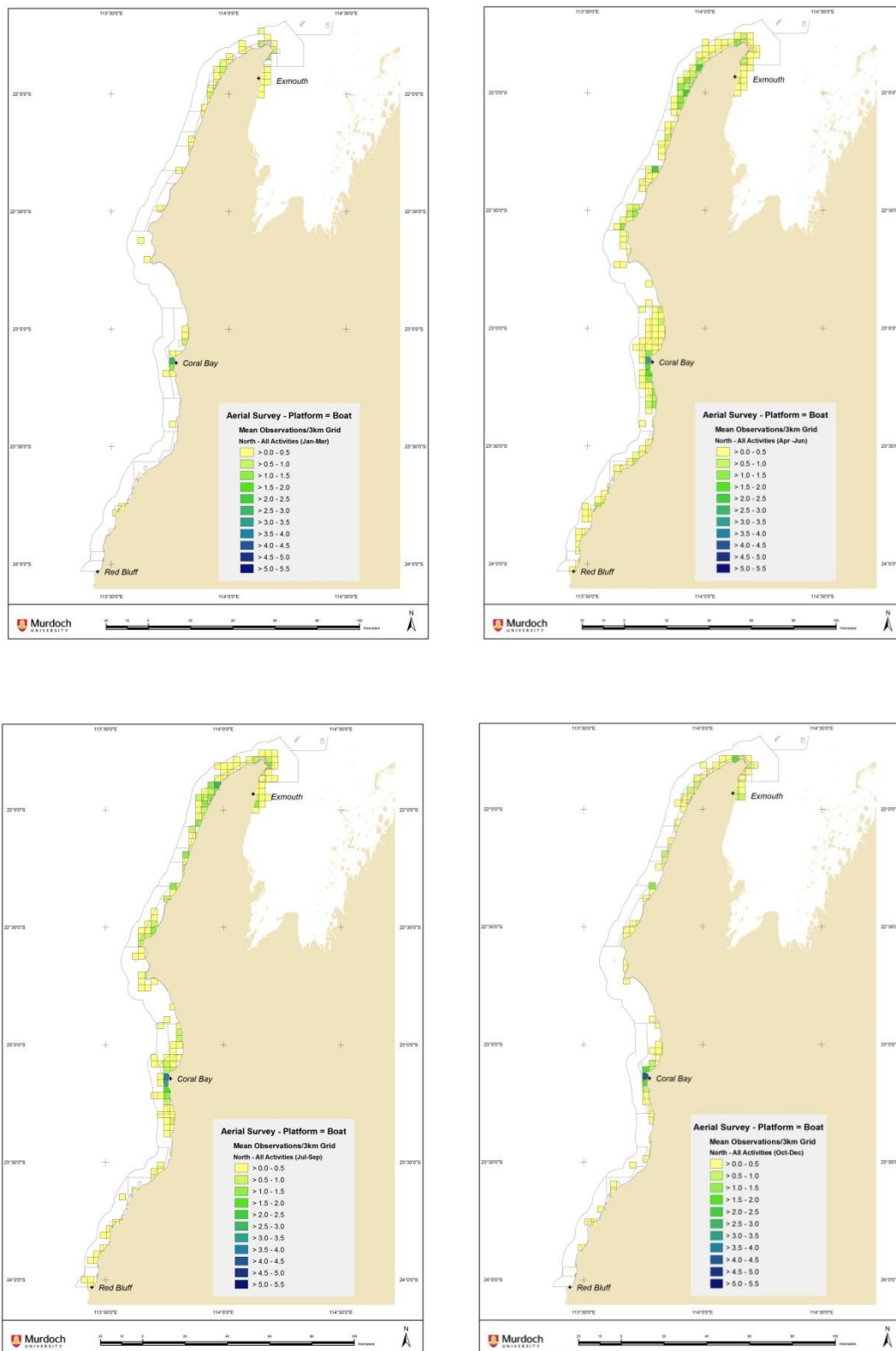


Figure 4-4. Mean number of boats participating in boat-based recreation within each 9 km² grid cell recorded during northbound aerial flights during Jan- March (number of flights = 6), April- June (number of flights = 10 flights), July-September (10 flights) and October to December (n = 8 flights).

Nevertheless, throughout the year, there was little boating activity observed in some parts of the NMP such as immediately to the south of Jane’s Bay on Ningaloo Station or near Cape Farquhar on Gnaraloo Station.

The intensity of boat-based recreational use was determined by the number of different activities occurring in a grid cell. Unlike density of use, which was higher in peak months, there were >10 activities/grid cell recorded in both periods, especially at Coral Bay, Oyster Bridge/Lagoon and Trealla Beach. Activities included fishing, spearfishing, diving, kayaking, motoring, snorkelling, sailing sports, wildlife viewing and wildlife interactions.

4.4.3 Shore-based activities

There were 4 341 observations of groups undertaking recreational activities from the shore during aerial surveys. Unlike the boat observations, it was usually possible to determine and record the number of people per observation. The mean group size across all aerial flights was 3.5 people, excluding 0.6% of groups whose size was undetermined. When applying standard decision rules (based on mean values for these activities in the entire dataset) to assign a group size to these missing values, the total number of people calculated was 15 393, of which 71.0% were recorded on northbound flights. The maximum northbound count was 910 people which occurred during the October school holidays.

The effects of temporal factors on shore activities were investigated and, like the boat-based results, showed significant differences between season and off-peak/peak months in terms of participation although there was no significant difference for school holiday versus other times of the year (Table 4-3). Pair-wise comparisons between seasons showed that strongest differences were between winter and summer periods ($R = 0.596$; $p < 0.05$). A SIMPER analysis determined which activities were responsible for these differences and highlighted low levels of dissimilarity (25.0 – 34.2%) between each pair-wise comparison. Dominant activities, particularly walking, surfing, swimming and relaxing, were present across all temporal periods.

Table 4-3. Result of 2-way crossed ANOSIM tests (based on Bray-Curtis similarities with square root transformed data) using total number of people on the shore across all aerial flights to investigate temporal factors (season, off-peak/peak, school holidays) and types of recreational activity. Note: * denotes significant result.

<i>Factor</i>	<i>Global R</i>	<i>ρ</i>
Off-peak/peak	0.269	<0.05*
Season	0.325	<0.05*
	<i>Pairwise comparisons</i>	
	Winter, Spring	0.199 >0.05
	Winter, Summer	0.596 <0.05*
	Winter, Autumn	0.242 <0.05*
	Spring, Summer	0.282 >0.05
	Spring, Autumn	0.304 <0.05*
	Summer, Autumn	0.486 <0.05*
School holidays	-0.01	>0.05

The mean number of people obtained per survey was mapped using 3 km coastal segments and, as with boating, there were higher densities of people recorded during northbound flights. An ANOSIM test showed significant differences in the number of people and composition of recreational activities on different flight directions ($R = 0.434$, $p < 0.05$). Although the R value was larger than found for temporal effects, a SIMPER analysis to determine the activities responsible for these differences in flight direction still had a low level of dissimilarity (37.2%). Northbound flight data were selected for further analysis of shore recreation based on the higher densities of people and for consistency with boating activity.

Periods of high density and expansion of spatial extent of people participating in shore-based activities were clearly identified (Figure 4-5). In peak months (April to October), people were observed in higher densities and distributed in 25.4% more coastal segments. Turquoise Bay in Cape Range National Park and Coral Bay consistently had high numbers of people engaged in shore-based recreational activities throughout the year whilst other locations around North-West Cape such as Bundegi Beach and Lighthouse Bay had high densities in peak season. Areas to the north of Yardie Creek, south of Jane's Bay on Ningaloo Station and around Cape Farquhar on Gnaraloo Station consistently had no shore activity recorded during the surveys.

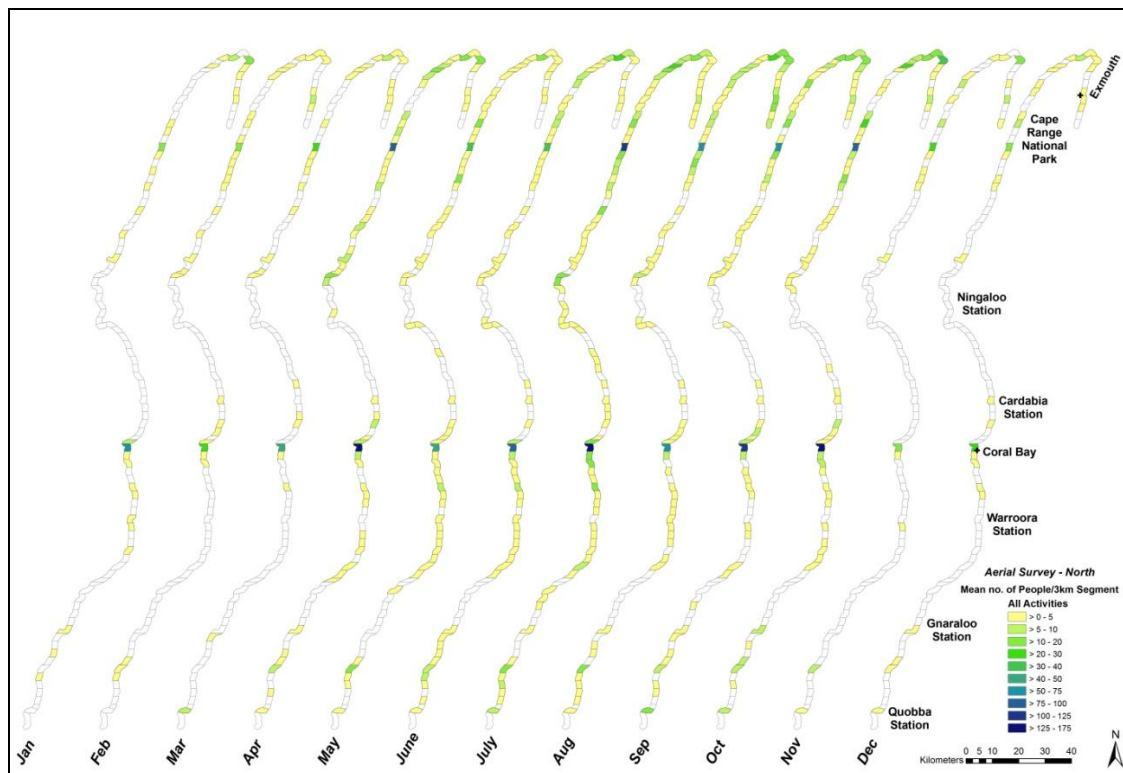


Figure 4-5. Mean number of people participating in shore-based recreation within each 3 km coastal segment of Ningaloo Marine Park recorded during northbound aerial flights during each month in 2007 (number of flights = 34).

Intensity of shore use was also determined by the number of different activities which occurred in each coastal segment. There were up to 13 activities/coastal segment recorded in both off-peak and peak months at Lighthouse Bay, Lefroy Bay, Coral Bay, 14 Mile and Gnaraloo Bay.

Activities such as fishing, swimming, snorkelling, relaxing, surfing, walking, sailing sports, beach games, wildlife viewing and wildlife interactions were undertaken at these locations.

As well as recording counts of people, there were also 7 696 observations of camps, boat trailers and vehicles as well as boats that were not being used for recreation at the time of observation (i.e. they were on moorings, anchored, in marina pens or on the beach). The total number of counts was even across all southbound and northbound flights as these were fixed locations where counts occurred on every survey. The only significant difference was obtained for vehicles and boat trailers, which had higher mean counts on northbound flights than southbound ones (Table 4-4; Figure 4-6).

Table 4-4. Mean, standard error and significance of dependent variables (one-way ANOVA) when comparing fixed counts of vehicles, camps and boats obtained on southbound and northbound aerial flights. Note: * indicates significant value.

<i>Dependent variable</i>	<i>Southbound</i>		<i>Northbound</i>		<i>ρ value</i>
	<i>Mean</i>	<i>± SE</i>	<i>Mean</i>	<i>± SE</i>	
Vehicles	96.6	7.9	202.0	16.3	$F_{(1, 66)} = 33.74, \rho < 0.05^*$
Camps	193.1	22.0	183.1	22.0	$F_{(1, 66)} = 0.10, \rho > 0.05$
Boat trailers	21.1	2.4	40.5	5.2	$F_{(1, 66)} = 11.23, \rho < 0.05^*$
Boats launching	4.4	0.5	3.9	0.8	$F_{(1, 66)} = 0.33, \rho > 0.05$
Boat on beach	64.1	7.7	55.3	7.0	$F_{(1, 66)} = 0.70, \rho > 0.05$
Moored boats	21.0	0.8	21.2	0.9	$F_{(1, 66)} = 0.03, \rho > 0.05$
Boats in pens	27.8	0.9	24.9	0.7	$F_{(1, 66)} = 3.30, \rho > 0.05$
Anchored boats	1.3	0.4	1.2	0.5	$F_{(1, 66)} = 0.002, \rho > 0.05$

Temporal trends were also evident when comparing the mean counts per month over the study period for both flight directions (Figure 4-6). There was low variability across the 12-month survey period for counts of number of moored boats and boats in marina pens, which were present even in the summer months. However, counts of vehicles, camps and boats on the beach showed seasonal variations, with higher numbers in the peak months between April and October. Boat trailers, boats launching from ramps and anchored vessels had highest frequencies during April and July but did not display the clear seasonal pattern of other counts.

Camps were distributed over a greater number of sites in peak months (April to October) and highest densities were recorded at 3 Mile, 14 Mile, Red Bluff and Lefroy Bay (Figure 4-7). In off-peak months, Red Bluff and 3 Mile still had high densities of camps whilst many sites in Cape Range National Park (CRNP) had low densities of campers. Camps in Coral Bay and Exmouth were not recorded as they were located within caravan parks and it was not possible to accurately survey these sites.

The finite number of camps available in CRNP (maximum of 109 sites) allowed for percentage capacity to be calculated, unlike for the majority of coastal camping areas on pastoral leases further to the south, which have undesignated sites with no appointed maximum capacity. Camping in CRNP achieved a mean occupancy >80% for June to September, while the remaining peak months had a mean >50%. This mean occupancy dropped to <15% for all off-peak months (November to March).

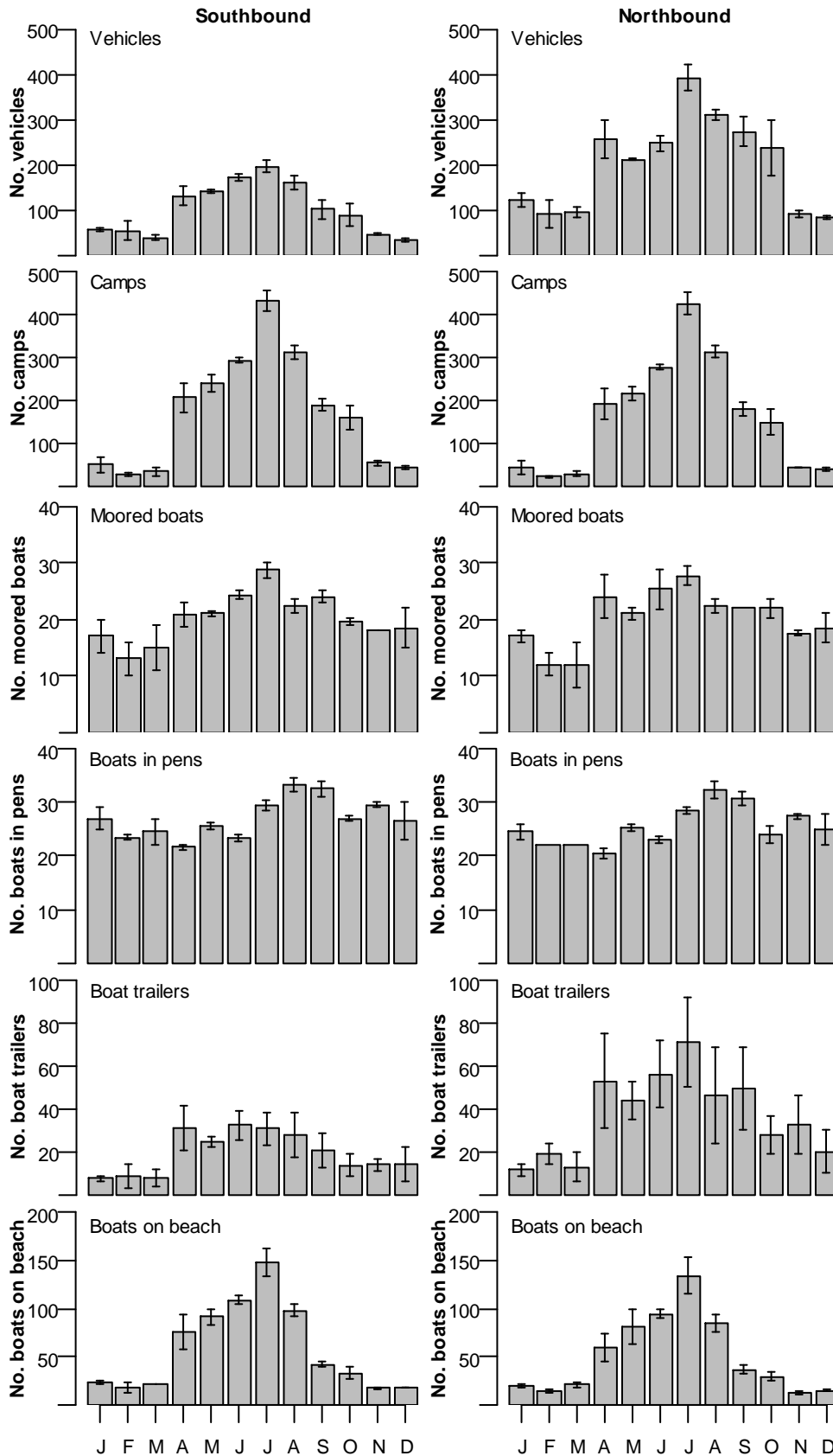


Figure 4-6. Mean number of vehicles (cars, buses and quadbikes), camps, boats on moorings, boats in marina pens, boat trailers and boats on the beach per month for southbound and northbound aerial flights conducted during 2007 ($\pm 95\%$ CI) (number of flights = 34).

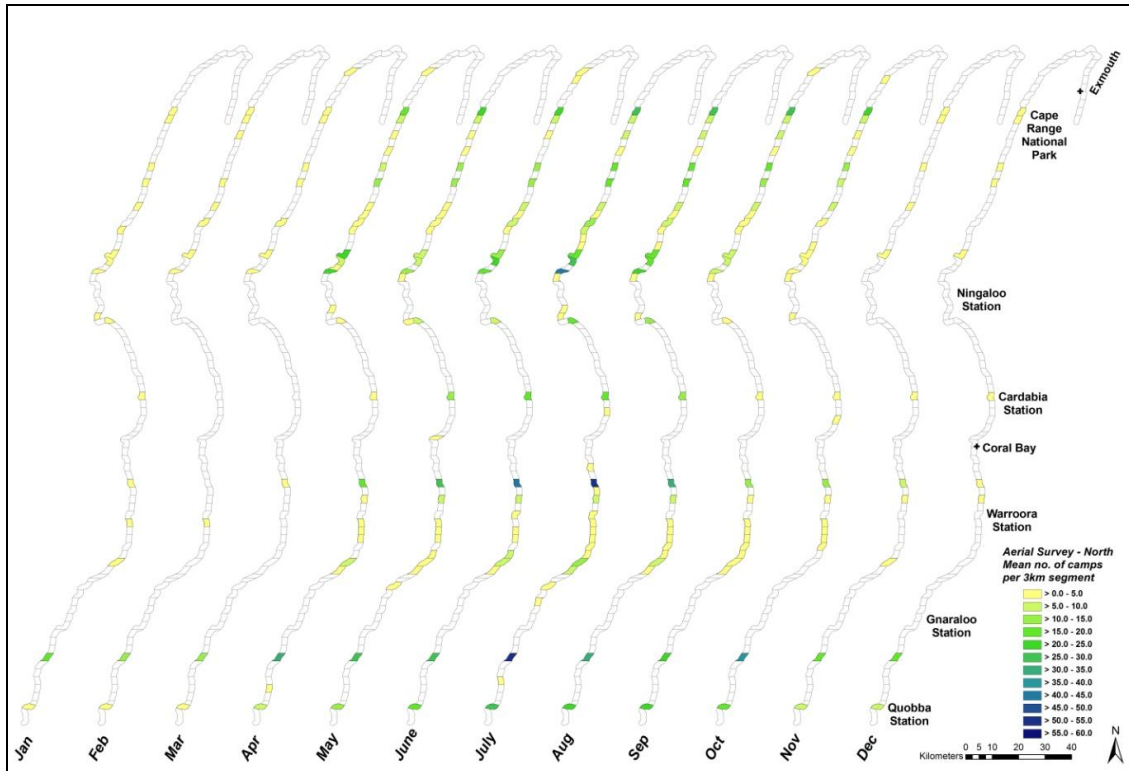


Figure 4-7. Mean number of camps per 3 km coastal segment recorded along the shores of the Ningaloo Marine Park during 34 northbound aerial flights throughout 2007.

Unlike camps, there was a more even distribution of vehicles during both off-peak and peak periods, although there were still higher densities recorded from April – October (Figure 4-8). The spread of vehicles was especially evident in CRNP and along North-West Cape where boat trailers were observed at fewer sites along the Ningaloo coast than camps or vehicles (Figure 4-9). The highest numbers were recorded during peak months in the parking areas at sealed ramps at Tantabiddi, Exmouth and also Bundegi. During most of the study period, the trailers associated with boats that were launched off the beach in Coral Bay were required to be parked in the caravan parks so were not able to be counted. The Coral Bay boat launching facility was opened in October 2007 and subsequently trailers from boats launched there could be counted.

Boats on the beach comprised those vessels that were not being used for recreation at the time of observation during northbound aerial flights. These generally consisted of tinnies that were pulled up on the beach adjacent to coastal camping areas and also charter boats at Coral Bay. Boats on the beach were recorded at more sites in the peak months, with the highest numbers recorded at Bundegi, Brudoodjoo, Coral Bay and 14 Mile.

4.4.4 Spatial accuracy

The spatial errors associated with shore and boat-based recreational activities were different, as co-ordinates were computed using separate techniques. However, the initial observed locations from which these co-ordinates were calculated were obtained using the same GPS and data logging devices. Therefore, every data point had an associated GPS position as well as information that could be used to determine spatial error. Of all data points, 22% were determined using known landmarks, which had previously been geo-referenced via land-based

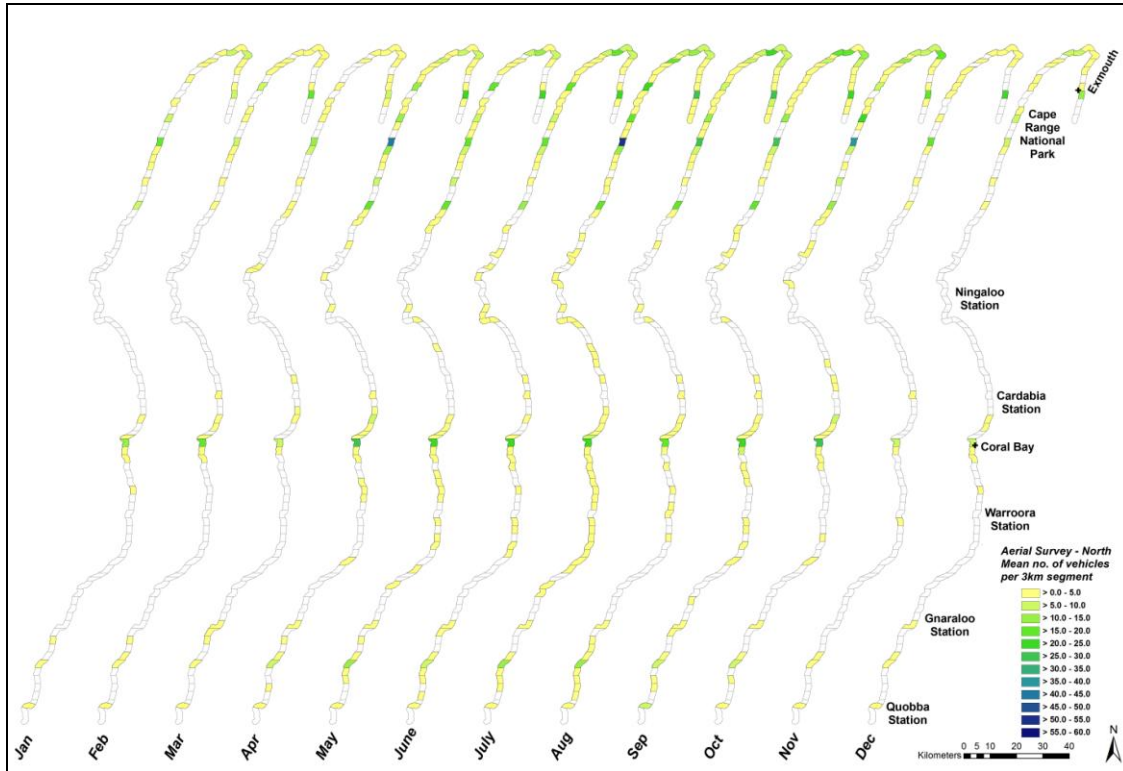


Figure 4-8. Mean number of vehicles adjacent to the Ningaloo Marine Park per 3 km coastal segment during 34 northbound aerial flights throughout 2007.

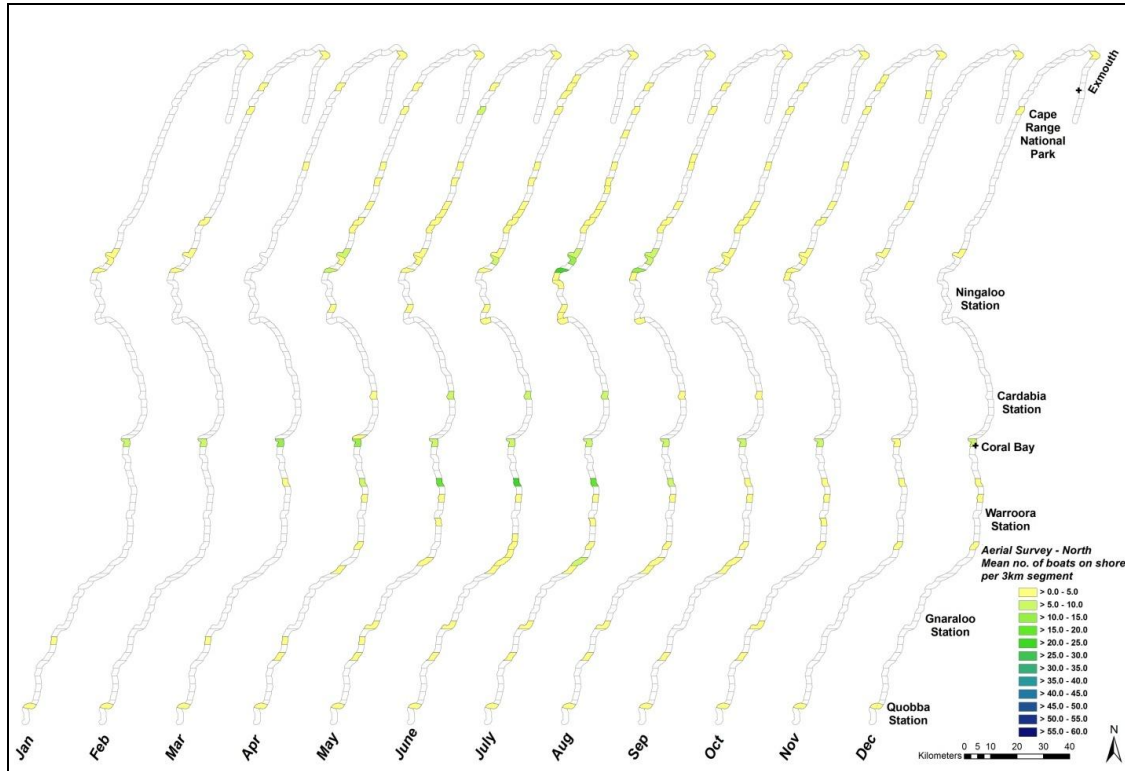


Figure 4-9. Mean number of boats on the shore adjacent to Ningaloo Marine Park per 3 km coastal segment recorded during 34 northbound flights throughout 2007.

surveys and therefore had no sampling error. For the remaining points, the NMEA output indicated that the Horizontal Position Error was small with a mean value of 4.5 m. Variation in altitude could also affect accuracy of boat positions, as the markers on the wing struts were calibrated to the plane flying at a height of 500 ft (151.5 m). Based on the recorded mean height of 164 m, the mean error in estimating distance for boat activities due to variations in altitude was 2.1 m ($SD = 4.0$ m).

Using the NMEA data strings, the mean spatial error associated with each vessel was 6.1 m ($SD = 6.4$) while for shore-based data points it was 4.3 m ($SD = 2.4$ m) which should be incorporated with inherent GPS biases of ~25 m. These errors do not take into account the markers on the wing struts being calibrated to a maximum distance of 1 500 m from the plane, even though features such as the reef crest were used to improve estimation beyond this distance. The mean distance to a boat from the observation point was 1 133 m and 75.2% of sightings were within 1 500 m. Only the remaining 24.8% of points would be subject to the increased error, which is difficult to quantify. In terms of completeness, less than half of boat observations to a distance of 1 500 m from the flight path had both activity and number of people identified and beyond 1 500 m, these details were seldom able to be determined by the observers (Figure 4-10). For shore activity the maximum distance for observations was 1 500 m, as the plane flew parallel to the coast. Shore observations had a much higher level of completeness, with nearly all observations with both activity and number of people identified (Figure 4-10).

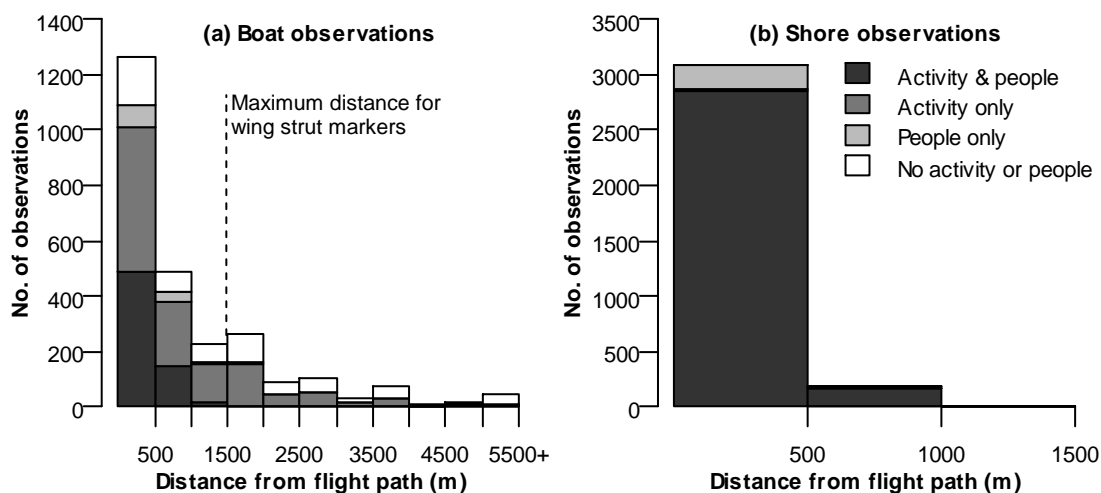


Figure 4-10. Distance from flight path, in metres, for all (a) boat and (b) shore observations and the completeness of the observation in terms of identifying number of people and activity type.

4.5 Discussion

Temporal factors such as seasons and school holidays are well-known to affect the distribution and density of tourism and recreational use of an area (Higham and Hinch, 2002; Fernandez-Morales, 2003; Jang, 2004). Ningaloo, and northern Australia in general, exhibit a unique pattern of visitation because of the very high temperatures and extreme weather events (such as cyclones) which occur during the summer months (BOM, 2009). Peak periods of visitation therefore occur outside of these months, during periods of lower wind speeds and cooler

temperatures (April – October), which is when the majority of previous visitor research at Ningaloo has been conducted (Wood, 2003; Worley Parsons, 2006). This was reflected in the greater spatial extent and density of recreational use occurring from boats and the shore during peak months. However, recreational use was also documented during off-peak months and this has been largely overlooked in previous research in the region.

In peak months, boating activity expanded along the coast and outside the sheltered lagoon environment. However, there were some locations at which little boating activity occurred in either off-peak or peak periods. This is chiefly due to the lack of suitable boat launching areas or a very narrow lagoon environment (<100 m wide) and limited access to the open ocean. Shore activities also had greater spatial extent and density in peak months although some areas had no activity observed at all during the flights. As with boating, this is likely to be related to the lack of access to these coastal areas.

The seasonal expansion of activities from boats and along the coast coincided with an increased number of camps, vehicles, boat trailers and boats on the beach. These facilities provide points from which visitors can access, and therefore impact, coastal and marine resources. Although this is a complex relationship, generally the highest human influences occur in areas closest to such facilities (Sanderson et al., 2002). Worley Parsons (2006) asked interview respondents at Coral Bay to identify the general region to which they would be travelling to by boat for recreation. Although distribution was evenly split between inside and outside the lagoon, the majority of respondents planned to only travel short distances from the boat launching site.

The number of sites available for camping in CRNP is finite and mean occupancy for the majority of peak months was >80%. Occupancy was observed to be slightly higher on the earlier, southbound flights, as they recorded camps prior to people departing the area. There is also a finite number of designated camping sites at 3 Mile (on Gnaraloo Station) and Red Bluff (on Quobba Station) but overflow areas boost the counts of camps beyond these limits. Many other camping areas, such as Lefroy Bay and Winderabandi Point (on Ningaloo Station) where camping is permitted on the beach in unassigned sites, appear to have no designated maximum limit.

At Ningaloo, aerial flights have been used to survey marine megafauna (Sleeman et al., 2007; Wilson et al., 2007) and turtles (Preen et al., 1997) but have been little used with respect to recreational use except for total counts of coastal camps by DEC each April and July since the mid 1990s. Although the single DEC count of 181 camps for April 2007 was similar to the April mean of 178 camps during this study, their July 2007 count of 561 camps was considerably higher than the July mean of 408 camps during this study. Inclement weather conditions may have influenced this with several periods of rain and strong winds caused by winter cold fronts resulting in vacation of coastal campsites. Variations in counting techniques between observers could be another source of the difference although for consistency between the surveys every effort was made by the researchers to standardize this technique prior to the commencement of the study.

Intensity of use, measured by the number of different activities occurring in a particular grid cell or coastal segment, exhibited a different pattern to density and spatial extent of recreational use. There was no marked change between off-peak/peak months and >10 activities were recorded from boats and the shore during both these periods. Highest diversity of boat-based

activities was concentrated north of Exmouth Marina and adjacent to Oyster Bridge, Coral Bay and Trealla Beach. Shore activities had the highest diversity at Lighthouse Bay, Coral Bay, 14 Mile, Lefroy Bay and Gnaraloo Bay.

This intensity of use at particular locations may be an indication of potential conflict, although this is highly dependent on the nature of these activities, as not all types are incompatible. However, extractive and non-extractive activities such as fishing and diving, which were found to be incompatible within a marine park in eastern Australia (Lynch et al., 2004), are occurring within the same locations at Ningaloo. This potential conflict is also of concern with expected increases in visitor numbers in the future (CALM and MPRA, 2005). Some conflict may have been mitigated within the NMP, with sanctuary zones constraining recreational fishers to other general use or recreation zones. The construction of a new boat ramp at Coral Bay which transferred boat launching further south was also aimed at separating boating away from popular snorkelling and swimming sites.

Aerial flights are a well documented technique for surveying marine recreational activities (Deuell and Lillesand, 1982; Sidman and Flamm, 2001; Falk and Gerner, 2002; Wardell, 2002; Warnken and Leon, 2006) and were effective in obtaining high resolution data at Ningaloo. However, they can be expensive, restricted by adverse weather conditions and it can be challenging to accurately record data from a fast moving platform (Pollock and Kendall, 1987; Logan and Smith, 1997; Southwell et al., 2002). In this study, errors were reduced using equipment, such as data loggers, to automatically record information and synchronising watches and cameras prior to the start of each flight. Locations were also geo-referenced prior to the aerial flights (during land-based surveys) to provide a known position that could be recorded and, hence, reduce the errors associated with these points. Aerial flights, which took four hours to complete, were cost-effective when balanced against the expense and time required to survey the same length of coast using land-based techniques (three days).

The standardised morning sampling regime was aimed at reducing the effect of the strong afternoon onshore sea breezes on opportunities for viewing recreational use. Higher numbers of camps (and also boats on the beach) were obtained during the earlier southbound flights, although this was not a significant difference. However, significantly more vehicles and boat trailers were obtained on the later northbound flights which also translated into more observations of boats and people engaged in recreation in the Marine Park during this time. Previous research by Neiman (2007) and Worley Parsons (2006) also found the highest number of boat launches occurred before 11h00. Therefore, the northbound flights provided a more comprehensive understanding of recreational activity with greater densities and spatial extent.

This study was designed to focus on recreational activities occurring along the shore and in the lagoon environment of Ningaloo. Nevertheless, 29.6% of boats recorded during flights were located outside the fringing reef crest (located an average of 2.5 km from the coast) demonstrating that aerial surveys also constituted a good method for surveying the wider marine park. The limitation to data collected during aerial surveys was the high number of observations of boats that had incomplete information especially number of people on larger vessels whose structures hindered observation. Missing data values could be estimated by using external data sources such as number of passengers that charter vessels are licensed to carry.

4.6 Acknowledgements

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5. FINE-SCALE PATTERNS OF RECREATIONAL USE IN NINGALOO MARINE PARK: A LAND-BASED COASTAL SURVEY APPROACH

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5.1 Summary

Recreational use of Ningaloo Marine Park and adjacent shoreline was ascertained by stratified, roving, land-based, coastal surveys over the period January-December 2007. The geo-referenced locations of observed boat-based and shore-based activities were used to explore fine-scale patterns of recreational use and complemented the synoptic overview of spatio-temporal distribution provided by aerial surveys. Generally, both boat-based and shore-based activities occurred over a wider spatial extent during peak season. Analysis focused on activities with the highest participation levels or spatial extent including the shore-based activities of relaxing, snorkelling and walking and boat-based activities of motoring, wildlife interactions and diving. Snorkelling and diving were aligned with sanctuary zones and coral reef habitats while fishing was associated with general use and recreation zones. Sandy beaches were the most popular location for activities such as swimming, sunbaking, relaxing and beach games. Boating was restricted by the fringing reef crest and recreational fishing from small boats occurred predominantly inside the sheltered lagoon waters although activities such as wildlife interactions generally occurred in the open ocean.

5.2 Introduction

Coral reef systems are usually associated with clear, warm water, relatively shallow depths and are well known for their exceptional biodiversity as well as their structural complexity (Soule, 1991; Hawkins et al., 2005; Almany et al., 2009). These attributes combine to create considerable appeal for visitors (Newsome et al., 2002; Davenport and Davenport, 2006) and Ningaloo Reef is no exception. Further, as one of the longest fringing coral reefs in the world (Wilkinson, 2008), it is more accessible to visitors than many barrier or offshore reef systems.

The spatial and temporal distribution of visitors in marine protected areas is affected by numerous environmental and anthropogenic influences. These include adjacent coastal infrastructure such as roads, campsites and boat ramps (Bruce and Eliot, 2006; Hadwen et al., 2007), coastal geomorphology (Valdemoro and Jimenez, 2006; Schlacher and Thompson, 2008), implementation of marine protected area zoning (Bohnsack, 2000) as well as influences like seasons (Amelung et al., 2007), daily variations in weather conditions (Berkhout and Brouwer, 2005) and word of mouth (Simpson and Siguaw, 2008).

These factors affect the distribution of visitors by concentrating use at specific sites which may lead to overcrowding and user conflicts resulting in displacement, either spatially (i.e. visiting alternative locations), temporally (i.e. visiting less frequently) (Hall and Shelby, 2000; Hall and

Cole, 2007) or cause resource or activity substitution (Arnberger and Hinterberger, 2003; Arlinghaus, 2005). Displacement has been well documented, particularly in terrestrial areas (Kearsley and Coughlan, 1999; Manning and Valliere, 2001; Hall and Page, 2006) and confined freshwater environments, such as lakes and reservoirs (Robertson and Regula, 1994; Hall and Shelby, 2000). Research into displacement in marine environments is more limited and has focused on changes to fishing effort (Halpern et al., 2004), with little work published on the effects of zoning regimes on other recreational activities.

Ningaloo Marine Park (state waters) (hereafter NMP) is a multiple-use marine park that comprises five different types of zones, namely, general use (50% of area), sanctuary (34%), recreation (14%), special purpose (Benthic Protection; BP) (2%) and ~ 0.3% special purpose (Shore-Based Activity; SBA) (CALM and MPRA, 2005). Each of these zones permits a suite of different activities thereby influencing the distribution of recreation. This is pertinent for extractive activities such as recreational line fishing, spear fishing and netting which are prohibited in sanctuary zones. Shell collecting is not permitted anywhere in the Marine Park, while netting and spear fishing are confined to general use and recreation zones located along the southern extent of Ningaloo Reef.

Ningaloo has a diversity of coastal geomorphology and habitats which have been broadly categorised into sandy beaches, a mix of beach/rocky shores, rocky shores and mangroves (Bancroft and Sheridan, 2000). Physical factors such as substrate, habitat, beach width or slope are known to affect the suitability or attractiveness of a site for specific recreational activities (Sarda et al., 2009). Sandy beaches are premier locations for shore-based recreation including passive activities such as sunbaking or high impact activities such as off-road driving (Priskin, 2003; Schlacher and Thompson, 2008). The beach and foredune environment are also popular locations for coastal camping (Hockings and Twyford, 1997; Remote Research, 2002). Reef geomorphology may also affect the distribution of boating activity as the fringing reef crest is likely to restrict the dispersal of boats into open waters. However, there are also benefits to this, with the fringing reef crest creating a lagoon environment sheltered from large swells. Coral reefs are attractive to divers, who are drawn to the high levels of biodiversity and interesting topographies found on reefs (Rouphael and Inglis, 1997; Davenport and Davenport, 2006). Divers prefer to see larger and more abundant fish species during dive charter trips (Rudd and Tupper, 2002). Some fish species also have specific habitat preferences which will attract anglers to a particular sites, e.g. large pelagic species are commonly associated with the outer reef environment (Babcock et al., 2008).

Synoptic patterns of recreational use throughout the NMP were identified using data collected during aerial surveys throughout 2007 (Smallwood 2009) and have provided an understanding of the spatio-temporal extent of recreation occurring from boats and the shore. This paper complements this synoptic work by characterising fine-scale patterns of recreational use ascertained by land-based coastal observation surveys (hereafter referred to as coastal surveys). Coastal surveys are well suited to determining relationships between recreational use and factors such as zoning and geomorphology. Researchers have a longer time to observe and document groups than when flying, and are able to integrate additional techniques (e.g., interviews) that can facilitate a more in-depth understanding of user behaviour and characteristics. The linear nature of the Ningaloo coastline enabled numerous vantage points with overlapping fields of view to be selected along the entire study area. Most previous land-based observational studies have been completed over smaller study areas, which required few vantage points. Examples include monitoring the behaviour of people interacting with turtles on selected beaches at Ningaloo (Waayers and Newsome, 2006) and counts of recreational boating traffic in Sydney Harbour (Widmer and Underwood, 2004). Observational studies conducted

over larger areas, with a greater number of vantage points, have been generally been limited to very few surveys at each point (Keirle, 2002; Arnberger et al., 2005).

The overall aim of this part of the study was to identify and describe the fine-scale patterns for specific recreational activities in the NMP using data collected during coastal surveys throughout 2007. This was achieved by describing specific recreational activities at fine spatial and temporal scales and investigating the effects of factors such as zoning, infrastructure, geomorphology and weather conditions on the distribution of these activities.

5.3 Materials and methods

The land-based coastal surveys were an on-site technique designed to complement data collected during the aerial flights (Smallwood 2009) by using the same geo-referenced sites and counting techniques. Similar on-site survey techniques using direct observation have been used to monitor boating and recreational activity in Australia (Widmer and Underwood, 2004; Lynch, 2006; Smallwood et al., 2006; Prior and Beckley, 2007; Smallwood and Beckley, 2008) and other countries (Bissett et al., 2000; Courbis, 2007; Dwight et al., 2007; Lloret et al., 2008). However, these studies collected data that were aggregated to broad view-sheds while the current study used GPS and laser rangefinder technology to pinpoint the location of recreational activity, thereby providing fine-scale data for analysis.

A 12-month fieldwork programme of land-based, coastal surveys was undertaken from January to December 2007, with a consistent intensity of surveys throughout the study period to develop an understanding of recreational use in both peak and off-peak periods. Sampling days were selected using a stratified random survey design which assumes that a heterogeneous population can be divided into mutually exclusive groups (or strata), which cover the entire sampling frame, and from which a random sample of cases are selected (Watson et al., 2000; Neuman, 2006; Theobald et al., 2007).

As well as appropriate strata selection, there were other factors that had to be addressed to ensure a robust sampling strategy. These were primarily due to the large study area and sandy access tracks that dominate the region and result in extended travel times and associated costs (i.e. fuel, off-road equipment). To overcome these challenges the Ningaloo coast was separated into three routes of about 150 km in length, each able to be traversed by 4WD vehicle in a single day (Figure 5-1). Even so, these distances, combined with the linear nature of the coast and road and track networks, did not allow randomisation of starting location. Day type (i.e. weekend/public holidays, weekday) was taken into account only in the northern extent of the study area but further stratification, such as time of day (i.e. morning/afternoon), which is often incorporated into survey designs, was not possible.

Surveys between Exmouth marina and Yardie Creek (in the northern third of the park) were undertaken as day trips that were evenly split between weekends/public holidays and weekdays. This was considered essential as the town of Exmouth is located such that residents (who work on weekdays) are easily able to access NMP for day trips on weekends and anecdotal evidence suggested this may affect the patterns of recreational use along section of the coast. All other surveys were allocated on random days, covering weekends/public holidays, weekdays and school holidays. Surveys between Yardie Creek and Red Bluff were undertaken as extended overnight trips, either two or four days in length, that required staying overnight at locations *en route*. On four-day trips, the researchers travelled from Yardie Creek to Coral Bay (middle

third) on the first day, continued on to Red Bluff (southern third) on the second day before returning to Yardie Creek via another overnight stop in Coral Bay. These four day trips occurred twice per month and were structured to reduce the cost and distance travelled by the researchers. Two-day trips were undertaken once per month and the researchers travelled between Yardie Creek and Coral Bay on the first day before returning on the following day.

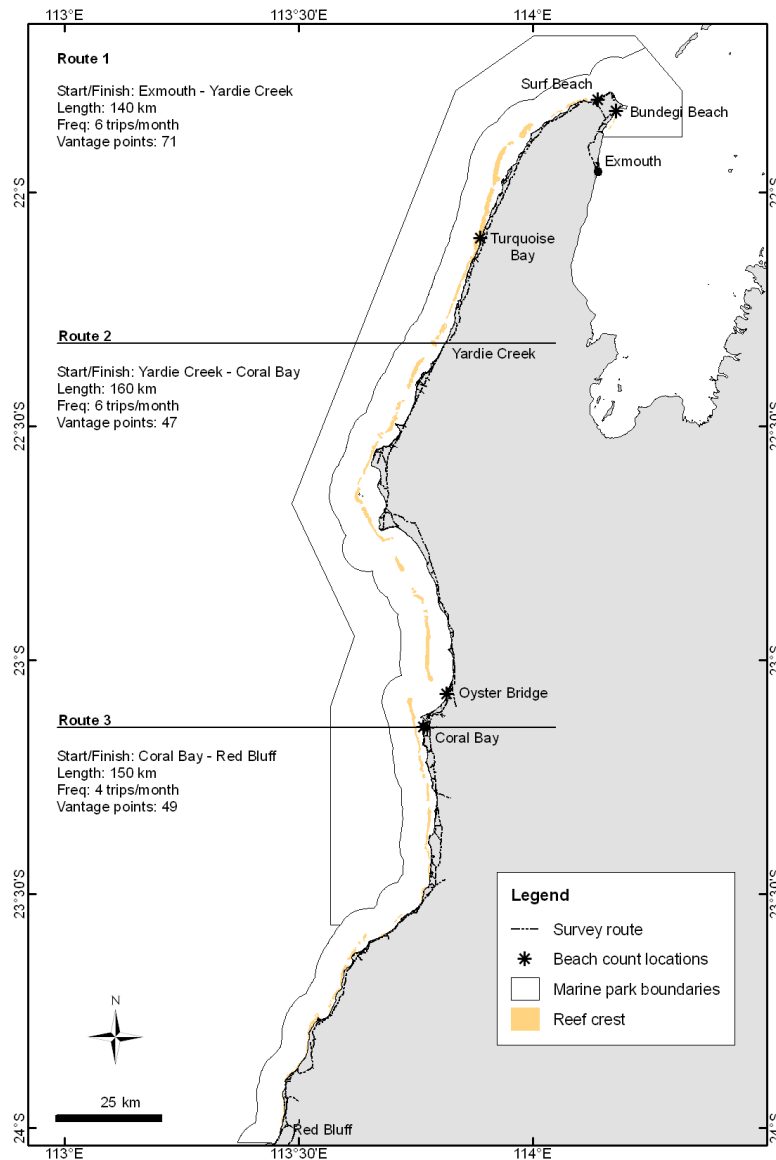


Figure 5-1. Location of the three land-based coastal survey routes at Ningaloo used for progressive counts of recreational use. Information on route length (km), sampling frequency, number of vantage points and sites for instantaneous beach count are also indicated.

Vantage points along the survey route were selected for their accessibility and their overlapping fields of view along the entire coastline and lagoon area. Geo-referenced observations of recreational activity and standard counts of coastal use were made from these points. Vantage points in surveys of boating or marine animals have been widely used (Steiner and Parz-Gollner, 2003; Widmer and Underwood, 2004; Courbis, 2007; Smallwood and Beckley, 2008). Furthermore, wherever possible, travel was along coastal tracks to provide an uninterrupted view of the beach and lagoon. Survey starting times were randomised (between 07h30 – 11h00)

to vary the time each location was visited. Trip direction was also reversed so that locations were visited in both morning and afternoon periods.

Observations from vantage points of groups of people on the shore or on boats were instantaneous counts but, as the coastal survey was conducted over a period of several hours, they collectively provided a progressive count (Pollock et al., 1994). Issues with multiple sightings of mobile groups may result from this technique, and this was avoided by the researchers deliberately excluding a group if they had been previously counted. However, if vessels were first observed whilst motoring (transiting) the Marine Park, but were later sighted undertaking a specific activity, then the details of the second observation were recorded and the first sighting deleted. Randomisation of survey days and starting times, and stratification by geographic area and day type were other techniques which were implemented in the current study to reduce the likelihood of introducing biases into the survey design (Robson, 1961; Schreuder et al., 1975; Wade et al., 1991; Hoenig et al., 1993).

Geo-referenced observations of groups of people on the shore or on boats were made using a handheld Garmin GPS to record the geographical location from which the observation was made and a rangefinder, to determine offset distance and bearing. This information could then be used to calculate the actual location of the group using Vincenty's formula (Vincenty, 1975). The rangefinder, a Newcon LRB 4000 CI, had a range of 4000 m (± 1 m) in optimal conditions (Newcon Optik, 2005) thereby allowing coverage for most of the lagoon environment. During fieldwork, distance and bearings were consistently obtained for objects >2 000 m. If the object could not be detected using the rangefinder, a handheld sighting compass was used to determine the bearing and proportional distance of the object between the shore and the reef crest was estimated. Nautical charts of the lagoon area were then used to determine the distance from the shore.

Once time and position (latitude and longitude) were obtained, the observers recorded (in order of priority), platform (i.e. shore or boat), type of activity and number of people in the group. For boating activity, additional data were collected which included (in order of priority) the type of vessel, status of the vessel (anchored, motoring, drifting, moored, unknown), substrate type over which the vessel was located (reef, sand, unknown) and whether the boat was inside or outside the lagoon environment. Beach counts were conducted at high use locations and entailed the observers walking the length of the beach, counting all beach users and their activities as they walked, similar to the approach used by Keirle (2002).

In some cases, particularly with boat-based activities, it was not possible to ascertain the exact number of people involved in the activity as they were often obscured by cabin or canopy structures. The number of people on smaller vessels (excluding charter boats, cabin cruisers and commercial vessels) was thus based on mean group size calculated across all other observations undertaking the same activity from the same boat type. The mean group size on larger charter and commercial vessels was calculated from secondary data sources. Based on Department of Environment and Conservation (DEC) logbook returns for whale shark trips, the mean number of passengers for 2007 was 16 people per trip (Wilson *et al.*, 2007). Data from Western Australian Department of Fisheries (DoF) logbook returns for charter vessels undertaking fishing, diving, snorkelling, wildlife viewing and sightseeing in the NMP between 2003 - 2005 showed a mean of 10 clients per tour (Northcote and Macbeth, 2008). Standard decision rules were therefore applied to assign charter vessels undertaking wildlife interactions (including whale shark tours) a value of 16 people per trip, while all others were assigned 10 people per trip. Commercial vessels and cabin cruisers were assigned a mean of 5 people per trip, which was based on minimum safety crewing levels (Srinivas, 2007).

For consistency, and based on statistical analyses, the spatial and temporal scales at which data for the coastal surveys were aggregated corresponded to those applied to the aerial surveys (i.e. 9 km² grid cells and 3 km coastal segments). However, for certain recreational activities, the geo-referenced data points were used to emphasise the fine-scale resolution of these data for specific sites within the study area.

The effects of daily weather conditions, coastal geomorphology, marine habitats and zoning on patterns of recreational use were also investigated. Weather conditions were determined using temperature (in degrees Celsius), wind speed (in km/hr) and wind direction (in degrees) obtained in hourly increments from the Bureau of Meteorology and Australian Institute of Marine Science. Geomorphology and habitats of the Ningaloo Marine Park were determined from broad classifications digitised from aerial photographs by Bancroft and Sheridan (2000). Statistical approaches used to determine the significance of various spatial and temporal effects on recreational use included univariate techniques, such as one and two-way Analysis of Variance (ANOVA) and correlation coefficients (r), to examine the relationship between continuous variables. Data were tested for assumptions of normality and homogeneity, and if these were violated, data were transformed or equivalent non-parametric tests (e.g. Kruskal-Wallis, Chi-squared tests) were utilised.

5.4 Results

5.4.1 Spatial and temporal patterns of use

Coastal surveys along the three survey routes were conducted over 192 days in 2007 and during this time, 8 957 observations of groups of people undertaking recreational activity from boats or the shore were documented. By the completion of fieldwork, all survey routes had been conducted an equal number of times in each direction (Figure 5-2).

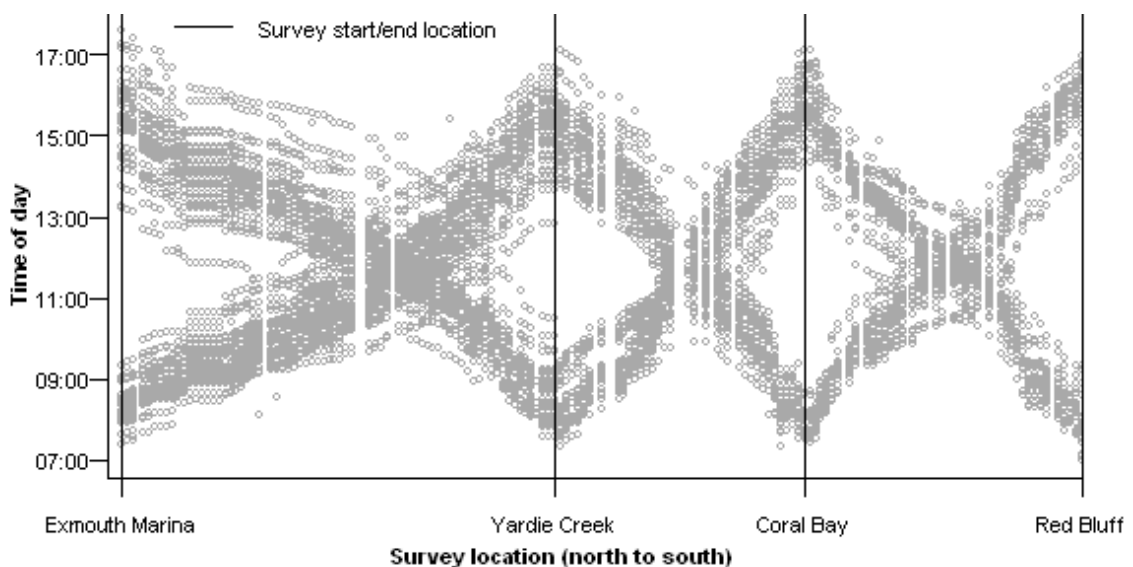


Figure 5-2. Time at each survey location, for all coastal surveys (showing route start and end points) between Exmouth Marina and Red Bluff during 2007 (number of surveys = 192).

The two northernmost survey routes (Exmouth – Yardie Creek and Yardie Creek – Coral Bay) were sampled six times per month and had a significantly higher number of observations (5 452 and 2 553 observations, respectively) than the southern route which was only sampled four times per month ($F(1, 188)=52.03, p<0.05$). Peak months between April – October had the highest number of observations for these routes, although there were > 200 observations recorded between Exmouth – Yardie Creek for each off-peak month (Figure 5-3). Although the southern route from Coral Bay – Red Bluff was sampled less frequently there were 932 observations made over the year and peak months also had the highest number of observations (Figure 5-3). The variation between off-peak and peak periods was significant ($(F(1, 189) =38.84, p<0.05)$ however, there was no interactive effect between this factor and route type ($F(1, 2)=3.00, p>0.05$).

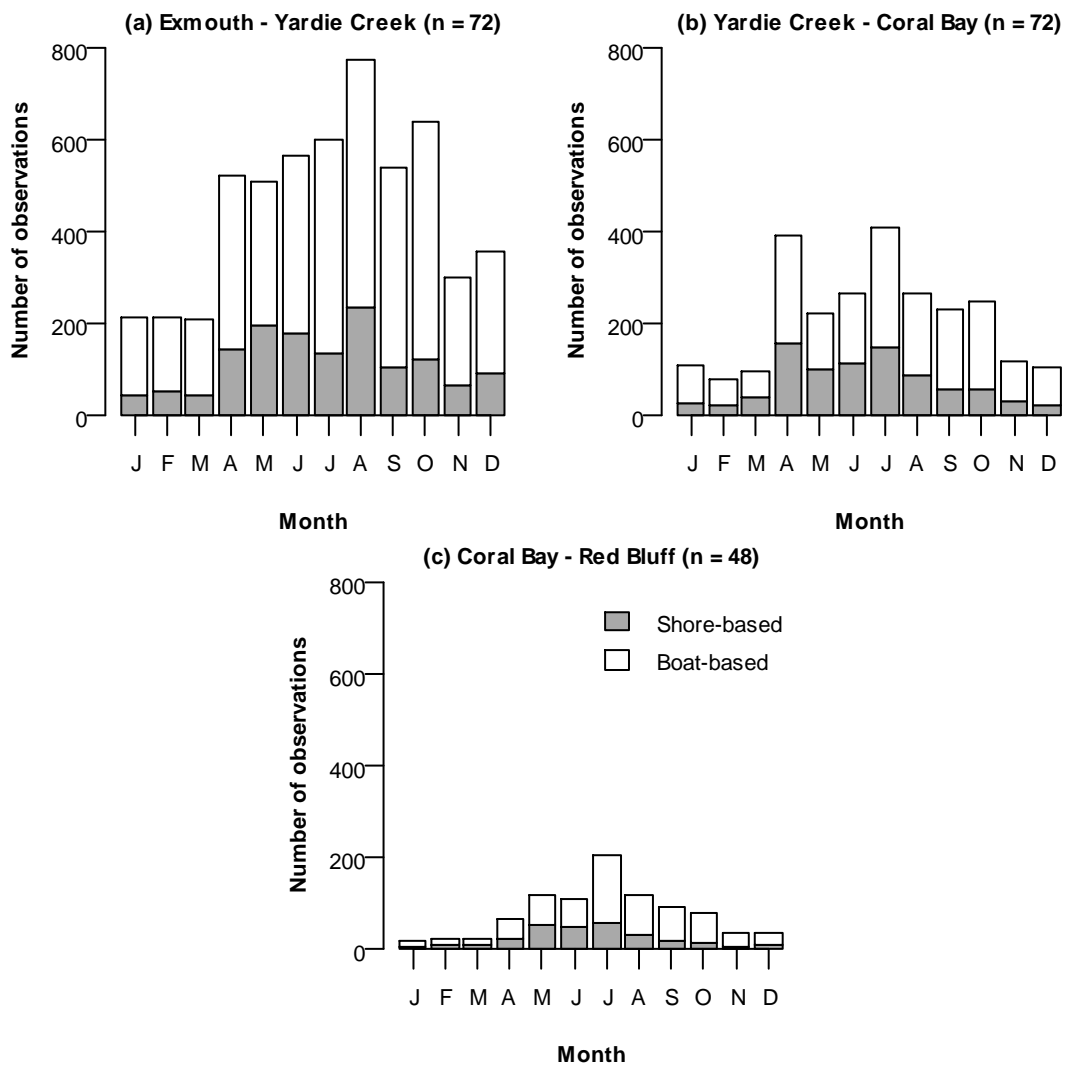


Figure 5-3. Total number of observations of groups of people engaged in shore- and boat-based recreational activity for each month during coastal surveys between a) Exmouth – Yardie Creek, (b) Yardie Creek – Coral Bay and, (c) Coral Bay – Red Bluff where n = number of surveys.

5.4.2 Boat-based activities

The majority of boat-based activity (61.6%) was recorded inside the lagoon with 15.2% outside the reef and the remaining 23.2% located adjacent to parts of the coast with no fringing reef crest. Of the 14 boat types recorded, tinnies (small aluminium vessels) (28.4%), charter vessels (18.3%) and open boats >5 m in length (17.6%) were the most abundant (Figure 5-4). The largest boats (charter vessels and open vessels >5 m in length) were recorded in the greatest numbers outside the lagoon whereas the smallest motorised vessels (tinnies and tenders) and non-motorised vessels, such as kayaks and yachts, were found almost exclusively inside the lagoon.

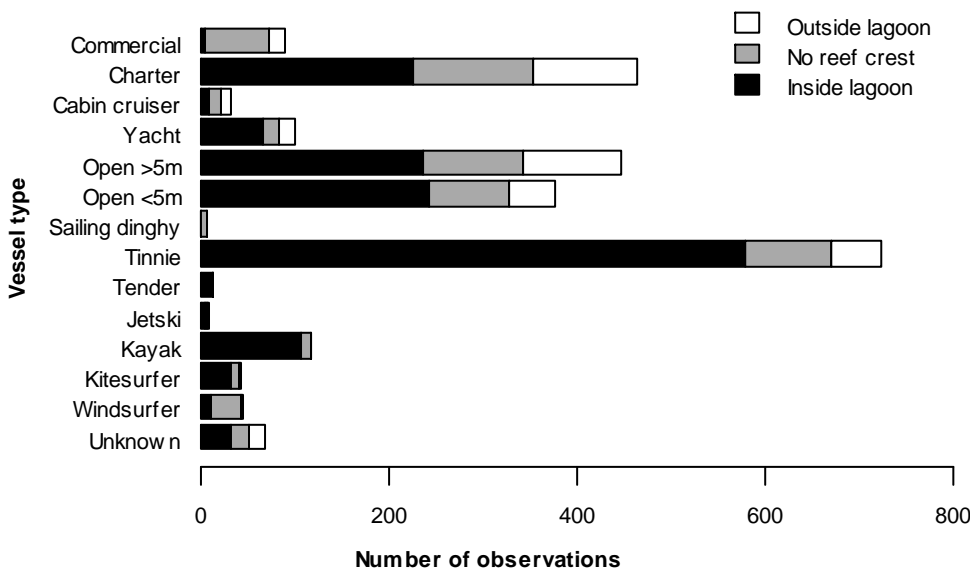


Figure 5-4. Total number of observations at Ningaloo for each boat type recorded inside and outside the lagoon as well as adjacent to areas with no fringing reef crest (number of observations = 2 545).

In total, there were 2 576 observations of groups undertaking recreational activities from boats during coastal surveys and mean group size was 2.3 people. However, for 52.5% of boats, which comprised mostly charter and commercial vessels, the number of people was undetermined. Applying the standard decision rules to assign a group size resulted in a total of 10 047 people, of which only 8.2% were recorded on the southernmost survey route (Coral Bay to Red Bluff).

Boating activity did occur in off-peak months and was concentrated adjacent to the coast, with the highest density at Coral Bay (Figure 5-5). Expansion along the coast and beyond the reef crest occurred in peak months and the highest densities of people, with a mean >5 people/grid cell/survey, were located adjacent to boat launching sites at Tantabiddi, Ned’s Camp and around Coral Bay as well as in Lighthouse Bay.

The most frequently recorded activities undertaken from boats were motoring (transiting), wildlife interactions and diving although in a considerable proportion (26.7%) the activity could not be ascertained (i.e. unknown) (Table 5-1). These activities had the highest number of participants and many also had large spatial extents (i.e. were present in a more grid cells across NMP). The differentiation between wildlife viewing and wildlife interaction is based on the classification applied in Moscardo and Green (1999) as well as expected variation in impacts associated with these activities. Wildlife viewing refers to activities such as whale

watching and coral viewing from glass bottom boats while wildlife interaction refers to snorkelling with whale sharks and manta rays. Although fishing only comprised 5.8% of the people observed, this activity was widely spread occurring in 16.1% of grid cells in the NMP.

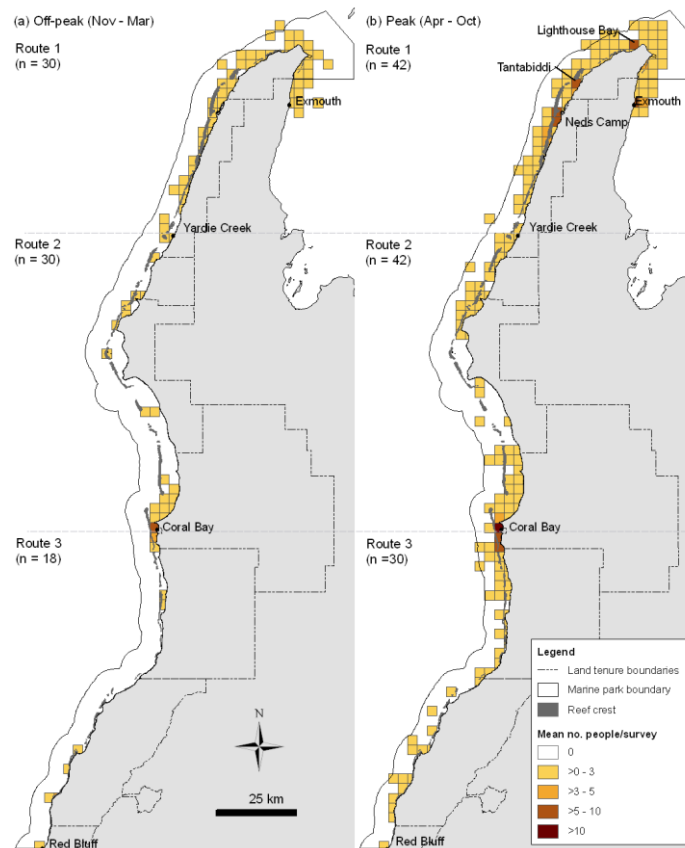


Figure 5-5. Mean number of people participating in boat-based recreation per coastal survey within 9 km² grid cells during (a) off-peak and (b) peak months (n = number of surveys).

Table 5-1. The most frequently undertaken boat-based activities recorded during coastal surveys at Ningaloo based on percentage of people and spatial extent for each recreational activity within 9 km² grid cells.

Boat-based activities	Number of people (%)	Spatial extent (%)
Motoring (transiting)	31.7	32.5
Unknown	26.7	41.0
Wildlife interaction	11.4	4.4
Diving	6.7	4.1
Fishing	5.8	16.1
Wildlife viewing	5.1	2.6
Sailing sports	3.6	11.4
Kayaking	2.9	9.6
Snorkelling	2.6	6.2

The highest numbers of people on boats within the NMP (state waters) were recorded in recreation (54.1%) and sanctuary zones (33.0%). There was no significant relationship between

the number of people and size of the zone ($r^2 = 0.03$; $p > 0.05$). However, there was a significant association between zone and activity type ($\chi^2(38) = 2468$, $p < 0.05$). Wildlife viewing, kayaking and diving were predominantly undertaken in sanctuary zones while fishing, wildlife interactions and unknown activities were undertaken more commonly in recreation and general use zones (Figure 5-6). Of the people fishing from boats, 12.7% were recorded in sanctuary zones.

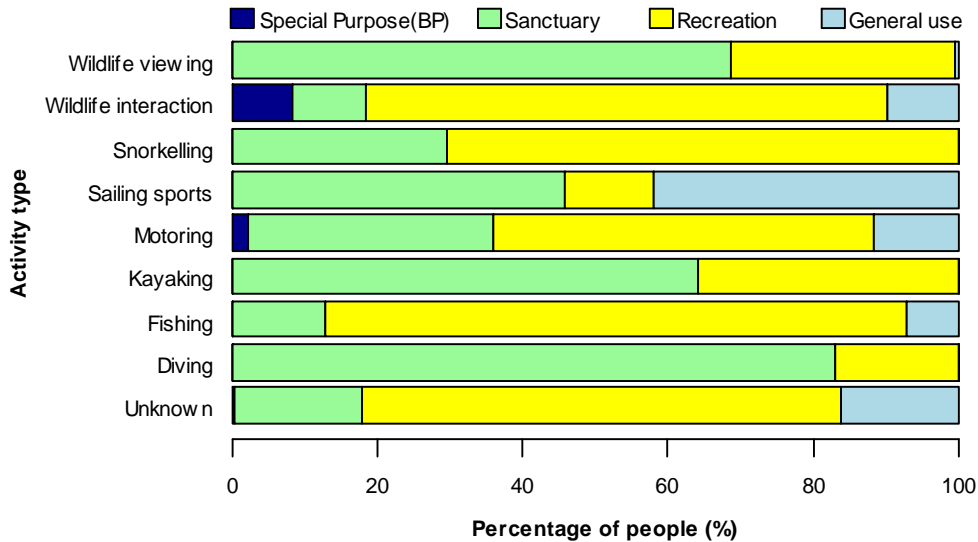


Figure 5-6. Percentage of people observed undertaking a specific activity type from boats within each NMP (state waters) zone type (number of people = 8 826).

The differences between recreational activity and the five broad marine habitat categories were found to be significant ($\chi^2(32) = 1416$, $p < 0.05$). The majority of activities were associated with coral reef habitats, especially diving and wildlife viewing, with >50% people on boats over this habitat type (Figure 5-7). Kayaking and sailing sports were most associated with sandy substrates.

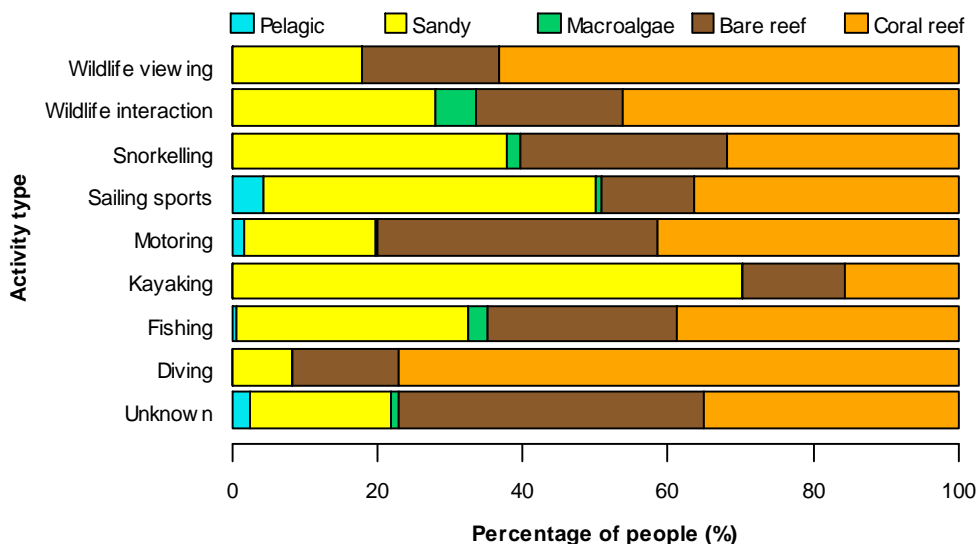


Figure 5-7. Percentage of people observed undertaking a specific activity type from boats within each broad type of marine habitat [adapted from Bancroft and Sheridan (2000)] (number of people = 8 729).

Weather conditions influenced participation in specific recreational activities, with significant differences for air temperature ($F(1, 8) = 26.08, p < 0.05$), wind speed ($F(1, 8) = 57.36, p < 0.05$) and wind direction ($F(1, 8) = 22.24, p < 0.05$). Further investigation found the majority of people were participating in boat activities within the 25°C – 35°C air temperature range and in wind speeds < 25 km/hr. However, sailing sports such as kitesurfing and windsurfing were predominantly performed in wind speeds > 30 km/hr. All activities were undertaken during easterlies and south-westerlies (the dominant wind directions for Ningaloo) though sailing sports were observed more frequently during south and south-westerly onshore winds.

5.4.3 Shore-based activities

There were 6 361 observations of groups of people undertaking recreational activities from the shore during the coastal surveys. The mean group size was 3.7 people, excluding the 0.4% of groups whose size was undetermined. When applying the standard decision rules to assign a number of people to these groups, the total number of people was determined to be 23 282, of which only 7.0% were recorded along the southernmost survey route (Coral Bay and Red Bluff).

There was a greater spatial extent of shore activity in peak months, with expansion into more coastal segments to the south of Coral Bay (Figure 5-8). The highest densities of shore activity occurred during peak months and were concentrated around Turquoise Bay and Coral Bay, with a mean >50 people/ 3 km coastal segment. Coral Bay also achieved this density of activity in off-peak periods. High densities of people were also evident during peak months in coastal segments at Bundegi Beach, to the south of Lighthouse Bay, and Lakeside.

The most popular activities undertaken from the shore were relaxing, walking, snorkelling and fishing (Table 5-2). These activities had the highest number of participants and many also had large spatial extents (i.e. were present in a more grid cells). Fishing from the shore was unique in that it had the largest disparity between number of people and spatial extent, comprising only 8.9% of people but occurring in 67.4% of coastal segments.

Table 5-2. Most frequently undertaken shore-based activities based on percentage of people and spatial extent for each recreational activity within 3 km coastal segments recorded during coastal surveys at Ningaloo Marine Park.

Shore-based activities	Number of people (%)	Spatial extent (%)
Relaxing	37.7	65.2
Walking	18.8	69.6
Snorkelling	11.7	41.3
Fishing	8.9	67.4
Swimming	7.6	43.5
Beach games	5.7	44.6
Surfing	3.4	16.3
Sightseeing/spectating	1.9	46.7
Wildlife interaction	1.7	7.6

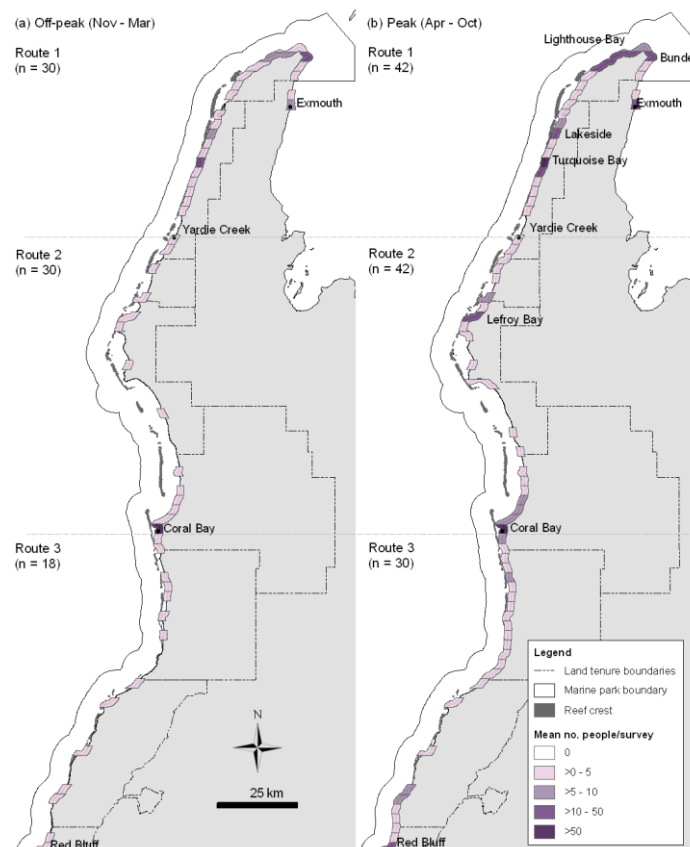


Figure 5-8. Mean number of people per survey recorded participating in shore-based recreation within each 3 km coastal segment during (a) off-peak and (b) peak months at Ningaloo (n = number of surveys).

People along the shore were recorded mainly in sanctuary (48.7%) and recreation (36.6%) zones within NMP. There were also 4.2% of people in special purpose (SBA) zones. There was no significant correlation between the number of people observed undertaking shore activities and length of the zone ($r^2 = 0.053$; $p > 0.05$) but there was a significant association between zone and activity type ($\chi^2 (66) = 9\,395$, $p < 0.05$). Snorkelling had the highest percentage of association with sanctuary zones (84.8%), along with wildlife interactions and relaxing (Figure 5-9). The majority of people were fishing in recreation zones though >30% were in special purpose (SBA) zones and <2% were in sanctuary zones. Shore-based wildlife interactions comprised fish feeding or commercial tours and occurred predominately in sanctuary zones.

The differences between shore activity and coastal geomorphology categories was significant ($\chi^2 (24) = 3\,387$, $p < 0.05$). The majority of activities were associated with sandy beaches, especially swimming and beach games (Figure 5-10). Fishing was associated with beach/rocky shore environments while surfing and sightseeing/spectating were frequently observed along rocky shores. Very few people were recorded undertaking activities in the limited area of mangroves at Ningaloo.

Weather conditions also influenced participation in specific recreational activities, with significant differences for air temperature ($F(1, 8) = 221.34$, $p < 0.05$), wind speed ($F(1, 8) = 11.54$, $p < 0.05$) and wind direction ($F(1, 8) = 64.22$, $p < 0.05$). Further investigation showed the majority of people were participating in shore activities within the 25°C – 35°C air temperature range and in wind speeds <20 km/hr. All activities were undertaken predominantly during easterly and south-westerly winds.

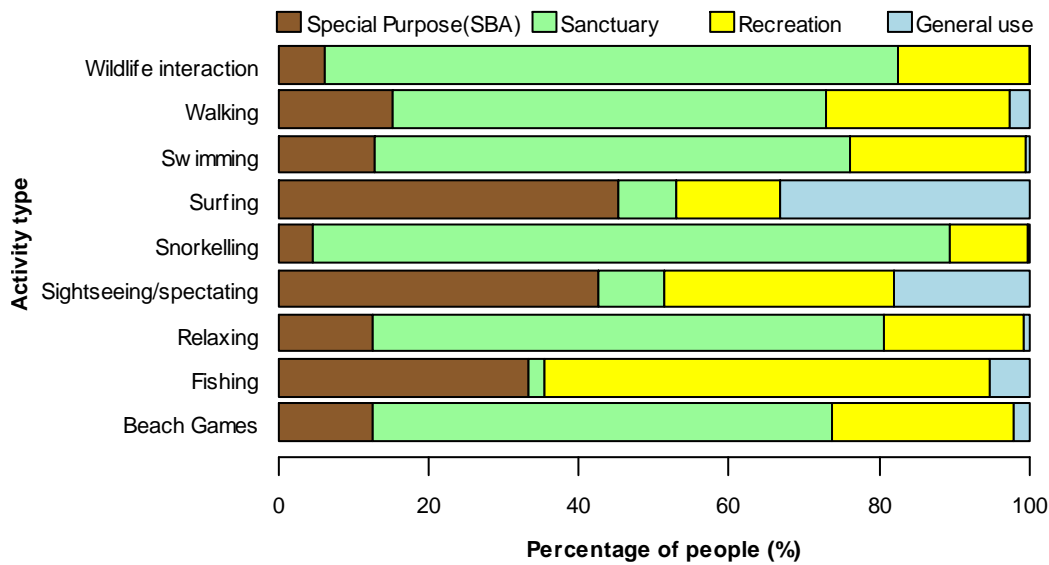


Figure 5-9. Percentage of people observed undertaking a specific activity type from the shore within each NMP zone type (number of people = 22 726).

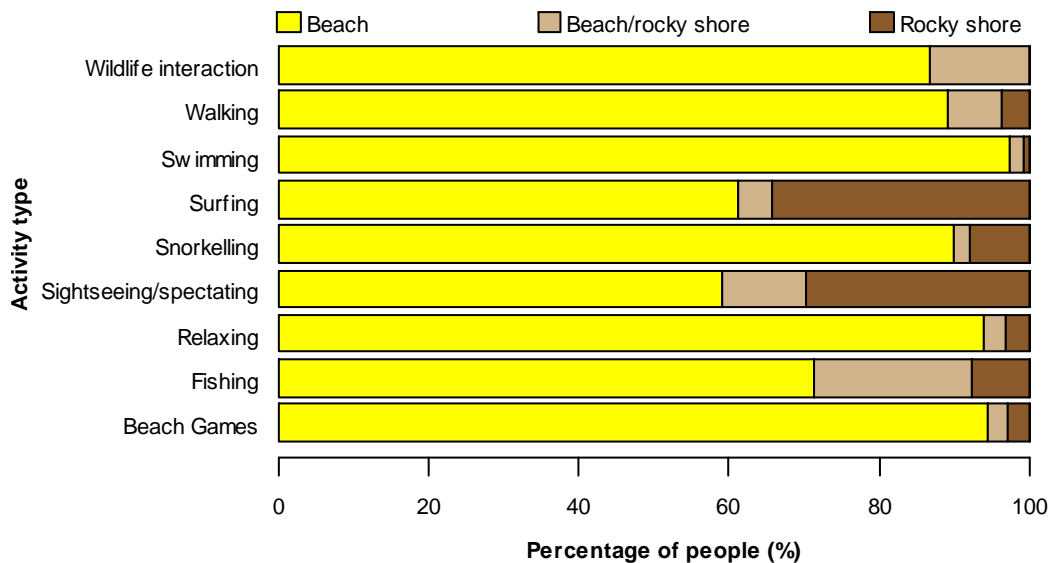


Figure 5-10. Percentage of people observed undertaking a specific activity type from the shore of Ningaloo Marine Park within each broad type of coastal geomorphology [adapted from Bancroft and Sheridan (2000)] (number of people = 22 726).

5.4.4 Case studies of specific recreational activities

As fishing from boats and the shore has been covered separately (See Chapter 7 - Smallwood & Beckley in prep.), motoring (transiting), wildlife interaction and diving were chosen as case studies for activities conducted from boats and relaxing, snorkelling and surfing were selected as case studies for shore-based activities.

Motoring was the most common boat-based activity, with 31.7% of people on boats recorded during the coastal surveys engaged in this activity. Motoring boats were recorded in 32.5% of grid cells within NMP (state waters). Higher densities were obtained during peak months, especially adjacent to Coral Bay, and activity expanded within the lagoon environment and outside the reef crest. During off-peak periods motoring boats were generally recorded around North-West Cape and also adjacent to Coral Bay, where activity was concentrated inside the lagoon (Figure 5-11).

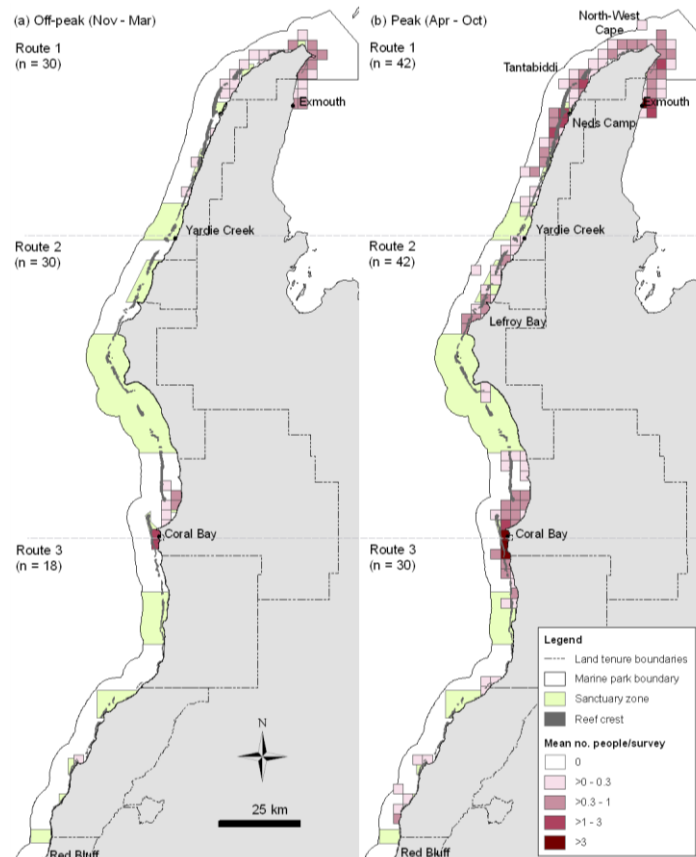


Figure 5-11. Mean number of people recorded on motoring boats during coastal surveys within each 9 km² grid cell in Ningaloo Marine Park for (a) off-peak and (b) peak months (n = number of surveys).

Wildlife interactions comprised activities such as swimming with whale sharks and manta rays, contributing to 11.7% of people associated with observed vessels. The spatial extent of this activity was much smaller than motoring vessels as it was recorded in only 4.4% of grid cells. This activity was located adjacent to Coral Bay all year round, but expanded offshore from CRNP in the peak months, corresponding to the annual whale shark season (Figure 5-12). Geo-referenced points for boats interacting with wildlife in the area offshore from CRNP showed they were largely concentrated outside the fringing reef crest and in general use zones (Figure 5-13). The group size for these vessels was also large (>10 people) as charter vessels are the dominant boat type involved in whale shark and manta ray tours. These vessels are also able to travel further due to their larger size and fuel capacity.

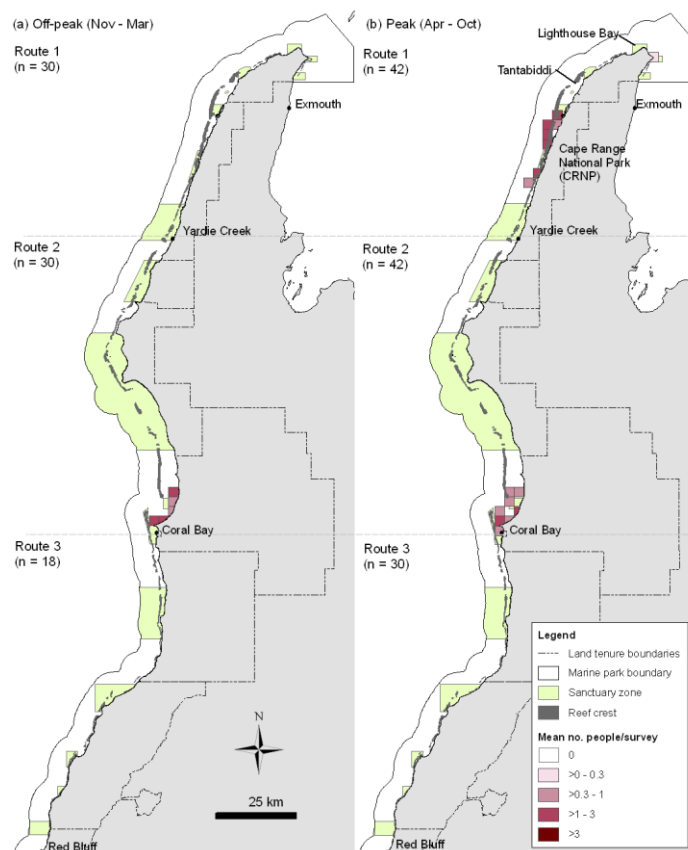


Figure 5-12. Mean number of people recorded interacting with wildlife from boats during coastal surveys within each 9 km² grid cell at Ningaloo for (a) off-peak and (b) peak months in the NMP (n = number of surveys).

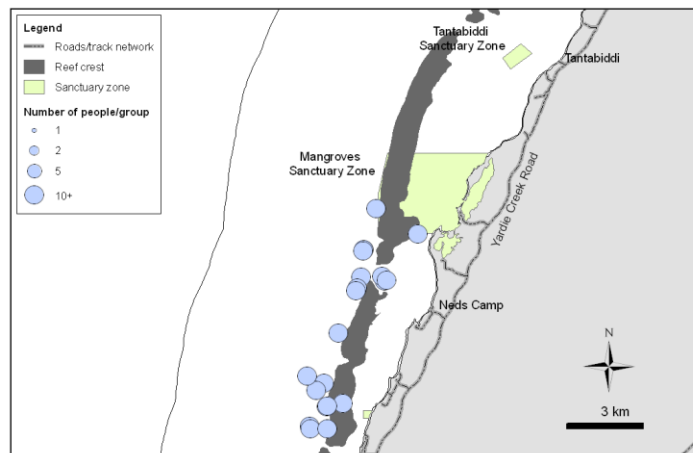


Figure 5-13. Geo-referenced location for each boat observed interacting with wildlife (whale sharks) in NMP offshore from Cape Range National Park, during coastal surveys in peak months (number of surveys = 42).

SCUBA diving was recorded at only a few specific sites throughout NMP. Activity occurred in both off-peak and peak months at these locations in Lighthouse Bay, Bundegi and Ned’s Camp as well as to the north and south of Coral Bay (Figure 5-14). There was no diving observed in the southern extent of NMP beyond Coral Bay. In peak months, boats from which people were

diving were concentrated within two locations around North-West Cape, namely, Lighthouse Bay Sanctuary Zone and Bundegi Sanctuary Zone (Figure 5-15). The large group size, which was generally >10 people, indicates that the majority of these vessels were charter boats, and their geo-referenced locations were clustered together due permanent moorings installed at these dive sites.

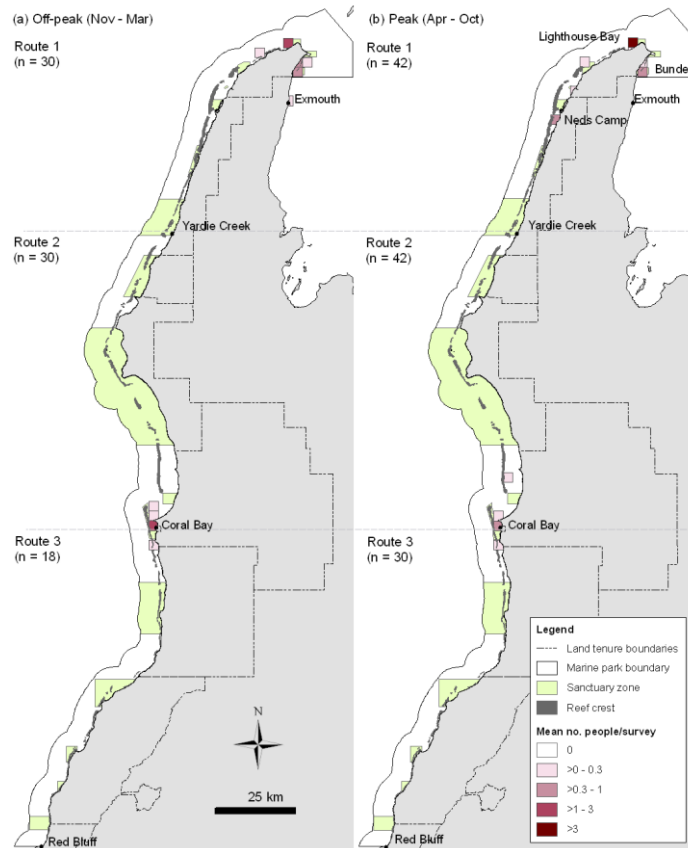


Figure 5-14. Mean number of people recorded diving from boats during coastal surveys in each 9 km² grid cell for (a) off-peak and (b) peak months in the NMP (n = number of surveys).

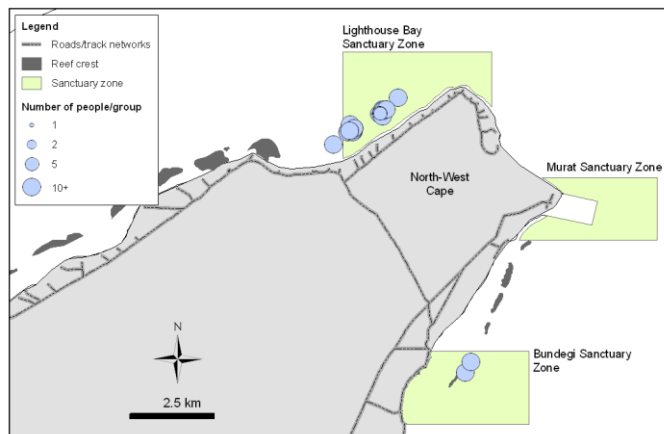


Figure 5-15. Geo-referenced locations of each boat observed with divers around North-West Cape, during coastal surveys in peak months in NMP (number of surveys = 42).

Relaxing on the beach was the most common activity undertaken along the shore in Ningaloo Marine Park, comprising 37.7% of people. It was also widely distributed in 65.2% of coastal segments (Figure 5-16). The highest densities of people relaxing (mean >10 people/3 km coastal segment) were obtained at Turquoise Bay and Coral Bay during both off-peak and peak months. There were also many locations along the length of the Ningaloo coast where people relaxing were consistently recorded during the survey.

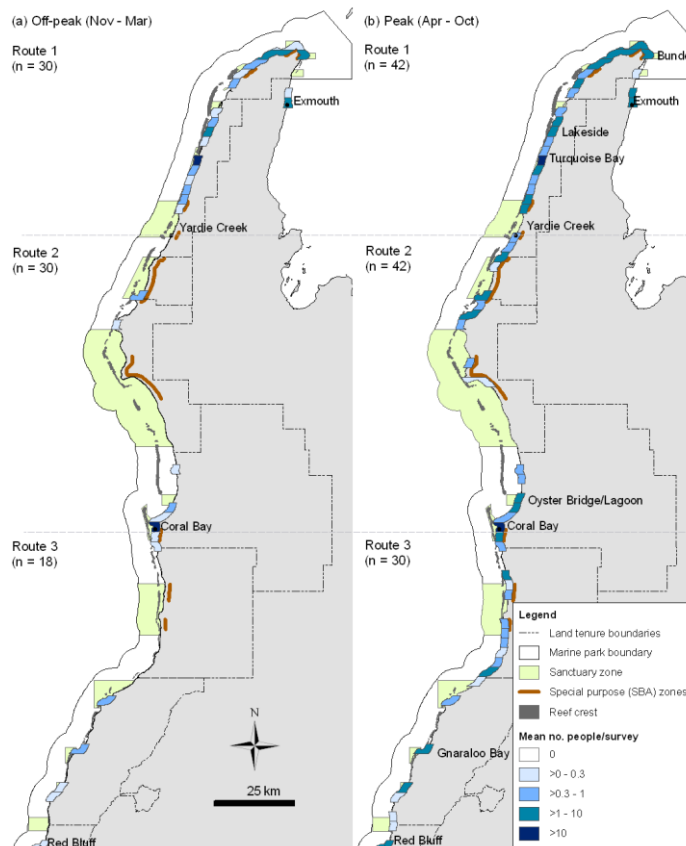


Figure 5-16. Mean number of people recorded relaxing on the beach during coastal surveys within each 3 km coastal segment of the NMP for (a) off-peak and (b) peak months (n = number of surveys).

Snorkelling from the shore was undertaken by 11.7% of people observed and the highest densities were in coastal segments that included Turquoise Bay, Lakeside and Oyster Stacks in CRNP, Coral Bay and Oyster Bridge/Lagoon (Figure 5-17). There were large tracts of coast to the south of Yardie Creek where no snorkelling was recorded. Oyster Stacks and the area extending southwards towards South Mandu were used as a case study with geo-referenced data points representing each group snorkelling at these sites during peak months. This area was selected instead of Turquoise Bay where the very high density of snorkelling activity precluded separating and geo-referencing individual groups of snorkellers. At Oyster Stacks, snorkelling was concentrated within the lagoon, which is very narrow at this point and adjacent to the carpark (Figure 5-18). The size of groups at South Mandu was also larger than at Oyster Stacks due to guided snorkelling tours at this site.

Surfers comprised 3.4% of all people documented from the shore during the study and were observed in a small number of coastal segments in off-peak and peak months (Figure 5-19).

This activity was centred around Lighthouse Bay in the northern extent of the Marine Park and at 3 Mile and Red Bluff at pastoral leases to the south.

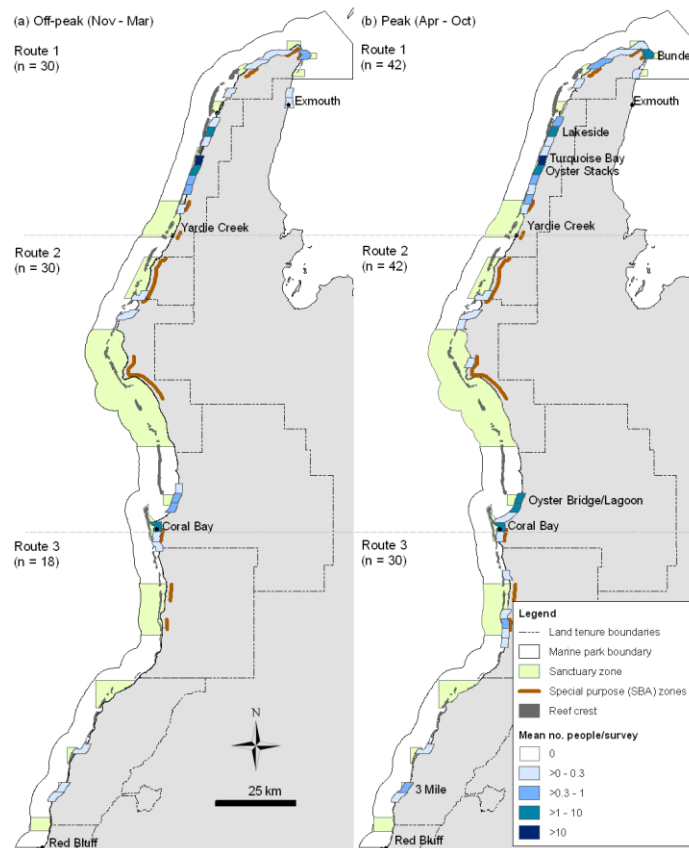


Figure 5-17. Mean number of people recorded snorkelling from the shore during coastal surveys within each 3 km coastal segment of the NMP in (a) off-peak and (b) peak months.

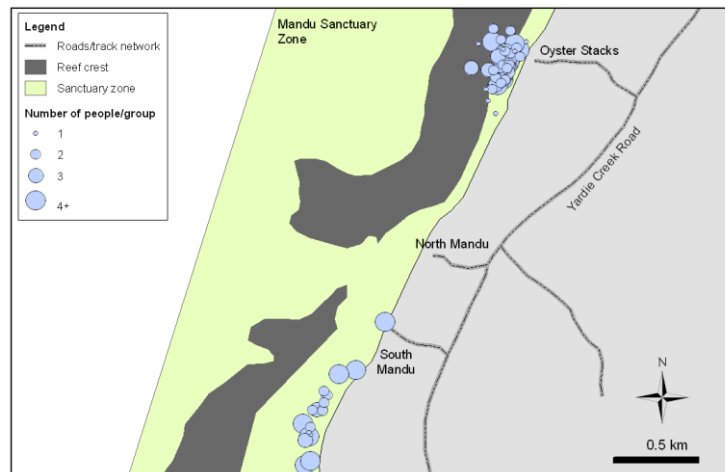


Figure 5-18. Geo-referenced location (and size) of each group observed snorkelling from the shore at Oyster Stacks and South Mandu during coastal surveys on the NMP in peak months (number of surveys = 42).

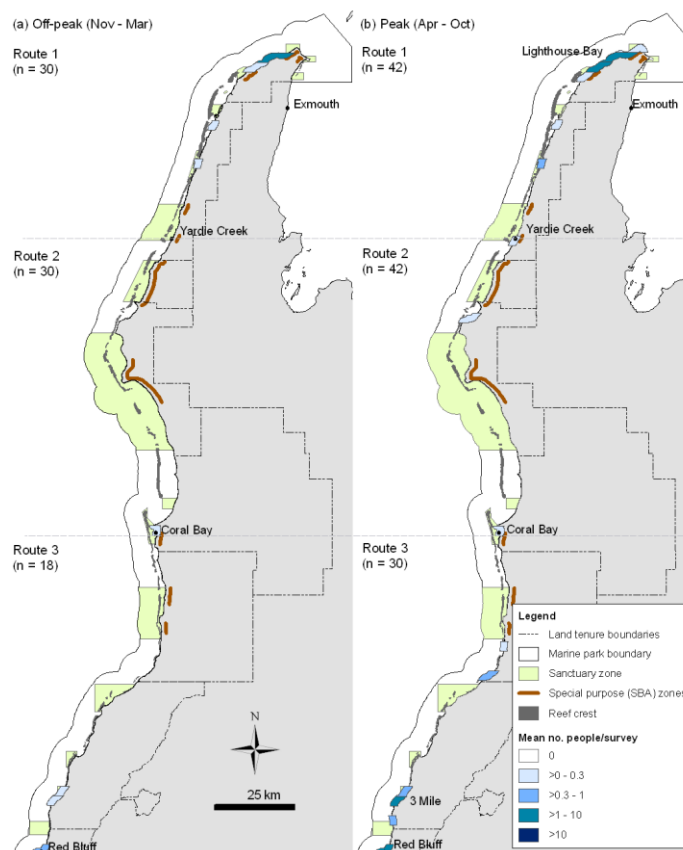


Figure 5-19. Mean number of people recorded surfing during coastal surveys within each 3 km coastal segment for the NMP in (a) off-peak and (b) peak months (n = number of surveys).

5.4.5 Spatial accuracy

The spatial errors associated with pinpointing the location of shore and boat observations were the same, as the geographical co-ordinates were determined using the same techniques. Fixed locations, such as a car park or boat ramp, were used to locate 20% of data points and an additional 15.4% were obtained by the researcher standing at the exact location. Therefore, these points had no associated sampling error. The NMEA output for the remaining points indicated that the mean number of satellites obtained during the coastal surveys was 10 (close to the highest possible number of 12) and Horizontal Position Error was small, with a mean value of 4.1 m.

The mean spatial error associated with each data point was 4.1 m (SD = 0.7 m), although this did not take into account error caused by estimating the distance to people undertaking shore and boat-based activity. The rangefinder can be used reliably for observations <2 000 m distant (87.1% of all observations) and the error associated with this reading was ±1 m (Newcon Optik, 2005). In terms of completeness, only half of boat observations <1 000 m had both activity and number of people identified, while for shore observations all data points had this information (Figure 5-20).

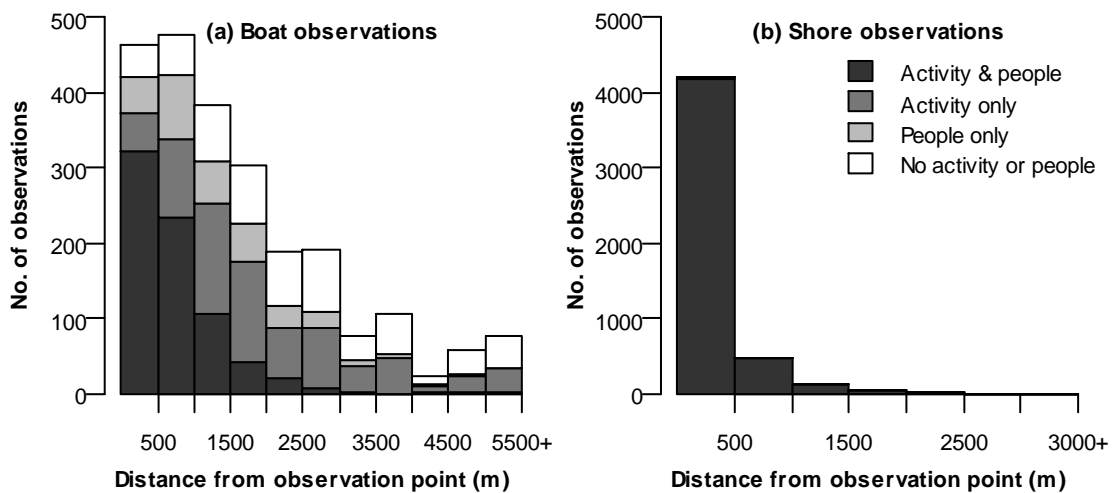


Figure 5-20. Distance from the observation point during the coastal surveys for all (a) boat and (b) shore observations in the NMP and the completeness of the observation in terms of identifying number of people and activity type.

5.5 Discussion

This is the first study at Ningaloo aimed at determining the number of people participating in specific recreational activities throughout the Marine Park using direct observation techniques. Previous studies have focused on other aspects of visitor behaviour or preferences by using interviews as a method to ascertain activities in which visitors had participated (or intended to participate) during their stay (Remote Research, 2002; Wood, 2003b; Moore and Polley, 2007; Ingram, 2008). Swimming, snorkelling, fishing (shore and boat), walking and viewing wildlife were the most frequently recorded activities by Northcote and MacBeth (2008) while boating, sightseeing and relaxing were popular with Exmouth residents (Ingram, 2008). A review of human use throughout Ningaloo (Cary et al., 2000) and in the CRNP (Moore and Polley, 2007) also found these activities to be popular, although the most popular activity listed by respondents was appreciating nature (85% of respondents).

There was a difference in the number of vessels recorded outside the reef crest when comparing coastal (15.2%) and aerial (29.6%) surveys (Smallwood 2009). This was partly due to difficulties in sighting objects from sea level as when waves break on the reef crest they may obscure vessels. This may result in under-representation of some activities, particularly recreational boat fishing, which is difficult to identify from the shore, and has been self-reported by anglers to occur outside the lagoon area (Sumner et al., 2002; Worley Parsons, 2006). Boat fishing was the most popular activity recorded at Coral Bay in 2006 during a survey of all vessels launching from this location and, larger vessels were more likely to be involved in this activity, especially those that travel outside the reef crest (Worley Parsons, 2006).

Obtaining data on vessels in open waters (outside the reef crest) is challenging and expensive. Respondents to boat ramp surveys at Ningaloo by Sumner et al. (2002) and Worley Parsons (2006) were self-reported in terms of location where activities were conducted and are exposed to response biases (Pollock et al., 1994). Recent developments and applications of electronic monitoring systems in studies of commercial (Deng et al., 2005; Bejder et al., 2006; Mills et al., 2007) and recreational (Pelot and Wu, 2007) vessels may be able to address this lack of data

from these offshore areas. In this study, vantage points were selected for their height above sea level to improve the field of view over the reef crest and minimise this effect.

Multiple-use marine protected areas in Western Australia are established for biodiversity conservation while also maintaining opportunities for recreation. Sanctuary (no-take) zones are established within these parks to ensure the populations and habitats at these sites are protected against future (or further) exploitation from extractive use. The creation of marine parks attracts visitors as they expect to find more abundant marine life (Hawkins et al., 2005). These coastal survey data showed that both snorkellers from the shore and divers from boats were found in higher numbers in sanctuary zones than other zones, and also within coral reef habitats. Other non-extractive activities such as wildlife viewing also occurred predominantly in sanctuary zones. This supports the opinion of Davenport and Davenport (2006) that participants in these activities are drawn to high levels of biodiversity, many of which are located within marine protected areas (i.e. the sanctuary zones in NMP). This pattern of increased diving from boats in sanctuary zones was also found during surveys in the Florida Keys (McClelland, 1996; Shivlani and Suman, 2000). Although these sites are protected from extractive activities, large numbers of snorkellers and divers are also known to impact on these ecosystems via direct physical damage or pollution (Hawkins et al., 1998; Schleyer and Tomalin, 2000; Rouphael and Inglis, 2001; Harriott, 2002; Lloret et al., 2008). This effect may be further exacerbated by commercial tours or charter vessels that are able to simultaneously introduce large numbers (with group sizes >10 people) into the marine environment at Ningaloo. Permanent moorings, such as at Lighthouse Bay, have been installed to reduce anchor damage, but may also concentrate divers (and associated environmental damage) in a particular area.

Special purpose zones were introduced to NMP in 2004 and this study found high levels of shore fishing in special purpose (SBA) zones, which was expected as they were created specifically to allow this activity to occur. However, surfing and sightseeing/spectating were also recorded in high concentrations within this zone type due to popular surfing sites, such as the Surf Beach, being located in Lighthouse Bay (which is special purpose zone). This distribution is likely to be related to the coastal geomorphology at Lighthouse Bay where there is no fringing reef crest (Cassata and Collins, 2008), thereby allowing swells to reach the shore and create a unique environment for surfers (and associated spectators).

The association of surfing with rocky shorelines is different to that of many shore-based activities, such as swimming, sunbaking or beach games, that were undertaken predominantly on sandy beaches. Sandy beach environments are often not protected within sanctuary zones as they are viewed as habitats with little merit for biodiversity conservation. However, they are diverse ecosystems with important functions for turtle nesting, water filtration, nutrient recycling and habitats for invertebrate species, which are being exposed to increasing pressures from recreation, such as off-road driving (McLachlan and Brown, 2006; Waayers and Newsome, 2006; Schlacher et al., 2007). Many sandy beaches at Ningaloo have been indirectly protected from off-road driving as they are situated adjacent to parts of the coast where this activity has been prohibited, such as in the CRNP. However, trampling from foot traffic may be an issue on several high use beaches, such as Turquoise Bay or Lakeside, along with camping which occurs in the fore dune environment, especially on pastoral leases to the south of CRNP.

Data from previous research (Sumner et al., 2002; Worley Parsons, 2006) support the distribution of vessels described in this current study, with boats generally clustered around launch locations. This was especially pertinent for activities such as diving, where aggregations were clearly identified around Lighthouse Bay, Bundegi and Coral Bay. These areas are not

only located within sanctuary zones dominated by coral reef habitats and have permanent moorings for dive vessels, but are also situated close to infrastructure (i.e. population centres, fuel, facilities for boat storage). Research in the Florida Keys also found dive operators targeted sites in close proximity to their dive shops (Shivlani and Suman, 2000). This clustering was not as evident for vessels participating in wildlife interactions that were widely dispersed, especially to the south of Tantabiddi, adjacent to CRNP. These vessels departed from Tantabiddi where they were moored (with passengers transported ~40 km by road from Exmouth) and they used spotter planes to locate charismatic megafauna, such as whale sharks or manta rays, with tour operators travelling as far as necessary to provide a satisfying visitor interaction (Mau, 2008).

Weather conditions also influenced recreation at Ningaloo, with wind speed and direction having the greatest effect on participation in different activity types. Sailing sports (i.e. windsurfing and kitesurfing) took place in stronger onshore winds (>30 km/hr) while all other activity types from boats and the shore were conducted in periods of lighter (<25 km/hr) winds. Wind speed has previously been identified as a major factor influencing water-based activities (Berkhout and Brouwer, 2005). Air temperature, wind speed and direction were the only meteorological factors tested in this study due to the limited availability of data on other variables such as cloud cover and rainfall which have been previously found to reduce the number of visitors participating in some types of recreation within protected areas (Brandenburg and Arnberger, 2001).

The sampling design of the coastal surveys was statistically robust, applying stratification and randomisation within the constraints of the large study area to obtain data from the entire sampling frame as recommended by Pollock et al. (1994). Similar methods have been used worldwide to conduct counts of recreational activities such as fishing and boating (Sumner et al., 2002; Widmer and Underwood, 2004; Smallwood et al., 2006; Courbis, 2007; Smallwood and Beckley, 2008). Although such roving-type surveys are usually land-based, in some cases it has been advantageous to use boats to move through a study area, but this is generally only suited to smaller, more confined, water bodies (Bissett et al., 2000; Adams et al., 2006; Lynch, 2006; Prior and Beckley, 2007). The spatial error of these coastal surveys (4.1 m) was smaller than for aerial surveys (6.4 m for boats; 4.3 m for shore groups) due to factors such as the vehicle being stationary during GPS readings and using a rangefinder to improve distance estimation. In the coastal surveys, this was further enhanced for 14.5% of shore groups where positional information was recorded at their actual location (i.e. not using an offset distance, which could introduce additional errors due to distance estimation and compass

5.6 Acknowledgements

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6. RECREATIONAL USE IN A MARINE PARK IN NORTH-WESTERN AUSTRALIA: EFFECTS OF ADJACENT LAND TENURE

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6.1 Summary

Ningaloo Marine Park protects a fringing coral reef system extending 300 km along the coast of north-western Australia and includes a sheltered lagoon area suitable for recreation along the shoreline. Visitors access the Marine Park via adjacent lands with a range of tenures (e.g. national park, government defence lands and pastoral leases). These are managed by various government agencies and individuals with different management arrangements and providing diverse services and infrastructure. Face-to-face interviews were completed with 1 208 people participating in recreation along the shoreline of Ningaloo Marine Park from January – December 2007 to investigate the influence of land tenures (and accompanying attributes) on visitor characteristics and recreational activity patterns. Respondents on pastoral leases were found to be more likely from intrastate and stayed for longer than those in the national park or the settlement of Coral Bay, who stayed for shorter periods and included many international visitors. Repeat visitation and site fidelity were high, especially on pastoral leases. Snorkelling was popular off the national park and Coral Bay and there was higher participation in recreational fishing adjacent to pastoral leases. This study highlights the complexity of managing a large coastal marine park with an array of adjacent land tenures, where conservation may not be the primary purpose. Collaboration and planning for sustainable use across tenures will maintain visitor satisfaction by providing a range of experiences while mitigating human impacts.

6.2 Introduction

Coastal ecosystems support a wealth of natural resources, have great aesthetic appeal and are easily accessible by humans. About 40% of the world's population lives within 100 km of the coast, and there are few developed countries where this coastal concentration is more evident than Australia, with 80% of the population being coastal residents (Short and Woodroffe, 2009). Australian coastal environments are not only highly valued (Huntsman, 2002) but also have high levels of public accessibility and are the focus of many outdoor recreational activities such as swimming, surfing, fishing, boating and relaxing (Zann, 1995).

The tourism industry, which includes recreation as well as provision of services such as accommodation, marinas, restaurants and transport, is the fastest growing facet of the global economy, and much is conducted within coastal regions (WRI, 2000). Types of recreational activities undertaken in coastal regions include those in which participants are located in or on the water, such as swimming or boating, as well as activities undertaken on land, but which are inextricably linked to the marine environment, such as sunbaking on the beach (Orams, 1999).

In Australia, participation in these activities is not restricted to residents or domestic travellers but is also popular with international visitors (TRA, 2009).

While there are significant economic benefits for coastal communities engaged in tourism, these coastal environments are under increasing pressure which may result in detrimental physical or ecological impacts (Hall, 2001), especially if poorly planned and managed (WRI, 2000). The major impacts can be summarised as those arising from land-based development (marinas, roads or resorts), marine-based infrastructure (moorings or pontoons), boat-induced damage (anchoring or waste discharge), water-based activities (diving, fishing or reef walking) and wildlife activities (fish feeding, whale watching) (Harriott, 2004). Many of these have been well documented and include marine pollution, habitat damage, erosion of sand dunes and exploitation of aquatic organisms (Ban and Alder, 2008, Lloret et al., 2008, Newsome et al., 2002). There are also social impacts which can include overcrowding, user conflicts and public safety (Brouwer et al., 2001, Falk and Gerner, 2002) as well as cultural impacts, which relate to effects of marine tourism on traditional land users (Harriott, 2004).

Managing coastal environments for sustainable use by tourism, including recreational activities and associated infrastructure development, is challenging. Coastal habitats are diverse (e.g. mangroves, sandy beaches, coral reefs, estuaries) and vary substantially in their resilience and attractiveness to human activities. This results in the uneven distribution of people and creates distinct nodes of tourism pressures, services and attractions (WRI, 2000) requiring different management approaches. Furthermore, coastal areas are overlaid by land tenures of varying size and purpose, forming a mosaic of overlapping, competing and complementary interests for involved parties (FAO, 2002). Such an arrangement enables the possibility of multi-layered management whereby several parties have rights to access or control the same land area. Management strategies for different land tenures will also vary significantly depending on their purpose. For example, national parks and marine parks are often created with the dual mandate of conserving biodiversity while providing opportunities for recreation (including equitable public access) (Newsome et al., 2002). Freehold land is controlled by individuals who may restrict public access while the primary purpose may vary widely from farming to residential.

Using 'land tenure' as a surrogate for investigating differences in management arrangements or primary purpose of an area is not novel. For example, effects on vegetation by management techniques (on different land tenures) have been examined in Namibia (Akhtar-Schuster et al., 2005) and northern Australia (Franklin et al., 2008). However, little research has examined the effect of land tenure and the associated management arrangements on tourism and recreation activities. This is particularly important on lands where public access may be restricted, even though it may be required to reach areas of significant attraction to visitors (e.g. camping or fishing sites). The facilities, services and infrastructure on different land tenures may also vary widely.

Visitors have different expectations, motives and behaviours which produce a variety of temporal and spatial use patterns. An understanding of how management arrangements, services and facilities applied on different land tenures affect these characteristics is essential to ensure sustainable management and maintain visitor satisfaction. Visitors are usually segmented based on origin (Arnberger and Brandenburg, 2007, Moscardo et al., 2001), motivation (Cha et al., 1995) and activity participation (Moscardo et al., 2001) but rarely have interactions between visitor characteristics, use patterns and land types been investigated. Nevertheless, in north America, comparisons have been made between different sites of the same tenure with respect to visitor values (Tanner et al., 2008) and campfire policies in protected areas (Reid and Marion, 2005)

This study investigated visitor (i.e. age, origin) and visit characteristics (i.e. length of stay) and recreational activity patterns within various land tenures located adjacent to the Ningaloo Marine Park (NMP) in north-western Australia (Figure 6-1). This Marine Park is managed by the Western Australian State Government and, although remote from large population centres, is a popular attraction for tourists. Access to NMP is via several land tenures (settlement, national park, defence lands and pastoral leases) on which an assortment of facilities, services and management arrangements are provided and employed by relevant authorities. This paper explores the influence of land tenure on the types of visitors and their activities. This exploration also included the effects of temporal factors (i.e. school holidays, peak tourist months) on visitor patterns and the differences between tourists and residents. Residents were defined as people who permanently resided near, or adjacent to, the Marine Park while tourists were those who had travelled from their usual place of residence to Ningaloo for leisure. Collectively, these groups are referred to as visitors.

6.3 Materials and Methods

6.3.1 Study area

NMP, located off north-western Australia, is ~300 km in length and extends ~ 3 nautical miles offshore (Figure 6-1). It encompasses a unique fringing coral reef system with a species diversity comparable to the Great Barrier Reef (Wilkinson, 2008). The fringing reef crest forms a shallow lagoon environment with a mean width of 2.5 km (CALM and MPRA, 2005), providing an ideal location for recreation (i.e. snorkelling, diving and fishing) from boats and the shore. NMP attracts 200 000 visitors annually, and this is expected to increase in future years (CALM and MPRA, 2005). The highest number of visitors occurs between April – October, coinciding with milder winter temperatures. The narrow continental shelf results in species such as humpback whales, whale sharks and pelagic fishes being found extremely close to the shore (Taylor and Pearce, 1999). Manta rays are found in the lagoon all year round while several turtle species nest on the northern sandy beaches between December – March (Sleeman et al., 2007).

The coastal geomorphology adjacent to NMP is highly variable and north of Cardabia Station is dominated by sandy beaches with isolated patches of mangroves and intertidal platforms, backed by a coastal plain and elevated limestone ridge (CALM, 2005). This ridge dissipates to the south of Yardie Creek and the southern extent of the study area is characterised by complex dune systems, rocky shores, intertidal platforms and limestone cliffs interspersed with pockets of sandy beaches (Payne et al., 1987).

The arid climate supports predominantly low lying vegetation, such as perennial shrubs or grasslands, along with annual species (Keighery and Gibson, 1993). High species richness and diversity of vegetation is complemented by the occurrence of many native terrestrial animals, including endangered rock wallabies (CALM, 2005). However, there are also a number of exotic species introduced by early settlers including domestic stock (i.e. sheep and goats), feral animals (i.e. foxes, cats and rabbits) and weeds.

Tourism along the Ningaloo coast was restricted for many years due to limited coastal access, although this did not prevent the area from being exposed to intense recreational and commercial fishing pressure during the 1960-70s (Weaver, 1998). Sites along the southern part of Ningaloo, such as Red Bluff (Figure 6-1), were also discovered as good surfing locations during these years (Wootton, 2007). The main road from the south was sealed in 1980 which,

along with the creation of additional access roads to the coast, further increased fishing pressure. However, it was not until the closure of a US Naval Communication Station in the early 1990s (around which the settlement of Exmouth was built) that a tourism industry emerged. Tourism has now replaced agriculture and fishing as the largest contributor to the economy along the Ningaloo coast (GDC, 2006). There are >40 tour operators, based in the settlements of Exmouth (population 2 000) and Coral Bay (population 150) (Figure 6-1), who offer a range of opportunities for tourists to experience the natural environment and interact with wildlife within NMP.

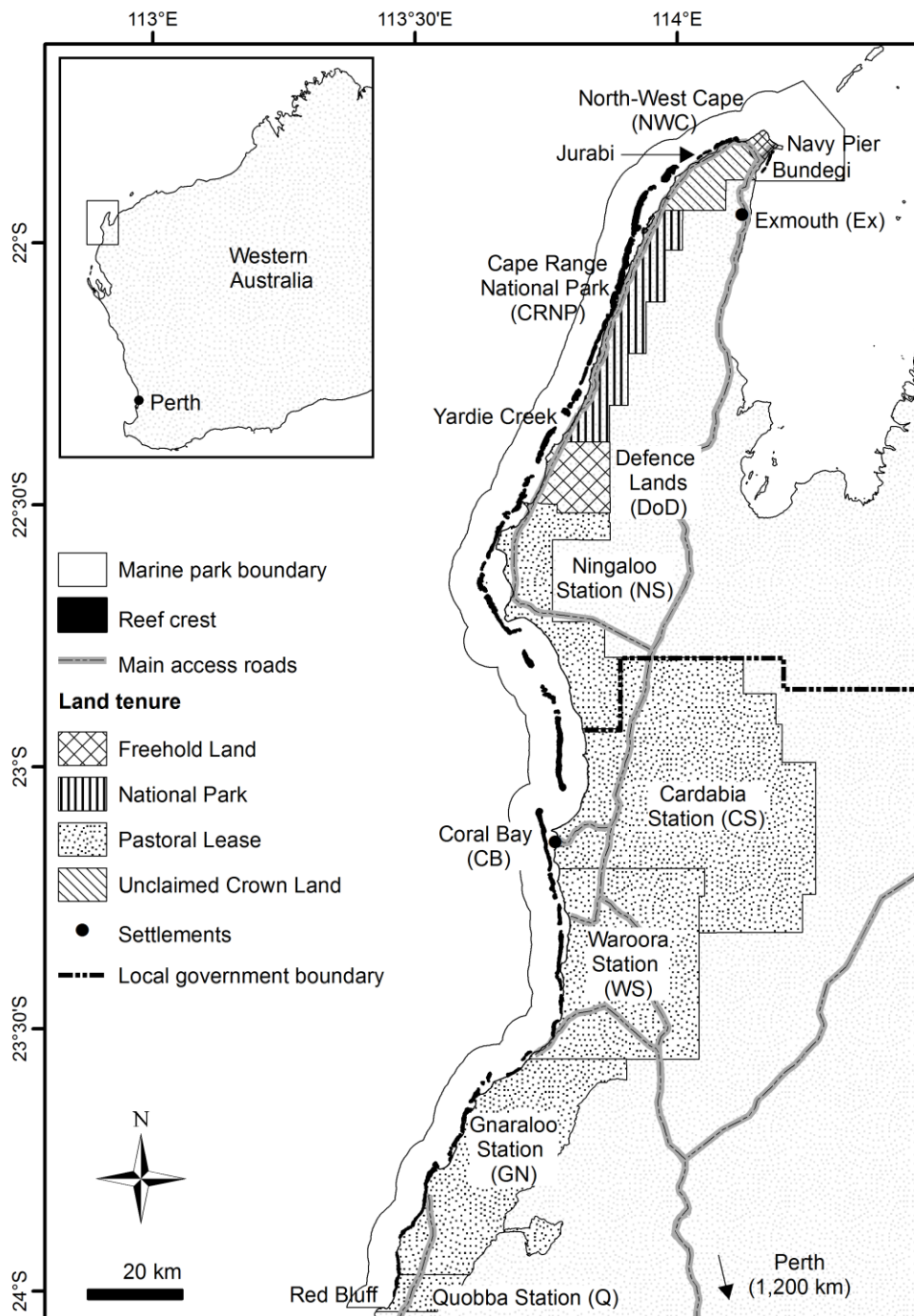


Figure 6-1. Location of the Ningaloo Marine Park and adjacent land tenures, main access roads and the fringing reef crest.

The tenures of the lands adjacent to NMP include Cape Range National Park (CRNP), several pastoral leases, Commonwealth Government defence lands (established for weapons testing and military training), unallocated crown land (owned by the State Government but not ‘allocated’ for any particular purpose) and freehold (privately owned) land (Figure 6-1). The ways these tenures are configured varies considerably along the extent of the interface with NMP, including their association with its landward boundary, and are described according to 10 ‘regions’ (Table 6-1; Figure 6-1). The northernmost region adjacent to the Marine Park around North-West Cape (NWC) is comprised of unallocated crown land as well as two small coastal parks (Jurabi and Bundegi), which are collectively managed by the State Government and the Shire of Exmouth (local government). The freehold land extending to the low water mark within NWC is managed by the Commonwealth Department of Defence, and a 400 m exclusion zone exists around the Navy Pier. Cape Range National Park (CRNP) is managed by the Western Australian State Government. The settlements of Exmouth (Ex) and Coral Bay (CB) are under the jurisdiction of the Shires of Exmouth and Carnarvon, respectively. Government defence land (DoD), used for weapons testing, is also located south of Yardie Creek, and adjoins NMP at the high water mark. Five pastoral leases (NS, CS, WS, GN and Q) occupy the hinterland of the southern two-thirds of NMP.

Pastoral leases (or stations) are unique to Australia and New Zealand and were created in the 1830s to address unauthorised land settlement whereby, instead of granting freehold tenure, the government retained control of land use by restricting the primary purpose to grazing livestock (Holmes and Knight, 1994). Each Australian state and territory has its own legislated pastoral lease arrangements. Such leases encompass 36% of Western Australia, may not be granted for more than a 50 year term and are all due to expire in 2015 (PBL, 2007).

Table 6-1 Summary of management and location of coastal boundary associated with each land tenure along the Ningaloo Coast (source: CALM & MPRA, 2005). Note: bracket indicates grouped for analysis purposes

Tenure name	Type	Management authority	Coastal boundary
Exmouth (Ex)	Settlement	Local government	Not applicable
North-West Cape (NWC)	Unallocated crown land	Local & state government	High water mark
	Coastal parks	Local & state government	High water mark
	Freehold land	Commonwealth government	Low water mark & exclusion zone (Navy Pier only)
Cape Range National Park (CRNP)	National park	State government	High water mark
Defence Lands (DoD)	Freehold land	Commonwealth government	High water mark
Ningaloo Station (NS)	Pastoral lease	Pastoral leaseholder	40 m above high water mark
Cardabia Station (CS)	Pastoral lease	Pastoral leaseholder	40 m above high water mark
Coral Bay (CB)	Settlement	Local government	High water mark
Waroorra Station (WS)	Pastoral lease	Pastoral leaseholder	40 m above high water mark
Gnaraloo Station (GN)	Pastoral lease	Pastoral leaseholder	Low water mark
Quobba Station (Q)	Pastoral lease	Pastoral leaseholder	Low water mark

The diverse purposes and management authorities associated with these tenures have resulted in different management approaches and provision of services, facilities and accommodation (Table 6-2). The settlements of Exmouth and Coral Bay offer a range of accommodation options, services and facilities while CRNP provides opportunities for coastal camping in designated sites. Camping is also available on all the pastoral leases, but with fewer facilities. In terms of conditions guiding use, length of stay is restricted to a maximum of 28 days in CRNP. The conditions are less restrictive for the pastoral leases and government defence lands with generators, fires and dogs allowed and no maximum stay limit.

Table 6-2 Summary of services, facilities, infrastructure and management controls associated with each land tenure unit along the Ningaloo coast. Note: bracket indicates grouped for analysis purposes. (✓ = yes, ✗ = no, sd = site dependent, na = not applicable).

	Tenure name									
	Ex	NWC	CRNP	DoD	NS	CS	CB	WS	GN	Q
Vehicle access										
Number of main access roads to coast	1	1	2	2	2	2	2	2	1	1
2WD	✓	✓	✓	✗	✗	✗	✓	✗	✗	✓
4WD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Accommodation										
Coastal camping	✗	✗	✓	✓	✓	✓	✗	✓	✓	✓
Caravan park	✓	✓	✗	✗	✗	✗	✓	✗	✗	✗
Self contained units	✓	✓	✗	✗	✓	✗	✓	✓	✓	✓
Safari tents	✗	✗	✓	✗	✗	✗	✗	✗	✗	✓
Hotels	✓	✗	✗	✗	✗	✗	✓	✗	✗	✗
Backpackers	✓	✗	✗	✗	✗	✗	✓	✗	✗	✗
Services and facilities										
Groceries	✓	✓	✗	✗	✗	✗	✓	✗	✗	✓
Fuel/gas	✓	✗	✗	✗	✗	✗	✓	✗	✗	✗
Toilet facilities	✓	✓	✓	✗	✗	✗	✓	sd	✓	✓
Access to freshwater	✓	✓	✓	✗	✗	✗	✓	✗	✓	sd
Management controls										
Maximum stay limit	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗
Coastal camping fee	na	na	✓	✗	✓	✓	na	✓	✓	✓
Locked camping areas	✗	✗	✗	✗	✓	✗	✗	✗	✓	✗
Generators permitted	na	na	sd	✓	✓	✓	na	✓	✓	✓
Fires permitted	✗	✗	✗	✓	✓	✓	✗	✓	✓	✓
Dogs permitted	sd	sd	✗	✓	✓	✓	sd	✓	✓	sd

6.3.2 Methods

The 300 km NMP coastline was divided into three survey routes which were travelled by researchers in a 4WD vehicle on 16 days/month from January – December 2007 in order to collect spatio-temporal information on distribution of recreational activities. Similar to roving and access point surveys developed for recreational fishers by Pollock et al. (1994), people were intercepted for a face-to-face interview on these survey days either during, or at the completion of, their recreational activity. The number of interviews was restricted to 5 – 10 per day due to time constraints caused by the large distances and poor road conditions (frequently

sandy tracks). Other survey options, such as mail and telephone surveys, were impractical at Ningaloo because of the isolated areas where many respondents were camping along the coast.

Groups were selected using quota and purposive sampling, both non-probability type methods (Neuman, 2006), to ensure that locations with highest use were sampled more frequently than those with low use, while also obtaining data on a wide spectrum of recreational activity types. Such group selection techniques are well documented in recreation and tourism research (Nyaupane et al., 2004, Sidman et al., 2000, Sirakaya et al., 2003). A respondent from within each group was selected based on who had the next birthday (Battaglia et al., 2008, Coombes et al., 2009, Oldendick et al., 1988). A high response rate of 99.5% was obtained which, along with a reduction of biases caused by self-reporting (Beaman et al., 2004, Tarrant and Manfredi, 1993), is a known benefit of face-to-face interview approaches (Schirmer and Casey, 2005).

The questionnaire was divided into several parts, consisting predominantly of closed-ended questions to facilitate quantitative analyses. Interview location was geo-referenced using a handheld Garmin GPS at the commencement of the interview and was followed by a number of questions on visitor characteristics (i.e. age, origin, group size and type), based on standard categories (ABS, 1999, Horneman et al., 2002). The main recreational activity that brought the respondent to the location (which was not necessarily the activity they were undertaking at the time of interview) and time spent at the beach were recorded, as were visit attributes such as place of accommodation, length of stay and whether the respondent had a boat or 4WD vehicle on their current trip. Patterns of previous visitation, planned future visits and main reason for choosing a place to stay were explored along with the level of participation in specific recreational activities during their current trip to NMP.

The 10 coastal regions (Table 6-1) were condensed into eight (indicated by brackets shown in Table 6-1 and Table 6-2) based on shared access routes, similarity in land tenure (which are inextricably linked to associated management arrangements and authorities), and provision of similar accommodation. Although Exmouth (Ex) is not located adjacent to NMP, it is used as a base for day trips (Northcote and Macbeth, 2008), and was excluded from some analyses. In Canada, similar analytical approaches have been applied using districts defined by separate planning and development jurisdictions (Murphy and Keller, 1990). Although the defence lands (DoD) offer the only location for free coastal camping along the coast, it was grouped with Ningaloo Station (NS), and indicated as NS/DoD, because of a paucity of interviews from this area. These areas are adjacent to each other and have shared (4WD drive only) access routes. Gnaraloo Station (GN) and Quobba Station (Q) were also grouped together (indicated as GN/Q) based on their limited coastal access (via a single road).

The majority of variables were categorical and summarised using cross-tabulation and descriptive statistics. Chi-square tests (χ^2) determined the level of significance of each variable in relation to the coastal regions at 0.05 level and, if significant, Cramer's V identified the strength of this association. Values of Cramer's V can vary between zero (indicating little association) and one (indicating a strong association). The Kruskal-Wallis test, a non-parametric equivalent of analysis of variance, was used to test the significance between continuous variables (such as length of stay) and coastal regions if assumptions of normality and homogeneity of variance were not met. Conversely, if these assumptions were met, then analysis of variance was used, and for variables with multiple factor levels, the Least Significant Difference (LSD) *post-hoc* test was used to identify the significant contributors to these effects.

6.4 Results

Face-to-face interviews were completed with 1 208 respondents participating in recreational activity along the shoreline of NMP from January – December 2007. Respondents were intercepted throughout all coastal regions with the greatest number obtained from areas with high use beaches; NWC (276), CRNP (393) and Coral Bay (CB) (196) (Table 6-3). There were 30 repeat interviews, of which two-thirds were along the shoreline of NWC and CRNP.

Table 6-3 Visitor characteristics of people interviewed while participating in recreational activities within each coastal region adjacent to the NMP from January – December 2007 (number of interviews = 1 172). (^ expected frequencies <5; results should be treated with caution).

Variable	Recreation (interview) region (%)						
	NWC	CRNP	NS/DoD	CS	CB	WS	GN/Q
<i>Number of interviews</i>	276	393	196	98	72	68	105
Gender (%)	$\chi^2(6) = 49.130, \rho < 0.05$; Cramer's V = 0.205						
M (41.1)	36.0	46.6	33.0	31.0	57.1	23.0	28.4
F (58.9)	64.0	53.4	67.0	69.0	42.9	77.0	71.6
Age (Years) (%)	$\chi^2(24) = 94.531, \rho < 0.05$; Cramer's V = 0.142						
18-24 (6.7)	7.2	8.1	2.1	4.2	9.2	1.6	4.9
25-34 (27.5)	20.1	32.6	19.1	21.1	36.2	9.8	33.3
35-44 (27.8)	32.6	23.2	24.5	36.6	22.4	23.0	43.1
45-54 (21.4)	19.3	20.8	30.9	19.7	17.9	39.3	17.6
55+ (16.6)	20.8	15.4	23.4	18.3	14.3	26.2	1.0
Origin (%)	$\chi^2(18) = 253.668, \rho < 0.05$; Cramer's V = 0.465						
Resident (within region) (11.6)	26.9	6.3	12.8	5.6	5.6	4.9	10.8
Intrastate (outside region) (50.9)	51.9	36.5	77.7	69.0	43.4	88.5	57.8
Interstate (13.7)	9.5	22.7	4.3	15.5	11.2	4.9	8.8
International (23.7)	11.7	34.6	5.3	9.9	39.8	1.6	22.5
Group type (%)	$\chi^2(24) = 66.351, \rho < 0.05$; Cramer's V = 0.238 ^						
Alone (16.4)	16.3	10.7	20.2	22.5	15.8	18.0	30.4
Couple (32.3)	29.5	37.8	29.8	33.8	24.7	31.1	15.7
Family (21.6)	23.1	22.7	19.1	16.9	21.4	21.3	19.6
Friends (24.3)	30.7	24.5	30.9	26.8	23.0	27.9	34.3
Tour group (2.5)	0.4	4.4	0	0	0.9	0.1	0
Accommodation type (%)	$\chi^2(36) = 844.629, \rho < 0.05$; Cramer's V = 0.348 ^						
Coastal camping (33.9)	3.4	37.6	97.8	12.7	0.5	91.8	82.2
Caravan park (34.9)	44.3	32.4	0	71.8	58.7	4.9	0
Backpackers (3.5)	1.1	1.6	0	1.4	16.4	0	0
Self-contained units (7.0)	7.3	6.5	0	5.6	12.2	0	9.9
Safari tents (0.5)	0.4	1.3	0	0	0	0	0
Hotels (8.9)	10.7	13.8	1.1	5.6	8.5	1.8	0
Private residence (11.3)	32.8	6.8	1.1	2.8	3.7	1.6	7.9

6.4.1 Visitor characteristics

Variables of gender, age, origin, group type and accommodation were all significant when compared to the coastal regions where respondents were engaged in recreational activity (Table 6-3). The strongest associations (indicated by a high Cramer's V) with the coastal regions were

found for origin of visitor (0.465) and accommodation type (0.348). The gender ratio (male: female) was 41.1%: 58.9% across the entire sample, although when examined by coastal region there were strong deviations on the southern pastoral leases (WS, GN/Q), where respondents were predominantly females (>70%). Respondents were mainly 25 – 54 years of age, and, more specifically, at CRNP and CB >40% of respondents were <34 years of age. Half of the respondents were intrastate visitors (50.9%) while residents comprised 11.6% of the sample. The mean length of time lived in either Exmouth or Coral Bay by residents was 6.0 years ($SD = 9.8$ years), with 27% residing in the area for <1 year. Residents were more frequently recorded along NWC (26.9%), the closest region to the settlement of Exmouth, while intrastate visitors were distributed across several pastoral leases (NS/DoD, CS and WS). Respondents of international origin were found predominantly within CRNP (34.6%), CB (39.8%), and also on GN/Q (22.5%).

The most common group types were couples (32.2%), friends (24.3%) and families (21.6%) (Table 6-3). The distribution of group types across coastal regions was similar, with the exception of respondents travelling alone being found predominantly on GN/Q (30.4%). Coastal camping (33.9%) and caravan parks (34.9%) were the dominant accommodation types for all the regions (Table 6-3). The number of respondents staying in private residences was highest for those intercepted along NWC (32.8%), while coastal camping dominated the pastoral leases of NS/DoD, WS and GN/Q. Although there are no caravan parks on CS, the majority of respondents engaged in recreational activities in this coastal region (71.8%) were staying in this type of accommodation, indicating cross-regional movement from the adjacent region (and settlement) of Coral Bay.

Temporal factors were also expected to influence visitor characteristics and visitation to NMP. Age ($\chi^2(4) = 41.650, p < 0.05$), group type ($\chi^2(4) = 10.519, p < 0.05$) and origin ($\chi^2(3) = 160.16, p < 0.05$) all showed significant differences between peak (April – October) and off-peak (November – March) months. Cramer's V was low (<0.189) for all variables except for origin (0.370), due to the higher than expected number of international visitors intercepted during off-peak months. The most significant result for school holidays was produced by group type ($\chi^2(4) = 46.027, p < 0.05$; Cramer's V = 0.198) as families were interviewed more often during these periods, and 82.4% of these groups had children of school going age.

6.4.2 Visit characteristics

Cross-regional movement of respondents, who had travelled to a different coastal region for recreation from where their accommodation was located, was significant and had a high Cramer's V (0.659) (Table 6-4). The strength of this association was driven by the low percentage of respondents both recreating and staying within NWC (25.2%), CRNP (38.6%) and CS (12.7%) as well as the high percentage of respondents on pastoral leases (>90%) who exhibited the reverse trend, with respondents both recreating and staying in these regions. Respondents on GN/Q all stayed within this region, indicating few day visitors. The majority of respondents recreating in NWC and CRNP were staying in Exmouth, located just outside the northern boundary of NMP (Figure 6-1). The majority of respondents recreating on CS were staying in CB.

The remaining visit attributes in Table 6-4 were all significant when compared to the coastal regions and the strength of these associations was similar. The shortest mean lengths of stay were for respondents in CRNP (10.9 days), CS (13.7 days) and CB (8.5 days). The remaining pastoral leases, and NWC, all had mean lengths of stay >20 days but with greater variability (indicated by higher standard deviation). The overall sample had a highly skewed result with

respect to respondents who had boats on their current trip to NMP (22.3%). Respondents recreating in CRNP and CB had the lowest percentage of boat possession, with 12.2% and 8.2%, respectively. The highest percentages of respondents with 4WD vehicles were on the pastoral leases where access was restricted to sand or gravel tracks, namely, NS/DoD (98.9%) and WS (95.1%). International respondents had the highest possession of 2WD vehicles (78%).

Table 6-4 Cross boundary movement, current visit characteristics and patterns of previous visitation for respondents participating in recreational activities within each coastal region adjacent to the NMP from January – December 2007 (number of interviews = 1 172). Note: *Kruskal-Wallis test.

Variable	Recreation (interview) region						
	NWC	CRNP	NS/DoD	CS	CB	WS	GN/Q
Cross boundary movement	$\chi^2(6) = 499.349, \rho < 0.05$; Cramer's V = 0.659						
Staying within region (44.0)	25.2	38.6	92.6	12.7	98.9	94.9	100
Staying outside region (56.0)	74.8	61.4	7.4	87.3	1.6	5.1	0
Length of stay (days)	H(6) = 117.311, $\rho < 0.05^*$						
Mean (15.2)	22.4	10.9	23.7	13.7	8.5	20.5	20.3
Std. dev. (23.3)	34.0	15.1	34.0	2.0	10.2	20.0	27.0
Have a boat on their current trip	$\chi^2(6) = 148.437, \rho < 0.05$; Cramer's V = 0.356						
Yes (22.3)	29.2	12.2	60.6	16.9	8.2	42.6	25.5
No (77.7)	70.8	87.8	39.4	83.1	91.8	57.4	74.5
Have a 4WD on their current trip	$\chi^2(6) = 182.155, \rho < 0.05$; Cramer's V = 0.394						
Yes (61.8)	67.0	50.0	98.9	83.1	36.2	95.1	72.5
No (38.2)	33.0	50.0	1.1	16.9	63.8	4.9	27.5
Have visited the NMP on a previous occasion	$\chi^2(6) = 129.246, \rho < 0.05$; Cramer's V = 0.332						
Yes (55.2)	71.6	38.3	71.3	53.5	41.3	80.3	74.5
No (44.8)	28.4	61.7	28.7	46.5	58.7	19.7	25.5
Always stay at the same location	$\chi^2(6) = 38.810, \rho < 0.05$; Cramer's V = 0.263						
Yes (43.9)	38.9	23.7	57.6	48.5	51.9	48.3	58.9
No (56.1)	61.1	76.3	42.4	51.5	48.1	47.2	41.1
Intend to visit again	$\chi^2(6) = 105.670, \rho < 0.05$; Cramer's V = 0.300						
Yes (82.2)	90.5	72.1	95.8	90.1	68.4	98.4	96.1
No (17.8)	9.5	27.9	3.2	9.9	31.6	1.6	3.9

Repeat visitation was determined by asking if respondents had visited NMP on a previous occasion. Overall, 55.2% of respondents were repeat visitors, and the highest percentages were along NWC (71.6%) and the pastoral leases NS/DoD (71.3%), WS (80.3%) and GN/Q (74.5%). Interestingly, of those respondents who were repeat visitors, 43.9% indicated they always stayed at the same location adjacent to NMP, indicating high site fidelity. The highest percentages were on pastoral leases, NS/DoD (57.6%) and GN/Q (58.9%). The majority (82.2%) of respondents also indicated they intended to visit NMP in the future. The questionnaire also obtained information on the number of trips the respondent had made to the NMP within the previous 12-months. As expected, this identified differences in visitation, with 39.1% of tourists visiting the Marine Park once in the previous 12-months whereas 90.0% of residents had visited >11 times.

The main reason that a respondent chose their accommodation location was an open-ended question which was subsequently ascribed to one of 13 general categories (Table 6-5). The most popular responses were that the location was recommended (17.5%) or based on activity preferences (11.9%). Significant differences in these reasons were also identified by coastal region ($\chi^2(72) = 461.770, p < 0.05$; Cramer's $V = 0.265$). Although this analysis contained expected frequencies < 5 and should be treated with caution, there was a clear association between respondents staying on GN/Q and those who had selected activities as their main reason for selecting an accommodation location.

Table 6-5. Main reason respondents chose to stay at a particular place of accommodation at Ningaloo (number of interviews = 1 095).

Category	Description	No.
Recommended	Recommended by friends, travel agents or tour guides.	192
Activities	Decision based on recreation preferences, e.g. good windsurfing or fishing locations.	130
Location	Decision based on location traits, e.g. close to facilities.	113
Environment	Decision based on natural attributes, e.g. beach.	110
Availability	Restricted by vacancies at accommodation.	106
Social	Chosen due to social attributes, e.g. with friends, good for children, big group.	93
Facilities	Facilities, such as toilets, BBQ and showers, available.	71
Access	Decision based on capability of transport (e.g. 2WD) to access a particular location.	58
Financial	Decision based on cost of accommodation.	55
Previous experience	Decision based on prior trips to the NMP.	49
Ambience/crowding	Chose location because isolated, quiet and not crowded.	46
Management	Decision based on controls or restrictions, e.g. no generators allowed or fires permitted.	42
Work/resident	Chosen because a resident or working in the NMP area.	30

6.4.3 Participation in recreational activities

Respondents had participated in a total of 18 different recreational activities in NMP from boats or the shore on the day of their interview. The mean time spent at the beach for shore activities was 3.1 hours ($SD = 2.3$ hours), of which they spent an average of 1.0 hour ($SD = 1.1$ hours) undertaking their main activity. Respondents undertaking activities from boats spent a mean of 2.4 hours ($SD = 1.6$ hours) out on the water. Recreational line fishing was the most frequently recorded main activity for which respondents visited the beach on their day of interview in all coastal regions, except CRNP and CB, where snorkelling was dominant (Figure 6-2). Swimming and relaxing were also popular in CB while sailing sports (i.e. windsurfing and kitesurfing) were most popular within GN/Q.

Tourists, and residents on extended trips (i.e. staying overnight adjacent to NMP), had participated in a mean of 3.4 activities ($SD = 1.6$ activities) during their stay up until time of interview. Residents on day trips from Exmouth or Coral Bay had undertaken a mean of 1.7 activities ($SD = 0.98$ activities), and were considered separately as they were only asked to list activities they had completed on their day of interview, to minimise the effect of recall bias due to numerous repeat trips to NMP throughout the previous 12 months.

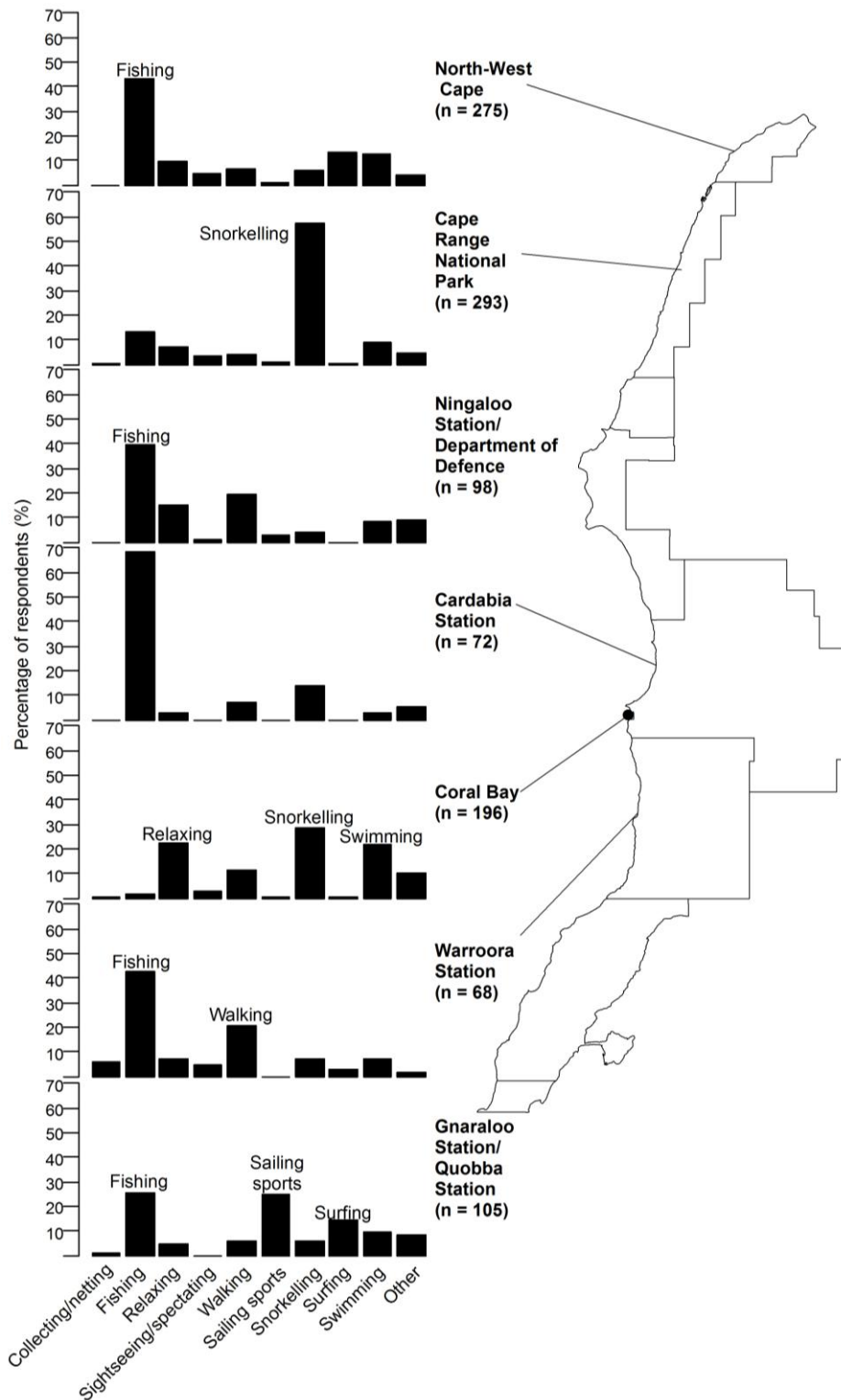


Figure 6-2. Percentage of respondents and their main activities for which they had visited the beach on the day of interview within each coastal region of the Ningaloo Marine Park (n = 1208).

Significant differences were found between the number of activities undertaken in each coastal region (ANOVA assuming equal variances, $F_{(4; 1,160)} = 6.299, p < 0.05$). *Post-hoc* tests revealed

NWC was significantly different from the other coastal regions, due to the number of respondents who had only undertaken one activity at the time of interview (predominantly fishing or walking on the beach). Pastoral leases (NS/DoD, WS and GN/Q) were also significantly different from the other tenures by having the highest number of activities undertaken by respondents.

Participation in the main activity respondents were undertaking on their day of interview was affected by temporal factors. Sailing sports predominantly occurred in off-peak months from October – March while respondents who were surfing were most frequently interviewed between August – October. Respondents participating in the remaining major activities (i.e. fishing, snorkelling and walking) shown in Figure 6-2 were more evenly distributed throughout the year.

6.5 Discussion

This was the first visitor survey to obtain continuous data over a 12-month period (incorporating peak and off-peak periods) along the 300 km of coastline abutting NMP. Previous studies were focused at peak times, and on specific regions, such as settlements (Ingram, 2008), pastoral leases (Wood, 2003) or CRNP (Moore and Polley, 2007). Wood (2003) provided the first indication of differences in visitor characteristics between these regions, and assisted with developing the land tenure hypothesis tested, and supported, in this study using face-to-face interviews. The stratified sampling design, based on statistically robust techniques from Pollock et al. (1994), along with quota and purposive group selection techniques, facilitated interviews with people on the shore and at the completion of boating trips, across the entire sampling frame. Although these data cannot be interpreted as representative of the entire visitor population, they provide a subset of people who visited NMP and undertook recreational activities in the different coastal regions.

6.5.1 Land tenure, management arrangements, visitor characteristics and activity participation

Analysis of visit and visitor characteristics, as well as recreational activity patterns, showed differences between the eight coastal regions, and hence land tenures, adjacent to NMP. Pastoral leases had more intrastate visitors when compared to CRNP and the settlement of Coral Bay, which both had more international visitors. Other visitor surveys have identified increases in international visitors to Ningaloo (Jones et al., 2009, Wood, 2003), and this has been supported by international tourism surveys (TRA, 2007). This increase is most likely due to increased publicity and marketing (i.e. guide books, advertisements), especially for popular snorkelling sites at Coral Bay and Turquoise Bay (in CRNP) as well as the creation of marine and national parks, which act as focal points attracting more visitors to an area (Gurran et al., 2007). The higher number of international visitors in these regions may also be attributed to road quality, with CRNP and Coral Bay having 2WD access, which was the dominant vehicle type amongst these visitors.

Residents were most frequently interviewed along North-West Cape, the closest region to the settlement of Exmouth. Generally, behaviours and characteristics of residents have been assumed to be homogeneous with those of tourists (Inbakaran and Jackson, 2005) but are now realised as different (Confer et al., 2005). Residents view the beach as a local resource (with regular and routine use) while for tourists it is a more isolated experience, which may be

repeated annually (Tunstall and Penning-Rowell, 1998). This pattern was clearly identified in the current study with the majority of residents travelling to NMP for recreation >11 times in the previous 12-months (and up to 150 times), while tourists visited once, although the high levels of repeat visitation indicate they are returning to replicate their experience. This has implications for expansion of population centres near, or adjacent, to attractions such as NMP, which can significantly increase the number of people who are able to undertake regular and frequent visits throughout the year.

Visitors on pastoral leases (except for Cardabia Station) had longer lengths of stay when compared to CRNP and Coral Bay, findings also supported by previous research within these regions (Jones et al., 2009, Wood and Dowling, 2002). Length of stay is an important choice for visitors (Decrop and Snelders, 2004), and is related to origin and familiarity with an area (Gokovali et al., 2007). Pastoral leases are more difficult to access (i.e. sandy tracks) and generally require visitors to be self-sufficient. A longer length of stay supports the significant time investment involved in accessing such remote areas (Lucas, 1990).

Pastoral leases have many similar characteristics, especially in terms of their limited services and facilities (including accommodation), and have often been aggregated for analysis as a single unit (Jones et al., 2009, Wood, 2003). However, the data collected in this study provided insight into how participation in recreational activity varies between leases, especially between Gnaraloo and Quobba Station at the southern extent of NMP and the remaining leases to the north. This southern region had a higher prevalence of participation in active water sports, such as kitesurfing, windsurfing and surfing. These activities are highly weather dependent and were more often occurring in windier off-peak months or periods of higher swell conditions (in late winter) (BOM, 2009). Such weather conditions, as well as temperature, are known to be major factors which influence recreational use (Ploner and Brandenburg, 2003). The coastal geomorphology along this southern section of coastline (with rocky shores and intertidal reef platforms) also differs from that in the north, providing ideal locations for surfing. The significant cross-regional movement of people from Coral Bay onto Cardabia Station on day trips also results in this pastoral lease being different from others. This is evident with shorter lengths of stay and more respondents choosing to stay in hotels and caravan parks (in neighbouring Coral Bay), rather than in the single coastal camping area on Cardabia Station.

Families were recorded across all coastal regions, and were more associated with school holidays, which create a window of opportunity for these groups to travel away from home. Such patterns have been documented elsewhere, generally resulting in increased visitation and variation in recreational use (Amelung et al., 2007). However, these results differ from previous research which indicated that less families visited Ningaloo, especially those with young children, due to long travel times from population centres (Wood, 2003). High levels of repeat visitation and site fidelity (with an accommodation site) were also found in this study, particularly along North-West Cape and on pastoral leases. Such strong site loyalty often reflects a high level of satisfaction with a location. Repeat visitors also have different characteristics to first-time visitors (Darnell and Johnson, 2001) and often form strong place attachments to these locations (Ormsby et al., 2004).

Distribution of recreation may be influenced not only by land tenure and the associated management arrangements and infrastructure, but also by management arrangements of the adjacent Marine Park, which has sanctuary ('no-take') zoning incorporating 34% of its total area (CALM and MPRA, 2005). This is supported by the low number of respondents involved in recreational fishing at Coral Bay, which encompasses a sanctuary zone. Fishing is permitted along sections of the coast adjacent to CRNP although there were still fewer respondents

engaged in this activity than in other regions. Turquoise Bay, a well known snorkelling location and high use beach which was targeted more frequently by researchers for interviews under the quota sampling method, is located within a sanctuary zone and this was the likely reason why fishing was not recorded as often here as in other regions.

Individuals undertaking stationary activities, such as fishing or sunbaking, were more likely to be interviewed as they are on the beach for longer periods than respondents engaged in active or water-based activities such as kitesurfing or snorkelling. This phenomenon is known as length of stay bias and is well-documented with respect to recreational fishing surveys (Pollock et al., 1994). This bias was mitigated by recording the current activity being undertaken, as well as asking the respondent to name the main activity for which they came to the beach. The researchers were also aware of this bias and made every effort to interview people involved in a range of activity types, which is consistent with a purposive, quota approach to group selection. Information on recreational activity participation was also obtained for a respondent's entire trip, up until time of interview, as opposed to proposed participation in activities which is often collected and combined across sites in many studies.

6.5.2 Management Implications

This study identified patterns in visit and visitor characteristics, as well as recreational activity, which can be explained by variations in land tenure, associated management arrangements and infrastructure. The complexity of coastal geomorphology and temporal factors also contributed to spatial and temporal variations. An understanding of these patterns is imperative to better plan for future sustainable use of the coastal environment, especially in light of the increasing importance of Ningaloo as a recreation and tourism destination. This understanding is also essential for other tourist destinations around Australia, as attraction to coastal environments is not limited to large cities, but is also occurring in smaller coastal communities, especially where a protected area may be a drawcard for visitors (Gurran et al., 2007).

The limited number of 2WD access roads in the region has implications for access by visitors, including large commercial tour groups on buses, who are restricted to travel on 2WD roads in North-West Cape, CRNP and Coral Bay. The easier accessibility to recreation sites along these parts of the coast increase the likelihood of environmental degradation through trampling, littering and erosion in terrestrial habitats as well as coral damage and impacts to marine wildlife in marine habitats (Newsome et al., 2002). The local and State government agencies responsible for these regions have implemented management strategies such as site hardening (i.e. provision of boardwalks over fragile vegetation), signage and rehabilitation to repair and reduce impacts from visitors (Newsome et al., 2002). It is likely that creating 2WD access along the entire Ningaloo coast would dramatically increase visitation to these other regions, and significantly alter patterns of use and visitor characteristics.

CRNP is the only tenure type along the Ningaloo coast with a maximum length of stay (28 days), which is a standard management strategy applied across all Western Australian national parks to maintain equity of access to users (CALM, 2005). Although the mean length of stay for other coastal regions was 23.7 days, the high variability indicates that respondents often stayed for longer than the 28 day limit set in CRNP, highlighting that this control measure affects people who stay in this coastal region. Maximum stay limits (sometimes only 1-3 nights) have been extensively implemented within national parks in north America to regulate visitor numbers and maintain access for an increasing numbers of visitors (Hammit and Cole, 1998, Lucas, 1990, Marion et al., 1993). Although shorter length of stays are opposed by 39%

of visitors to CRNP (Polley, 2002), such a measure has been suggested for peak school holiday periods (CALM, 2005).

Access to the Ningaloo coast has changed over time, especially on pastoral leases where public access has traditionally been restricted by leaseholders. This provided protection to coastal environments from land-based visitors and a perception of low levels of participation and environment impacts (Davies et al., 2009). However, increasing demand from the public and economic stresses (i.e. falling incomes from grazing) has seen coastal camping (for a nightly fee) become more prevalent on pastoral leases as pastoralists seek to diversify into other activities (i.e. tourism, non-conventional livestock and wildlife conservation). Pastoralists are responsible for managing this camping and have implemented controls suited to long-term visitors in a remote setting (i.e. no stay limit and campfires). Interestingly, much of this camping occurs within the NMP, which extends to 40 m above high water mark when adjacent to a pastoral lease, except on Gnaraloo and Quobba Stations (low water mark). Such camping may result in habitat degradation, erosion of fragile dune environments and trampling of sandy beach fauna by vehicles and caravans (Schlacher and Thompson, 2008).

The Commonwealth Department of Defence has the ability to restrict access to defence lands (located to the south of CRNP). Although rarely enforced, this would impact significantly on camping and travel movements along this section of the Ningaloo coast. Another consideration is access rights of indigenous Australians, who have a long association with the Ningaloo coast (Morse, 1993). Sites of cultural significance, such as burial grounds or archaeological material, are protected under the *Aboriginal Heritage Act 1972*. The *Native Title Act 1993* also provides claimants the right to access land for traditional activities, such as ceremonial activities or hunting. A claim is currently being processed which covers a large area of the Ningaloo coast but the outcome is not yet known (National Native Title Tribunal, 2009).

Coastal marine parks are predominately accessed via adjacent lands and this may be affected by various property rights. Access via the marine environment is different. National jurisdiction is defined by the United Nations Convention on Law of the Sea as extending up to 200 nm offshore, while also providing right of access for transiting vessels. However, within these national jurisdictions, marine areas are often considered as a public space belonging to all (Frangoudes et al., 2008), where there are high expectations for access by residents and visitors (Sloan, 2002). Marine parks, like their terrestrial counterparts, have the dual objectives of biodiversity conservation and equitable access. Achievement of these objectives is in the interests of all management bodies, as it will ensure protection of the coastal environments which attract people to Ningaloo while continuing to support the tourism industry by maintaining visitor satisfaction and numbers. However, unlike many multi-tenure reserve networks, where conservation is the primary aim of all involved (Fitzsimons and Wescott, 2007), the different purposes of lands adjoining NMP encumber a united approach to management. Similar situations are likely to exist adjacent to many large coastal marine parks and can benefit from collaboration, information exchange and strategic planning across tenures.

The complexity of land tenures along the Ningaloo coast attracts a diverse range of visitors who seek a range of experiences, including remote coastal camping which is found in few places around the world. Such diversity supports the provision of a range of accommodation, facilities, services and recreational opportunities to maintain visitor satisfaction. However, the different land tenures create challenges for sustainable use and maintaining access to the marine environment. It also hinders the collection of core data required for understanding use patterns, such as total visitor numbers and levels of recreation participation, as there are different purposes (and priorities), limited resources and collaboration between management bodies.

Ningaloo's isolation has maintained visitation and development pressure at low levels when compared to other iconic Australian destinations, such as the Great Barrier Reef. However, expanding national and international recognition of the unique natural features of Ningaloo, including recent nomination as a World Heritage site, will encourage more visitors and these issues will need to be addressed to ensure sustainable management of the coastal environment.

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7. SPATIAL EXTENT, SEASONAL VARIABILITY AND ZONING COMPLIANCE OF RECREATIONAL FISHING IN AN AUSTRALIAN MULTIPLE-USE MARINE PARK

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7.1 Summary

Extractive activities within multiple-use marine parks have significant implications for conservation and resource management. However, the collection of comprehensive spatial and temporal data on such activities is rarely undertaken. The Ningaloo Marine Park encompasses a fringing coral reef system extending for 300 km along the coast of north-western Australia and annually receives about 200,000 visitors. Integrated, geo-referenced aerial and land-based coastal surveys were conducted throughout 2007 to identify patterns of extractive recreational use and compliance with park zoning. In terms of overall use of the park, extractive use represented ~12% of the observed activity from boats and the shore although activity type could not be determined for 35% of boats. Line fishing was the dominant extractive use and occurred in higher densities with wider spatial distribution in autumn and winter, along with clustering around infrastructure (e.g. boat launching locations and beach access points). Non-compliance with zoning by fishing vessels was 12%, which increased to 20% if vessels for which the activity engaged in could not be determined were incorporated. Interviews with recreational fishers along the shore found overall catch per unit effort to be below (<1 fish/person/hour) and spangled emperor (*Lethrinus nebulosus*) was the most common out of the >30 species caught. Respondents displayed a high level of knowledge about the location of sanctuary zones and the majority stated that current zoning had not affected their fishing activity. This integrated survey approach and high resolution spatial data provided a comprehensive and complementary understanding of extractive use at Ningaloo with implications for management of the large multiple-use marine park.

7.2 Introduction

Marine protected areas (MPAs) are widely accepted as the foremost tool for conserving marine biodiversity through the management of human activities (Wilkinson et al., 2003). Specific benefits of MPAs include protection of ecosystems and target species from overexploitation (McClanahan and Mangi, 2000), maintaining opportunities for tourism (Bohnsack, 1998; Badalamenti et al., 2000) and separating incompatible activities (Lynch et al., 2004; Halpern et al., 2008). MPAs may also provide connective networks which enhance ecosystem resilience (Almany et al., 2009). Worldwide, MPAs now protect ~2.2 million km² or 0.6% of marine habitats, although only 0.08% are 'no-take' (Laffoley, 2008). 'No-take' areas are those in which extractive activities, such as recreational or commercial fishing are prohibited (Agardy et al., 2003).

The majority of MPAs are designed using ecological criteria, such as the selection of representative marine habitats, to ensure ecosystem function (Roberts et al., 2003). The success

of these criteria is measured using indicators, such as increases in biomass or species richness, which reflect biodiversity and community structure (Halpern and Warner, 2002). However, it is also essential to incorporate social and economic information into MPA- design to minimise societal costs, especially those linked to activities such as subsistence fishing or tourism, which may sustain the livelihoods of many people (Klein et al., 2008; Ban et al., 2009). Recent studies have demonstrated how the inclusion of data from commercial fisheries into MPA design successfully minimised economic losses while still achieving conservation objectives (Stewart and Possingham, 2005; Richardson et al., 2006).

Social and economic data should be incorporated into MPA planning during the design stage (Sanchirico and Wilen, 2001; Richardson et al., 2006), although a lack of information often hinders this approach (St. Martin and Hall-Arber, 2008; Ban et al., 2009). Adaptive management techniques should be used to assimilate new knowledge into existing MPAs (Wilkinson et al., 2003; Pomeroy et al., 2004; Day, 2008). This knowledge can be obtained through research projects or ongoing monitoring which, along with compliance (Mora et al., 2006; Guidetti et al., 2008; Sethi and Hilborn, 2008), community acceptance (Oracion et al., 2005) and evaluations of management effectiveness (Alder et al., 2002; Pomeroy et al., 2004), can contribute to the success of a MPA in achieving its stated objectives.

A strategic plan to promote a national representative system of MPAs was developed in Australia in the early 1990s and supported the implementation of multiple-use frameworks (ANZECC, 1999). Multiple-use marine parks seek to balance conservation with social and economic components by allowing extractive and non-extractive uses to be undertaken within their borders (Agardy et al., 2003; Ormsby et al., 2004). Spatial zoning measures are the primary management tool through which this is achieved (Smith and Wilen, 2003; Day, 2008) by restricting recreational and commercial activities from areas of intrinsic ecological value (Day, 2002). Governments of each Australian state and the federal Commonwealth have since worked towards implementing a representative system of marine parks within their area of jurisdiction.

Western Australia currently has nine marine parks that were selected based on the need for biodiversity protection, increasing anthropogenic pressures and public support. Zoning is a generic management strategy applied across all nine marine parks to achieve management objectives such as maintaining coral diversity and finfish biomass. Other generic strategies are education, enforcement, research, monitoring and direct management intervention (CALM and MPRA, 2005). Standardised zone categories used in Western Australia are entitled sanctuary ('no-take'), recreation, general use and special purpose zones. Such zones have been implemented throughout the Ningaloo Marine Park (NMP) in north-western Australia Figure 7-1).

The NMP was declared in 1987 to protect one of the largest fringing coral reefs in the world, extending ~ 300 km along the coastline. The diverse array of marine life at Ningaloo is comparable to that of the Great Barrier Reef and includes >900 fish species, 250 coral species and 600 mollusc species (Storrie and Morrison, 2003). Ningaloo is also recognised for its indigenous history (Balme and Morse, 2006), recreation and commercial activities (CALM and MPRA, 2005), and is one of the few locations in the world with a tourism industry based on interactions with whale sharks and manta rays (Preen et al., 1997; Mau, 2008). The sheltered lagoon located behind the fringing reef crest has a mean width of 2.5 km and provides an ideal location for recreation from boats and the shore. These unique natural features attract 200,000 visitors annually, often for extended trips, and this figure is expected to increase in coming years (CALM and MPRA, 2005). The tourism industry is also the main source of income for a

permanent population of 2,000 people in the service centres of Exmouth and Coral Bay (GDC, 2006). Visitors stay in these two centres, or in the numerous coastal camping areas dispersed along the coast, and are attracted to Ningaloo from April to October thereby avoiding the high temperatures and cyclones which occur during the remaining months (November to March) (BOM, 2009). The bulk of previous recreation and tourism research has been conducted during peak visitor months, and within this, school holidays (April, July and October) are known to have higher levels of visitation (Wood and Dowling, 2002; Northcote and Macbeth, 2008; Jones et al., 2009).

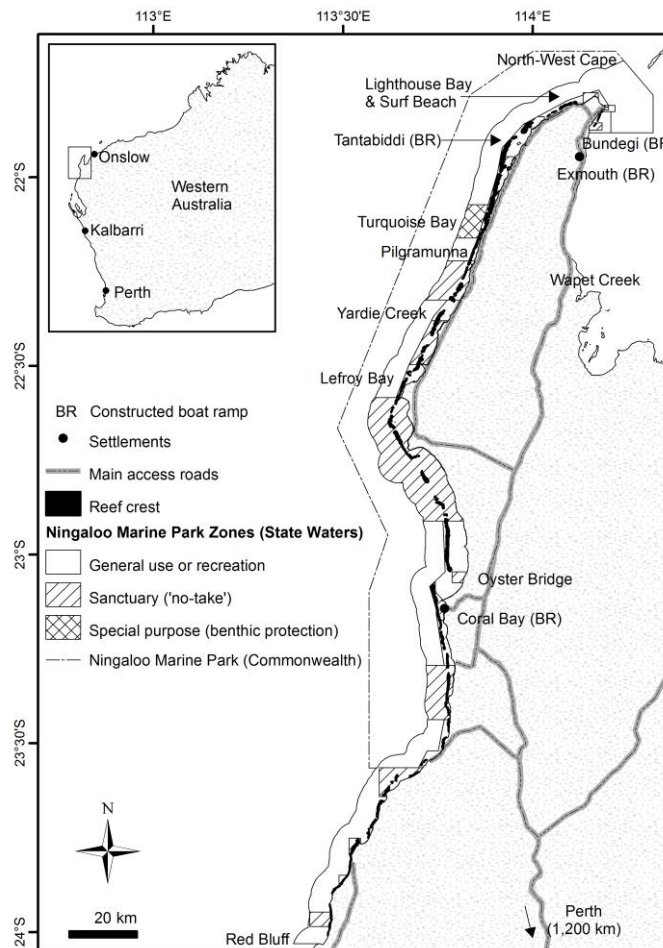


Figure 7-1. Study area of the Ningaloo Marine Park on the coast of north-western Australia along with zone types, major access roads to the coast, fringing reef crest and settlements. Note: special purpose (shore-based activity) zones are located along the shoreline of most sanctuary zones.

The NMP (state waters) extends ~3 nautical miles seaward, beyond which the NMP (Commonwealth waters) extends further offshore (CALM and MPRA, 2005). Both marine parks were declared separately under state and Commonwealth legislation, but are managed as a single unit under a memorandum of understanding by the Western Australian Department of Environment and Conservation (DEC) and Western Australian Department of Fisheries (DoF).

The initial zoning plan for the NMP (state waters) comprised <10% sanctuary area, which was increased to 34% in 2004 (CALM and MPRA, 2005). Currently, there is no zoning within the NMP (Commonwealth waters). Sanctuary zones aim to conserve marine biodiversity by excluding activities that are likely to have adverse environmental impacts (i.e. extractive use)

and sanctuary zones in the NMP are maintaining greater biomass and abundance of targeted finfish species (Westera et al., 2003; Babcock et al., 2008). Recreation zones are managed for both conservation and recreation, and permit recreational fishing and commercial tourism operations (excluding commercial fishing). General use zones permit commercial and recreational fishing as well as aquaculture and petroleum exploration, provided they do not compromise ecological values (such as coral communities, water or sediment quality). Spearfishing is restricted to specific areas within general use and recreation zones, as is netting, which requires a licence issued by the DoF (DoF, 2009a). Special purpose zones exist for benthic protection, where only fishing for pelagic species is allowed, and for shore-based activities (SBA). At Ningaloo, SBA zones were implemented to accommodate recreational line fishers, who are permitted to fish from the shore adjacent to sections of eight of the 17 sanctuary zones. There is currently no licence required for recreational line fishers in Western Australia.

During a survey of recreational fishing at Ningaloo (Sumner et al. 2002) people on vessels were intercepted at four constructed boat ramps and data on fishing locations were self-reported using a map with 5 x 5 nautical mile (nm) blocks. This showed the highest concentrations of fishing from vessels to be around North-West Cape and Coral Bay, while vessels launching directly off the beach adjacent to coastal camping areas were found along the entire length of the coast, particularly between Yardie Creek and Coral Bay (Sumner et al., 2002). A concurrent roving creel survey revealed that shore-based fishing was highest from North-West Cape to Wapet Creek in Exmouth Gulf. Self-reported data from charter fishing operators (also at 5 x 5 nm resolution) have indicated that this activity occurs further offshore, outside the NMP (state) boundary (Northcote and Macbeth, 2008). In Western Australia, most commercial fishing activity is reported at 60 x 60 nm resolution and also occurs predominantly outside the NMP (state) boundary (CALM and MPRA, 2005). The coarse spatial scale of these datasets makes it difficult to investigate the effect of zoning on fishing activity. However, visitor and resident surveys have indicated some displacement of recreational boat fishing due to sanctuary zones (Ingram, 2008; Northcote and Macbeth, 2008). Displacement may be spatial (i.e. visiting an alternative location where zoning allows fishing), temporal (i.e. visiting less frequently) or result in activity substitution (Lynch et al., 2004; Arlinghaus, 2005).

In light of the importance of Ningaloo as a recreation and tourism destination, combined with challenges facing managers in accommodating increased visitation and ascertaining management effectiveness, it is essential to develop a better understanding of recreational activity patterns. The overall aim of this study was to determine the fine-scale spatial and temporal patterns of all recreational use throughout this large, multiple-use marine park. Of specific interest was the level of participation in extractive activities, particularly line fishing and an integrated survey approach was applied to determine distribution and seasonal variation as well as provide an indication of compliance with zoning in the NMP.

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7.3 Methods

7.3.1 Observation surveys

Aerial surveys and land-based coastal surveys (hereafter referred to as coastal surveys) were undertaken from January - December 2007 to collect geo-referenced observational data on all shore and boat-based activity occurring within the NMP. Associated with each data point were information on platform (i.e. shore or boat), group size, activity type and, if the activity was boat-based, type of boat was recorded.

Survey designs were developed using techniques documented by Pollock et al. (1994) for recreational fishing surveys, which may incorporate stratification and/or randomisation to reduce sampling errors and increase the accuracy of participation estimates. However, the aim of this study was to determine patterns of recreational use and not estimate total participation or total catch; similar to surveys by Reed-Anderson et al. (2000) and Dalton et al. (2010). Other factors considered in the survey design were the large size of the study area, strong afternoon on-shore seabreezes and limited access routes to, and along, the coast which increased travel times, fuel and equipment costs.

7.3.2 Aerial surveys

The elongate and linear nature of the NMP make aerial flights an ideal technique for surveying the shoreline and marine environment as a single transect and enabled coverage of the entire study area. The speed of air travel ensures data are collected over a short time frame and there is little chance of duplicating observations, thereby providing a synoptic overview of activity. Aerial survey is a cost-effective method for surveying large tracts of land or ocean which has been successfully applied to studies on recreational fishing (Brouwer et al., 1997), beach use (Coombes et al., 2009), coastal camping (Hockings and Twyford, 1997) and boating (Sidman and Flamm, 2001; Warnken and Leon, 2006).

There were 34 aerial flights completed throughout the NMP during the 12-month study, with a maximum of four flights undertaken in peak months with school holidays (April, July, October) (Figure 7-2). The light aircraft (Cessna 172) flew at an altitude of 500 ft (~150 m) and, with an average speed of 100 knots (185 km h⁻¹), it took ~4 hours for a trip from Exmouth to Red Bluff and return (Figure 7-1). The outward (southbound) and return (northbound) flights were considered as two separate counts of recreational activity, with the turning time at Red Bluff regarded as the start of the return flight. Surveys were completed in the morning with departure times for all flights standardised at 8 am to enable the best opportunities for viewing recreational use. The lighter, mainly offshore wind conditions in the morning as well as reduced wind action and glare on the water surface, increased the likelihood of observers identifying vessels and people. Digital cameras were also used to record observations, further improving data quality.

The position of the aircraft was recorded every two seconds using a Garmin global positioning system (GPS) linked to a PalmPilot for data storage. Time, altitude and heading were also obtained which, along with an offset measurement (i.e. distance of the object from an observation point), enabled the actual location of vessels and people on the shore to be calculated (Vincenty, 1975), similar to observation studies of marine megafauna (Logan and Smith, 1997). To improve accuracy, the offset was estimated using calibrated markers taped to

the wing strut (representing distances of 100, 300, 1000 and 1,500 m out from the plane), another technique adapted from wildlife studies (Grigg et al., 1999; Ottichilio and Khaemba, 2001). The location of the high water mark and fringing reef crest were additional reference points used to further improve distance estimation for shore and boat-based activity, respectively.

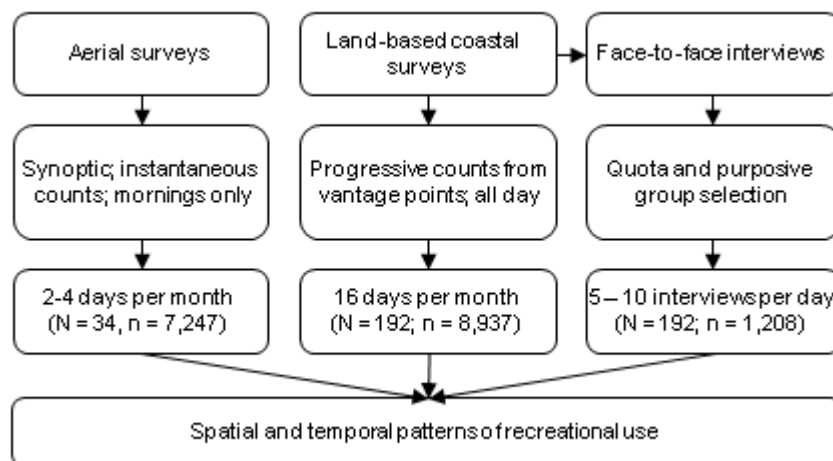


Figure 7-2. Diagrammatic representation of the integrated design of aerial and land-based coastal observations surveys as well as face-to-face interviews conducted in the Ningaloo Marine Park from January – December 2007. Note: N = total number of survey days, n = total number of observations or interviews.

7.3.3 Coastal surveys

Coastal surveys are an on-site survey technique, similar to roving creel surveys of recreational fishing (Pollock et al., 1994). They have been used to monitor boating and other recreational activities in Australia (Widmer and Underwood, 2004; Lynch, 2006; Smallwood and Beckley, 2008), Europe (Bissett et al., 2000; Lloret et al., 2008) and Hawaii (Courbis, 2007) but have rarely been undertaken over such an expansive area as Ningaloo.

Coastal surveys complemented data collected during aerial flights by applying the same geo-referenced counting techniques, albeit from coastal vantage points visited by the observers in an off-road vehicle. These points, distributed along the entire coast, were selected for their accessibility and overlapping fields of view along the shoreline and into the marine environment. The slow rate of travel by off-road vehicle was further reduced by the narrow, sandy tracks which resulted in observations being made progressively over a period of several hours (Pollock et al., 1994). Errors arising from multiple sightings of the same object were reduced by the observers deliberately excluding them from subsequent counts. However, if a vessel was first observed motoring (or transiting), but was later sighted undertaking a recreational activity, then details of the second observation were recorded and the first sighting deleted.

The coastline was split into three routes of 140 km – 160 km in length which could be completed in a single day starting and finishing at Exmouth, Yardie Creek, Coral Bay or Red Bluff (Figure 7-1). Thus, it was possible to survey the entire length of the NMP in three days. Surveys were conducted 16 days per month throughout the entire 12-month study (Figure 7-2).

The northern routes (Exmouth – Yardie Creek – Coral Bay) were completed six times per month while the southern route (Coral Bay – Red Bluff) was completed four times per month due to difficulty in accessing this isolated section of coast. Randomisation of starting location was not incorporated due to the long travel times and linear nature of routes. To minimise biases, starting times were varied between 7.30 am – 11 am, and trip direction was reversed, so sites were visited in both mornings and afternoons. Surveys were allocated to random days covering weekends/public holidays, weekdays and school holidays so that, by the completion of fieldwork, all day types had been sampled during each route.

Data on shore and boat-based activity observed during coastal surveys were collected using a Garmin GPS to geo-reference the location of observations, similar to the aerial surveys. However, as the observations were made from a stationary vantage point it was possible to use a range and bearing finder (Newcon LRB 4000) to calculate an actual location, similar to previous studies of boating (Sidman et al., 2000; Lynch et al., 2004; Dalton et al., 2010). In this study, distances >2,000 m were consistently achieved, thereby allowing coverage of the majority of the lagoon environment. Beyond this range, a handheld compass was used to determine bearing, and distance was estimated using the reef crest and nautical charts to provide additional reference points.

7.3.4 Interviews

Interview techniques have been used widely in tourism and recreation research, and can be effectively integrated with observation surveys to provide complementary interpretative information (Newsome et al., 2002; Cessford and Muhar, 2003). A higher response rate is also usually attained, especially when using trained researchers (Schirmer and Casey, 2005). Other off-site survey options, such as mail and telephone surveys, were impractical at Ningaloo because of the remote, isolated areas where the majority of respondents were camping.

Face-to-face interviews were nested within the coastal surveys and were conducted after all shore and boat-based activity was recorded from a vantage point (Figure 7-2). Similar to the roving and access point surveys developed for recreational fishers, people were intercepted either during, or at the completion of, their activity (Pollock et al., 1994). Groups were selected based on quota and purposive sampling techniques, which are both non-probability type methods (Neuman, 2006), ensuring that locations with highest use were sampled more frequently than those with low use, while also obtaining data on a wide spectrum of activity types. Such techniques are well documented for selecting groups during recreation and tourism studies (Sidman et al., 2000; Sirakaya et al., 2003; Nyaupane et al., 2004). Respondents within each group were selected based on who had the next birthday, also a widely accepted technique (Oldendick et al., 1988; Battaglia et al., 2008; Coombes et al., 2009). Due to the large distances travelled each day, the number of interviews was restricted to 5 – 10 per survey day.

The aim of the questionnaire was to obtain information on the demographics, visit attributes and activity patterns of visitors to the NMP. The interview location was geo-referenced at the commencement of the questionnaire, followed by a number of questions on demographics (i.e. age, group size or group type) based on standard categories (ABS, 1999; Horneman et al., 2002). If engaged in recreational fishing from the shore (or just returned from a boat-based fishing trip), then the respondents were also asked specific questions about this activity relating to catch and effort. Catch per unit effort was calculated for each species by dividing the number of fish retained or released by the fishing effort (time spent fishing multiplied by number of people fishing). Questions were asked pertaining to the effect of sanctuary zones on fishing

activity as well as incidence of fishing at night, which is traditionally a difficult activity to measure. Frequency of participation in recreational activities for the respondents' entire trip to the NMP (up until time of interview) was also obtained.

7.3.5 Spatial mapping

A synoptic overview of boating was obtained by aggregating the geo-referenced data points from aerial surveys into 3 x 3 km (9 km²) grid cells. It was difficult to identify the number of people on vessels, especially charter vessels or those with cabin accommodation, as they were obscured from view of the observers. Therefore, these boating data were aggregated based on number of observations (where one observation represents one vessel). Data collected on shore activity during aerial surveys were aggregated into 3 km long coastal segments which extended 0.5 km inland and 0.5 km seaward of the mean high water mark. It was not possible to distinguish separate groups of people at Bundegi Beach, Surf Beach, Turquoise Bay, Oyster Bridge and Coral Bay (Figure 7-1) due to high numbers at these sites. A total count of people participating in different recreational activities at these sites was therefore linked to a central geo-referenced location and shore activity was displayed using number of people, as an observation could represent >50 people.

The benefits of collecting spatially explicit data were demonstrated by displaying 'zoomed' views of extractive activity obtained during the coastal surveys. Focusing on a localised area clearly showed the relationship between activities and factors such as the fringing reef crest, sanctuary zones, special purpose (SBA) zones and boat launching locations. Each boat observed is represented as a single data point, while shore activity is displayed as a scaled marker indicative of group size.

7.4 Results

Aerial surveys recorded a total of 2,906 observations of boats and 15,464 people participating in recreation along the shoreline of the NMP during the 34 flights from January – December 2007 (Figure 7-2). Maximum numbers of boats (>100 vessels) were obtained on northbound flights in June and July while >650 people were counted along the shore during northbound flights in the July and October school holidays. The later, northbound counts (10 am – 12 noon) were used for all further analyses. Coastal surveys on 192 days documented 2,576 observations of boats and 23,282 people participating in recreation along the shore. Maximum numbers of boats (>50) were recorded between Exmouth – Yardie Creek in August while the highest counts of people along the shore (>500) were during July and October school holidays along the same route. In total, 1,208 face-to-face interviews with people participating in recreational activities on the beach were completed during coastal surveys.

7.4.1 Participation in extractive recreational activities

The level of participation in extractive activities observed from boats was relatively low for northbound aerial surveys (11.5%) and coastal surveys (10.2%) (Figure 7-3a,c). Motoring and unknown were the most frequently recorded activities for boats, each contributing >25% of the total number of observations. Motoring vessels were those transiting the NMP at high speed (and were unlikely to be trolling) while unknown indicated that the activity type could not be ascertained by the observers.

Extractive activities along the shoreline were observed in lower numbers than for boats, comprising 7.4% of people recorded during northbound aerial flights and 9.4% for coastal surveys (Figure 7-3b, d). There were a few people for which an unknown activity type was recorded during aerial surveys (2.6%) while coastal surveys identified an activity for all people observed.

Interview data collected on the main activity for which respondents came to the NMP showed a much higher percentage of extractive use occurring from boats (64.3%) and the shore (25.8%) than the observation surveys (Figure 7-3e, f). The roving nature of the coastal surveys, during which time face-to-face interviews were completed, resulted in a higher likelihood of intercepting respondents conducting stationary activities (e.g. line fishing along the shore) and decreased the likelihood of intercepting respondents participating in activities such as fishing from boats, who spent most time on the water. This was reflected by the low total number of interviews conducted with people participating in boat-based activity (Figure 7-3e).

Extractive activities could also be specifically identified and included recreational line fishing, netting (cast and haul), collecting (for shells, bait and octopus), spear fishing and the use of snares or pots to target crabs and crayfish. Line fishing comprised >97% of extractive activities observed from boats during the aerial and coastal surveys (Table 7-1). A similar dominance (>94%) of line fishing was observed for people participating in extractive activities along the NMP shoreline. Line fishing was also the dominant extractive activity recorded from boats and the shore for respondents who participated in a face-to-face interview (>92%). Spearfishing from boats was an activity nominated by 7.4% of respondents as their main activity when intercepted at the completion of a boating trip.

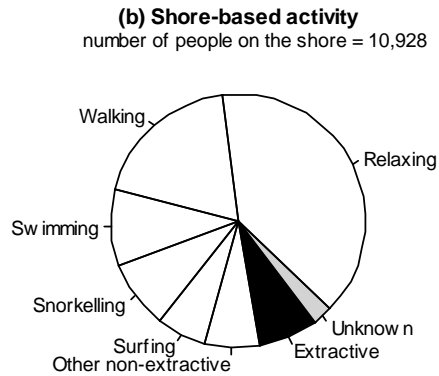
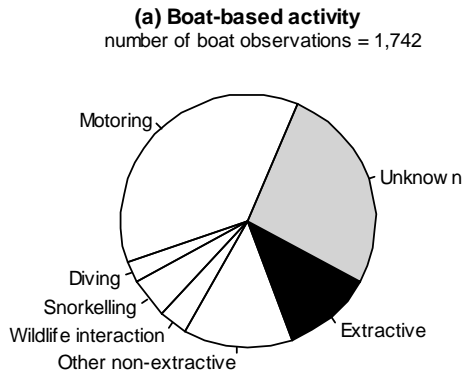
Table 7-1. Percentage contribution of specific extractive activities within each survey technique (northbound aerial surveys, coastal surveys and face-to-face interviews). *calculated from: number of vessels; ^ number of people; # number of interviews.

Extractive activity	Aerial (Northbound)		Coastal		Interviews	
	Boat*	Shore^	Boat*	Shore^	Boat#	Shore#
Line fishing	98.1%	98.6%	97.7%	94.8%	92.6%	97.3%
Netting (cast, haul)	0%	1.0%	0%	1.1%	0%	0.3%
Collecting (bait, shells, octopus)	0.6%	0%	0%	2.6%	0%	1.7%
Spearfishing	1.3%	0.4%	1.2%	1.2%	7.4%	0.3%
Potting/snares (for crayfish)	0%	0%	1.1%	0.3%	0%	0.3%

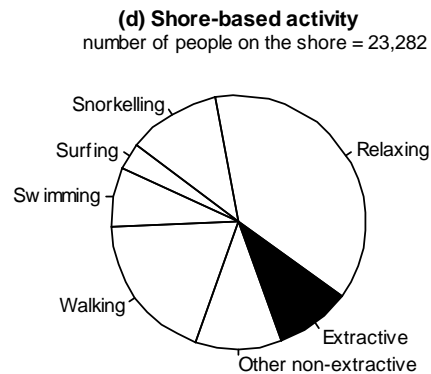
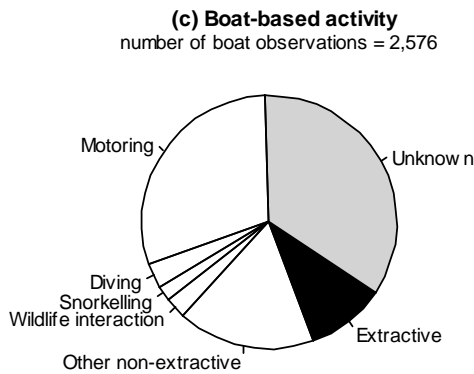
7.4.2 Seasonal variation

Maps of the spatial distribution of recreational line fishing within each season of the study period (January – December 2007) showed that wider spatial distribution and higher densities of boats engaged in line fishing were observed in autumn and winter, when the NMP is known to have higher levels of visitation (Figure 7-4). Distribution spread further along the sheltered lagoon environment (including to the south of Coral Bay) in these autumn and winter months, while the highest densities of boats were observed adjacent to Tantabiddi, Neds Camp, Lefroy Bay, Bruboodjoo and Coral Bay. Line fishing from boats was still observed in summer and spring, albeit in lower densities than the other seasons, and was concentrated south of Coral Bay and around Tantabiddi. Areas adjacent to Jane Bay, Pelican Point and Cape Farquhar had little boat-based fishing activity observed throughout the study.

Aerial surveys (N = 34 northbound flights)



Coastal surveys (N = 192 survey days)



Face-to-face interviews (N = 192 survey days)

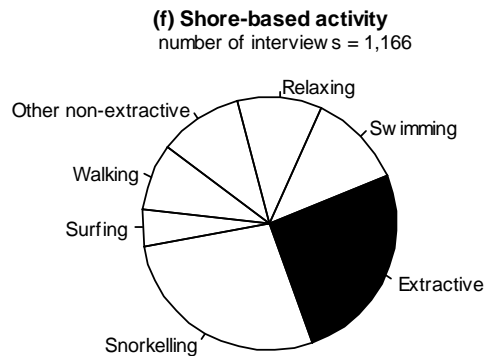
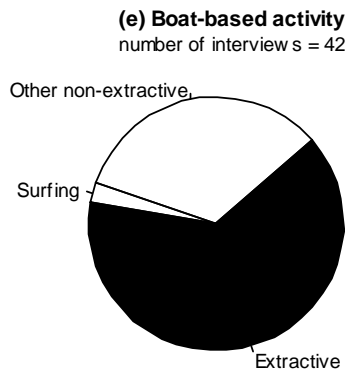


Figure 7-3. Percentage of (a) observed boats and (b) number of people on the shore participating in recreational activities during northbound aerial surveys; percentage of (c) observed boats and (d) number of people on the shore participating in recreational activities during coastal surveys; percentage of respondents and the main activity for which they visited the NMP on their day of interview from (e) boats and the (f) shore.

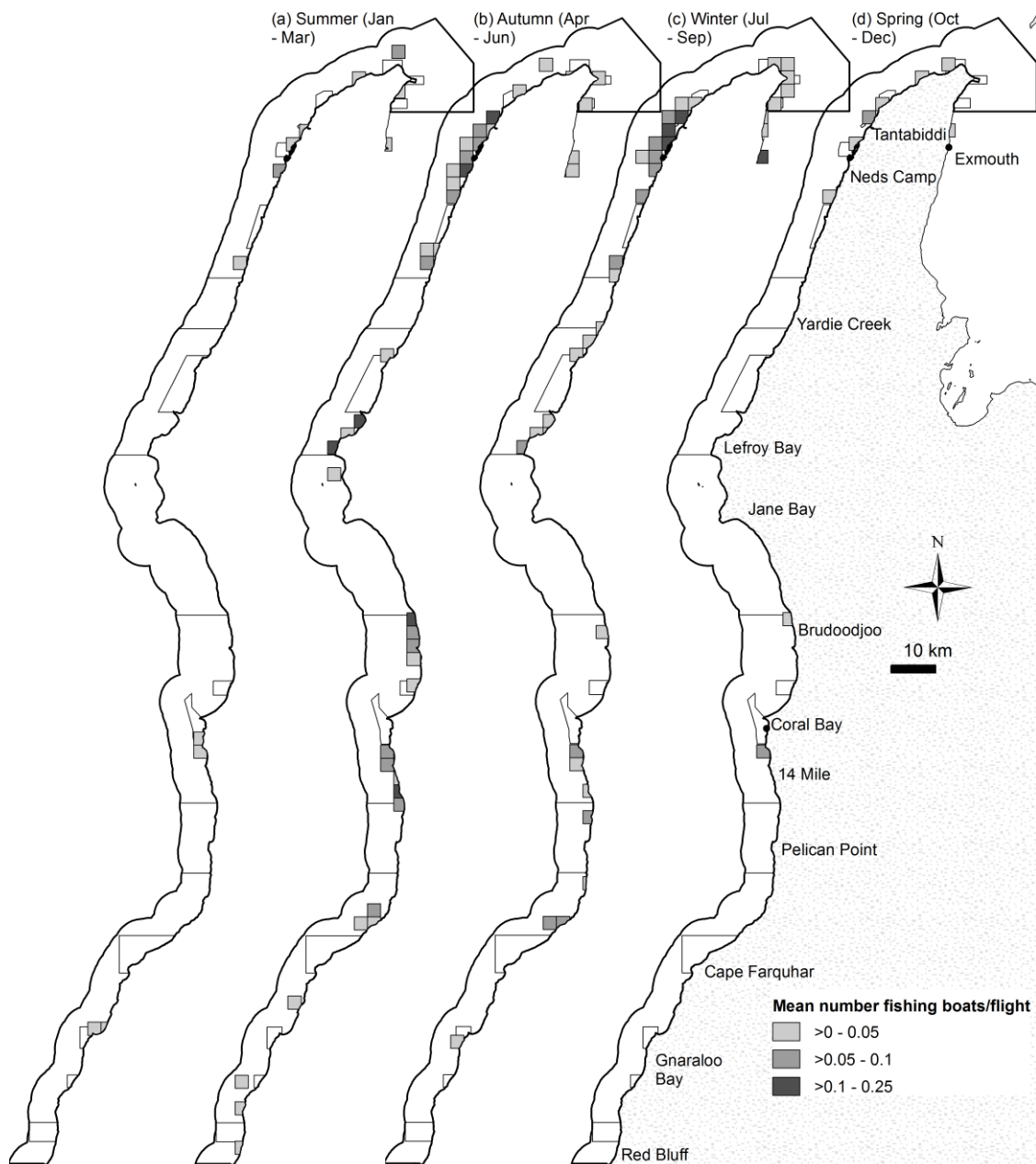


Figure 7-4. Spatial variation in mean number of boats observed to be engaged in recreational line fishing during northbound aerial surveys throughout the NMP in (a) summer, (b) autumn, (c) winter and (d) spring (number of flights = 34).

Vessels participating in an unknown activity type, which comprised 26.6% of all observations during aerial surveys (Figure 7-3a), were incorporated into the spatial distribution of vessels engaged in recreational fishing. Large commercial vessels (i.e. oil rig tenders) with an unknown activity type were highly unlikely to be fishing and were excluded from this analysis to improve data quality. This allowed visualisation of a possible scenario where all vessels observed with an unknown activity during northbound flights were actually engaged in recreational fishing. In this scenario, spatial distribution of vessels doubled in autumn and winter, and was spread widely along the sheltered lagoon environment and out towards the seaward edge of the NMP (Figure 7-5). The maximum density of boats within each 9 km² grid cell also doubled from 0.25 to 0.5 boats per flight. The highest concentrations of vessels in this scenario were observed

adjacent to Tantabiddi, Neds Camp, Lefroy Bay and Coral Bay (extending southwards to Pelican Point).

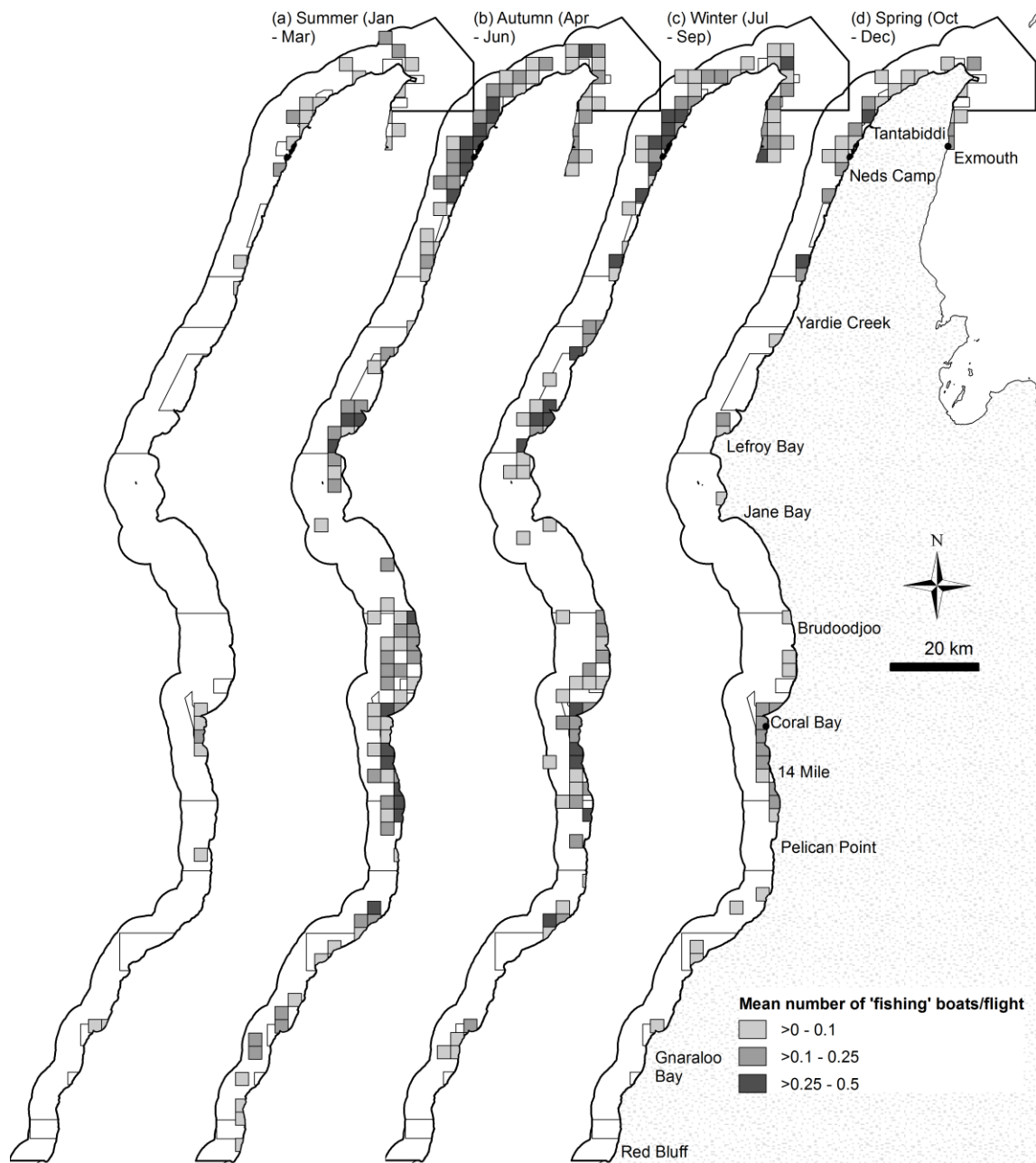


Figure 7-5. Spatial variation in mean number of boats observed to be engaged in recreational line fishing plus those participating in an unknown activity (possibly fishing) during northbound aerial surveys throughout the NMP in (a) summer, (b) autumn, (c) winter and (d) spring (number of flights = 34). Note: large commercial vessels with an unknown activity were excluded

Autumn and winter also had the highest densities of recreational line fishing from the shore, especially at Exmouth, Lighthouse Bay and around Coral Bay (Figure 7-6). There was spatial expansion of shore-based fishing in these peak seasons, especially south of Yardie Creek and south of Coral Bay. However, line fishing was also regularly observed within coastal segments in and around Lighthouse Bay and surrounding Coral Bay in summer and spring. Very little

fishing was recorded from shore throughout the study period to the north and south of Jane Bay, and to the north of Gnaraloo Bay.

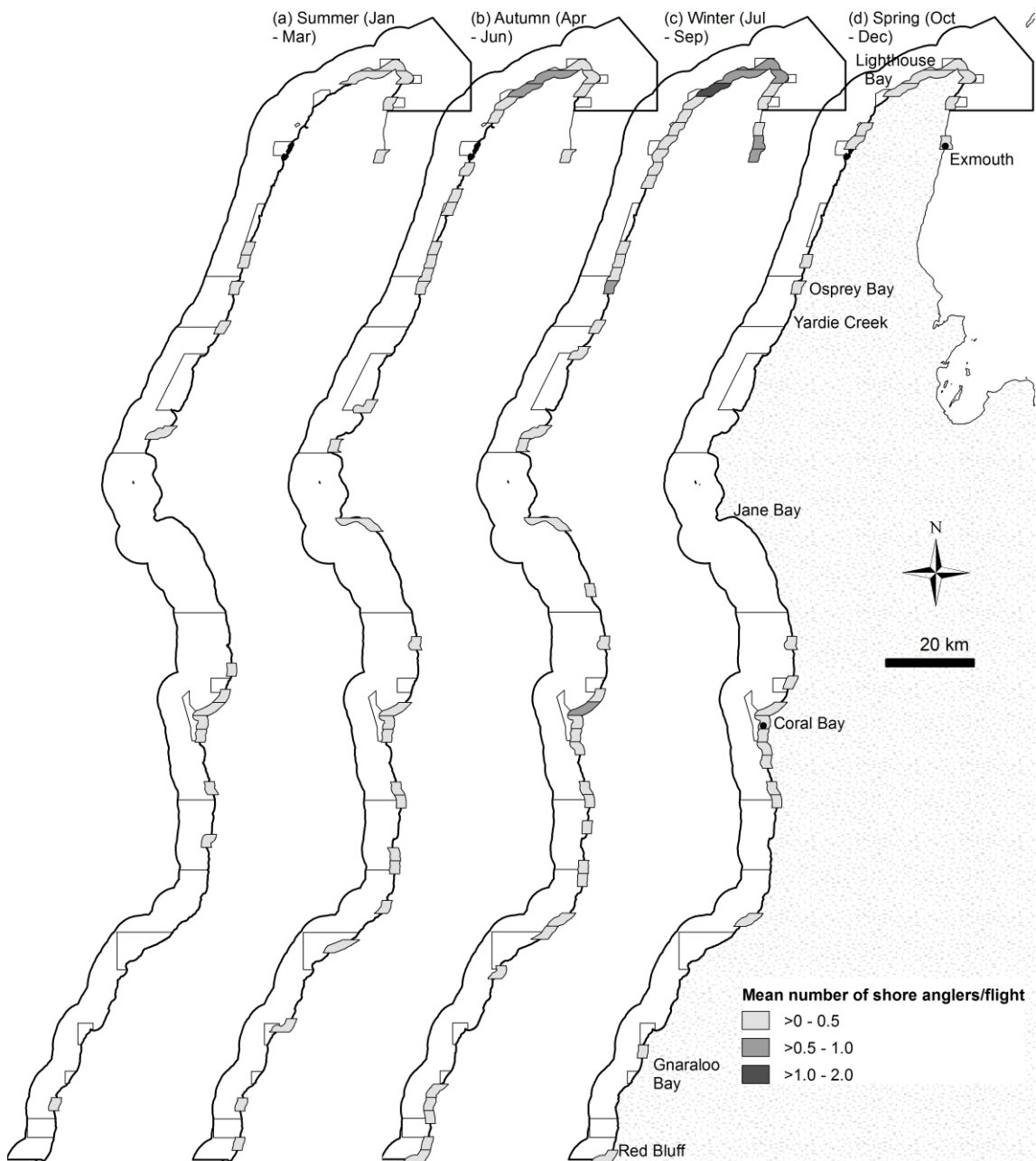


Figure 7-6. Spatial variation in shore-based recreational line fishing activity obtained from northbound aerial surveys throughout the NMP from January – December 2007 using number of observed people in (a) summer, (b) autumn, (c) winter and (d) spring (number of flights = 34).

7.4.3 Compliance with sanctuary zoning

Synoptic patterns of line fishing collected during aerial surveys provided an understanding of seasonal variation across the NMP. Based on the original geo-referenced data points collected during the northbound aerial surveys, 7.5% of boats were observed to be fishing in sanctuary

zones, as were 4.4% of people observed fishing from the shore. Geo-referenced data points collected during coastal surveys were similar with 12.0% of the boats observed fishing, as well as 2.1% of the people observed fishing from the shore, located in sanctuary zones. However, vessels for which an activity could not be ascertained, and who may have been engaged in recreational fishing, were also observed within sanctuary zones throughout the Marine Park. If such vessels were incorporated into this analysis, then non-compliance increased to 18.8% and 19.3% for aerial and coastal surveys, respectively.

Vessels observed to be line fishing were largely clustered around boat launching locations as well as inside the fringing reef crest in the regions surrounding Tantabiddi, Coral Bay and Winderabandi Point (Figure 7-7). Vessels with an unknown activity type were more widespread than vessels observed to be fishing, and were more often recorded outside the fringing reef crest. There was evidence of non-compliance at all sites, with boats observed to be fishing inside Mangroves, Maud and Winderabandi sanctuary zones. Vessels with unknown activity were also observed within sanctuary zones, especially to the north of Winderabandi Point and adjacent to Coral Bay.

Geo-referenced data points indicating shore fishing were scaled to indicate the size of groups observed at Lighthouse Bay, Pilgramunna and Maud's Landing (Figure 7-8). Fishers were clustered around access tracks and camping areas. There was also substantial fishing activity from the shore observed in the special purpose (SBA) zones located adjacent to sanctuary zones at Lighthouse Bay (Figure 7-8a) and in Coral Bay (Figure 7-8c). No fishing was observed in Mandu Sanctuary zone located to the north of Pilgramunna.

7.4.4 Characteristics of recreational line fishers

Aerial and coastal surveys provided synoptic and fine-scale data on line fishing, while data from face-to-face interviews provided insights into the demographics and trip characteristics of the fishers. Of the 1,208 respondents, 328 (27.1%) cited line fishing as their main reason for visiting the NMP that day or were undertaking this activity at the time of interview. An additional 224 respondents had participated in line fishing at some time during their trip to the NMP (up until time of interview), but were not conducting this activity when interviewed.

The mean group size for boat-based fishers was 1.4 people ($SD = 1.1$ people), who were predominately adult males (76.7%), while for shore-based fishers the mean group size was 2.1 people ($SD = 1.1$ people), also predominantly adult males (68.9%). Mean time spent fishing was 3.5 hours ($SD = 1.6$ hours) for boat fishers, who were interviewed when they returned from a fishing trip, and 1.3 hours ($SD = 1.5$ hours) for shore fishers, who were interviewed while still fishing. Fishing at night had been undertaken by 56 of the 328 respondents during their current trip to the NMP.

7.4.5 Knowledge and effects of sanctuary zones

The location of the nearest sanctuary zone was correctly identified by 76.6% of the 328 respondents who were fishing at the time of interview. A further 17.1% of respondents did not know the location of the nearest sanctuary zone and the remaining 6.3% incorrectly identified its location. When asked if sanctuary zones had affected their fishing, 76.1% of interviewees responded in the negative, and the main reasons cited were that they could still fish from the shore, fished elsewhere or that there were still plenty of fishing options available outside sanctuary areas. Of the 24.1% of interviewees who indicated that sanctuary zones had affected

their fishing, the main reasons cited were not being able to fish at their preferred site and having to travel further to fish.

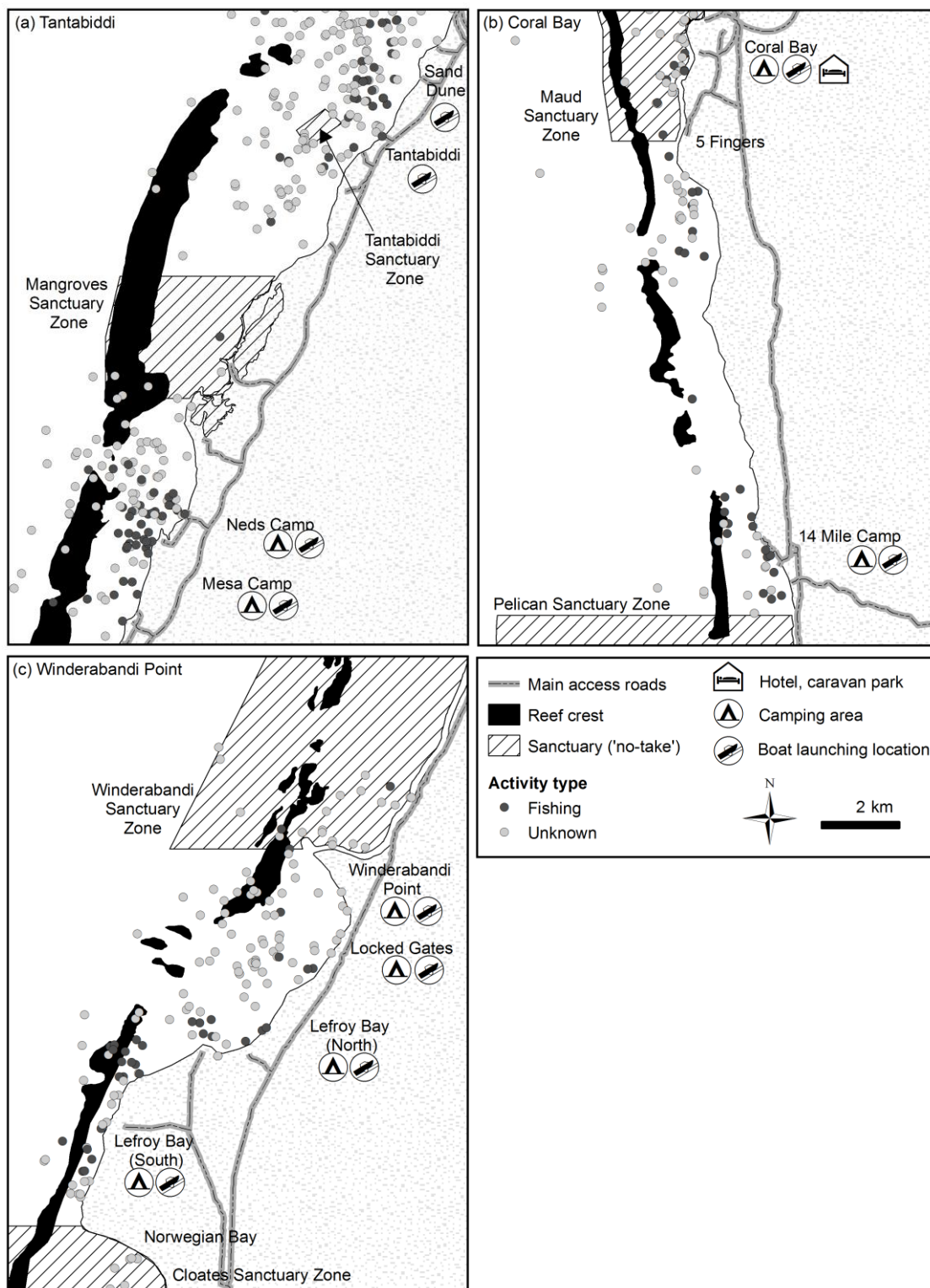


Figure 7-7. Spatially explicit data identifying boat-based fishing or participation in an unknown activity (possibly fishing) relative to sanctuary zones and the fringing reef crest at (a) Tantabiddi, (b) Coral Bay and (c) Winderabandi Point obtained during coastal surveys (number of surveys = 72).

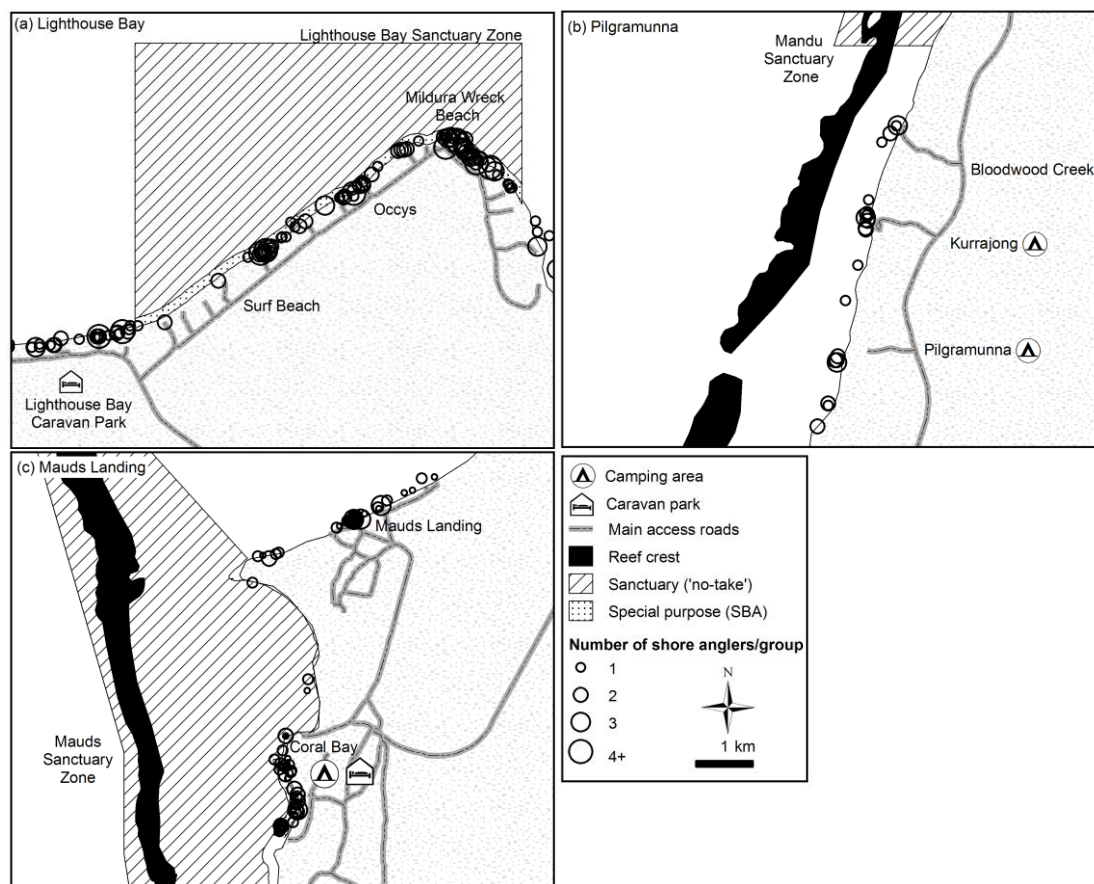


Figure 7-8. Spatially explicit data identifying shore-based fishing activity, sanctuary and special purpose (SBA) zones at (a) Lighthouse Bay, (b) Pilgramunna and (c) Mauds Landing obtained during coastal surveys (number of surveys = 72).

7.4.6 Species composition and catch per unit effort

There were insufficient data collected from <40 face-to-face interviews with boat-based fishers to adequately describe species composition and catch per unit effort, therefore these were only determined for those respondents engaged in shore fishing. A total of 39 fish species plus 20 general categories (identified to family level) were retained and/or released by respondents. The most frequently retained or released species from the shore were spangled emperor (*Lethrinus nebulosus*), chinaman cod (*Epinephelus rivulatus*), robust garfish (*Hemiramphus robustus*), golden trevally (*Gnathanodon speciosus*) and the common dart (*Trachinotus botla*). As an indicator of trip success, 48.2% of shore-based fishers had retained or released fish on the day of interview.

The mean overall catch per unit effort for shore-based fishers was 0.23 and 0.28 fish/person/hour for retained and released fish, respectively. The highest catch rates for retained fish were for robust garfish (*Hemiramphus robustus*) (4.8 fish/person/hour), golden-lined whiting (*Sillago analis*) (3.8 fish/person/hour), yellow-finned whiting (*Sillago schomburgkii*) (1.0 fish/person/hour) and western yellowfin bream (*Acanthopagrus latus*) (1.0 fish/person/hour) while for released fish it was unidentified wrasse (Labridae) species (3.0 fish/person/hour), stripey seaperch (*Lutjanus carponotatus*) (2.2 fish/person/hour), black-

spotted wrasse (*Austrolabrus maculatus*) (2.0 fish/person/hour) and tailor (*Pomatomus saltatrix*) (1.4 fish/person/hour).

7.5 Discussion

7.5.1 Survey design

Direct observation and face-to-face interviews have been widely developed for surveys of recreational fishing (Pollock et al., 1994; Lynch, 2006; Smallwood et al., 2006; Meyer, 2007) as well as broader recreation and tourism studies (Cessford and Muhar, 2003; Arnberger et al., 2005; Dalton et al., 2010). These techniques formed the basis of an integrated survey approach which obtained geo-referenced data on extractive use throughout the NMP. The different survey types each contributed to a comprehensive, and complementary, understanding of these activities which had additional benefits for improved sampling efficiency and cross-validation between datasets (Kemper et al., 2003; Vaske and Manning, 2008).

Relatively low levels of participation in extractive activities from boats and the shore were obtained during aerial and coastal surveys which cross-validates their findings, and supports either method for future monitoring. Aerial flights are a well-documented survey technique for rapid data collection over large areas and were enhanced by using GPS and electronic data storage to streamline information on position, altitude and bearing, which were required for analysis. Digital cameras provided a permanent record of observations for validation and were synchronised with all other electronic equipment. Distance estimation is one of the largest sources of error in aerial surveys (Pollock and Kendall, 1987) and was mitigated by using fixed geo-referenced locations at popular recreation sites as well as placing markers on wing struts, similar to Ottichilio and Khaemba (2001). A standardised 8 am departure for aerial flights was aimed at maximising counts of boating activity by avoiding the strong onshore afternoon seabreeze. Additional randomisation of start times and reversal of survey direction were incorporated into coastal surveys to improve coverage over the entire sampling frame. The slower coastal surveys used fixed geo-referenced locations to reduce distance errors and the observers were able to spend more time ascertaining the attributes associated with each group or object, thereby improving the likelihood of extractive activities, which are often difficult to identify, being correctly documented.

The high number of vessels with an unknown activity type observed during the current study needs to be considered, especially when previous studies using self-reported data from people launching or retrieving their boats found participation in fishing to be much higher. In 1997/98, surveys of 1,738 people at the four constructed boat ramps at Ningaloo found that 97% had participated in boat-based line fishing during their trip (Sumner et al., 2002). The concurrent roving creel survey interviewed 695 fishers who had launched directly off the beach at some point during their trip (Sumner et al., 2002). A more recent study (2006/07) of boaters departing Coral Bay revealed that fishing was intended as the main activity by 73% of respondents (Worley Parsons, 2006). Such results may indicate a decline in recreational fishing participation, a shift already suggested from longitudinal visitor surveys at Ningaloo (Wood and Dowling, 2002). However, even with the suggested decline, comparison with these other studies indicates that vessels with an unknown activity type were likely to have been participating in recreational fishing.

Face-to-face interviews with recreational participants revealed much higher levels of participation in extractive activities when compared to observation surveys, especially for

boaters, although the sample size was small. The roving nature of the coastal surveys, during which the face-to-face interviews were completed, resulted in a higher likelihood of intercepting respondents conducting sedentary activities such as shore angling. It also decreased the likelihood of intercepting respondents participating in activities such as fishing from boats, who spent most time on the water. A similar effect was experienced by Sumner et al. (2002) who only intercepted 1.7% of 695 boat fishers as they actually returned from a boating trip to a beach launching location. The level of participation in extractive use from boats obtained from interviews in the current study was 64.3%, almost as high as that obtained from previous research (Sumner et al., 2002; Worley Parsons, 2006). However, data from those interviews were self-reported, and although they recorded less vessels with an unknown activity type, they had less spatial resolution (i.e. 5 x 5 nm grid blocks) when identifying fishing locations.

7.5.2 Spatial and temporal patterns of extractive use

Recreational line fishing at Ningaloo displayed heterogeneity across temporal and spatial scales. Aerial surveys identified clear seasonal variations, with greater densities and wider spatial distribution throughout the NMP during autumn and winter, especially within the sheltered lagoon environment. These seasons experience increased visitor numbers as people generally avoid the high temperatures and cyclones which occur during the remainder of the year (BOM, 2009). However, fishing from boats and the shore was also observed outside peak periods and should be incorporated into monitoring, compliance and educational activities.

Data from coastal surveys revealed that shore-based fishers were generally clustered around camping areas and access points thereby identifying sites which can be targeted for compliance and educational activities by management staff through direct contact or signage. Numerous access points within Lighthouse Bay enabled shore-based anglers to easily fish along this entire section of coastline while, at Pilgramunna, little activity occurred distant from the limited number of access points. Clustering of recreational fishing around beach access points has been documented adjacent to a highly populated area in Hawaii (Meyer, 2007) while isolated areas with limited accesses, such as at Ningaloo, are also likely to have higher dependence on road and track networks (Coombes et al., 2009).

The highest concentrations of fishing vessels were evident around boat launching locations and inside the fringing reef crest, especially at Tantabiddi and Neds Camp. This pattern reflects known behaviour of recreational boaters, who select a launch location based on its close proximity to a favourite locale (Sidman et al., 2004). It also reflects the lack of safe passages from which vessels can access the open ocean, except around North-West Cape where the fringing reef crest dissipates. The concentration of vessels inside the reef crest may be an artefact of survey biases, if the observers could not adequately see outside the reef crest (i.e. obscured by breaking waves). Analysis of all data points indicated there was coverage of vessels outside the sheltered lagoon environment, comprising 29.6% and 15.2% of vessels observed during aerial and coastal surveys, respectively (Smallwood, 2009). Aerial surveys also provided good visibility over the reef crest while vantage points for coastal surveys were selected for their good field of view, including height above sea level. However, the strength of these geo-referenced data is their high resolution within the lagoon environment, while self-reported data from recreational fishers or charter operators provide coarse resolution further offshore, outside the NMP (state) waters.

No line fishing was observed in several areas of the NMP, such as Jane Bay, Pelican Point and Cape Farquhar (boat fishers) and to the north of Gnaraloo Bay (shore fishers). North of

Gnaraloo Bay is a general use zone and the lack of shore fishing activity can be attributed to the restricted public access along this part of the Ningaloo coast by means of a locked gate on the pastoral station (WAPC, 2004). The implications of restricted public access and remoteness from infrastructure on extractive activities are considerable, as it offers protection to these areas from extractive activities, even though they may be zoned as general use or recreation. Such natural spatial refugia for targeted species are becoming more rare with improved technology and systematic depletion of accessible stocks (Dayton et al., 2000).

Geo-referenced data points obtained from coastal surveys identified that line fishing occurring from vessels and by people on the shore was located primarily in general use, recreation and special purpose (SBA) zones. Non-compliance (fishing in sanctuary zones) was observed for 12.0% of vessels and 2.1% of people on the shore. The scenario including vessels both fishing and with unknown activity increased non-compliance up to 19.3%. These findings have implications for management strategies at Ningaloo and in marine parks across Western Australia, and for biodiversity conservation in these areas. The benefits of sanctuary areas for increasing biomass, abundance and size of exploited species have been recognised worldwide (McClanahan et al., 1999; Roberts et al., 2001; Galal et al., 2002; Barrett et al., 2007). However, non-compliance is often not considered (Kritzer, 2004; Sethi and Hilborn, 2008) and these benefits may be compromised if poaching occurs (Roberts, 2000; Maliao et al., 2004; Guidetti, 2006; Byers and Noonburg, 2007). It is therefore important to monitor non-compliance and adjust enforcement, and other management strategies, to ensure marine parks meet their stated objectives.

Vessels and people who were compliant with sanctuary zones while participating in extractive recreational use may have been spatially displaced by the implementation of these zones throughout the NMP. This displacement is difficult to determine from observational data due to this study being completed after the implementation of current zoning strategy in late 2004. However, interviews with recreational participants in the current study revealed that sanctuary zones had affected fishing within the Marine Park for only 24.1% of respondents. Currently, there are no temporal restrictions for recreationally targeted species in the Ningaloo region, except for western rock lobster (DoF, 2009b). Resource or activity substitution is another type of displacement and further investigation into the behaviour of recreational fishers would be required to determine if this had occurred.

7.5.3 Linking research findings to management

The need for current, comprehensive and reliable spatial information on human elements in marine environments to inform decision making, is widely accepted (Canessa et al., 2007; Dalton et al., 2010). Observation is often used as a method to collect data on extractive recreational use, although few ascertain the level of participation when compared to non-extractive activities. This may hinder the implementation of effective management initiatives if a complete understanding of anthropogenic activities is not developed (Pomeroy et al., 2004; St. Martin and Hall-Arber, 2008). The current study at Ningaloo provided geo-referenced data on the level of participation and patterns of extractive use during a 12-month study to fill this knowledge gap and provide information to assist generic management strategies (i.e. enforcement, education and monitoring) applied in marine parks across Western Australia.

Non-compliance in sanctuary zones within the NMP, and other marine parks, can be addressed through enforcement and education. Recent research has identified that significant investment in enforcement within sanctuary areas is necessary to maintain the fishery benefits of this management tool (Guidetti et al., 2008). Agency collaboration will also reduce issues

associated with inter-jurisdictional and multi-agency management which affect many marine parks worldwide (Dayton et al., 2000).

The aim of educating visitors is to ensure voluntary compliance and support for management measures (MacLennan, 2000), such as zoning and fisheries controls (i.e. bag limits). Examples include placing signage at access points to sanctuary areas and distributing brochures containing geographical co-ordinates to locate offshore zone boundaries using GPS devices from vessels. Communicating findings from research to the community is also essential to develop support for current and future zoning strategies, as traditionally there has been significant opposition to the implementation of such areas, particularly in Australia (McPhee et al., 2002).

Monitoring is required to determine if management strategies have been effective in reducing non-compliance. Such monitoring may consist of analysis of the number of infringements issued over a selected period within a marine park based on the number of hours invested in enforcement or time spent on education. However, ongoing monitoring will also provide an indication of level of non-compliance. Aerial flights enable rapid data collection over a large area, while coastal surveys can be targeted at specific locations regularly visited by agency staff. These data can be used to determine the level of participation in extractive recreational activities but also select specific locations for targeted surveillance or enforcement. Although line fishing was the dominant extractive activity in the NMP, participation in other extractive uses are also important to monitor for changes in spatial extent and density, which may require management attention if participation levels increase. Collecting fine-scale data is also beneficial as analysis can be adapted to suit management requirements, as demonstrated by the different representations of data collected during aerial and coastal surveys.

Coastal regions have the highest concentration of human activity and are likely to experience strong growth for the foreseeable future (O'Mahony et al., 2009). The challenge for managers to minimise non-compliance will continue, especially with recent research concluding that visitors to a marine park in the Mediterranean (rather than residents of the surrounding catchment) were less aware of zoning regulations and associated penalties (Karamanlidis et al., 2004). Other issues that arise from this study are the likelihood of achieving 100% compliance given the isolation and high costs of patrolling remote sanctuary areas, especially as ecosystem studies are documenting benefits (i.e. increased fish abundance and biomass) when compared to non-sanctuary areas (Westera et al., 2003; Babcock et al., 2008). Furthermore, research in the Great Barrier Reef found enforcement in isolated offshore sanctuary areas was less effective than in those located in close proximity to the coast and populations centres (Davis et al., 2004). A holistic approach to MPA management also needs to consider non-extractive activities, such as boating, snorkelling and reef walking, as they also have well documented impacts on ecosystems and maintenance of biodiversity (Allison, 1996; Halpern et al., 2008; Leujak and Ormond, 2008; Lloret et al., 2008).

The remoteness of the Ningaloo Marine Park from major population centres has restricted the number of visitors, while the limited infrastructure along the coast has hindered access to those pursuing extractive activities, providing natural spatial refugia for targeted species. However, a growing population and increasing publicity is resulting in increased visitor numbers and development pressure which is highly likely to alter these use patterns. This study has highlighted the benefits of collecting fine-scale data to better understand the distribution and density of fishers as well as compliance with zoning measures. Aerial surveys provided a synoptic overview of activities, although there was a high proportion of unknown activities, while coastal surveys provided a good opportunity to observe activity and also interview people

and cross-validate findings. Such approaches are applicable to monitoring in marine parks worldwide and can provide linkages with biological datasets while providing a basis for evaluating management effectiveness.

7.6 Acknowledgements

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8. TRAVEL NETWORKS RELATED TO RECREATIONAL USE OF NINGALOO MARINE PARK, NORTH-WESTERN AUSTRALIA

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8.1 Summary

This study quantified the distance travelled by people to participate in recreation in Ningaloo Marine Park. The analyses showed there was spatial variability in the distances travelled by interviewees along a road network for recreation between various parts of the Marine Park. These patterns were influenced by attributes such as demographics, length of stay and repeat visitation. Visitors were highly clustered around beach access points, clearly identifying areas which are more likely to be exposed to high levels of shore-based recreational pressure such as at Lighthouse Bay, Turquoise Bay and Coral Bay. Such areas could also be identified for boat-based recreation which, although more dispersed throughout the Marine Park, had highest concentrations around North-West Cape and Coral Bay. The distribution of these motorised vessels was linked with attributes such as boat length and the location of the fringing reef crest.

8.2 Introduction

The patterns of movement of tourists between destinations, and their spatial relationships, can be complex (Holt and Kearsley, 1998). Not only are there different itinerary types (McKercher and Lau, 2008), but these relationships are influenced by the location of recreational resources (Leung and Marion, 1998), diversity of user characteristics and motivations (Flognfeldt, 1992; McKercher and Lew, 2004) as well as infrastructure, access and distance decay. Distance decay is based on the assumption that activities and attractions exhibit decreasing interaction with increasing distance from origin (McKercher and Lew, 2003). However, actual decay curves may feature a plateau, resulting from a limited number of tourism opportunities along a linear route, or a secondary peak caused by distant destinations strongly attracting visitors.

An understanding of demographics, visit attributes and activity patterns of recreational participants in the Ningaloo Marine Park (NMP) in north-western Australia is important for implementing appropriate management and planning practices. An appreciation of visitor flows is also relevant as this information can be utilised to redirect, concentrate or disperse visitor use to minimise impacts (McVetty, 2002), forecast future changes to visitor movements (Higham et al., 1996) or influence decision making with respect to infrastructure and transport development (Cole and Daniel, 2003; McKercher and Lew, 2004). These data can also be combined with spatial datasets, such as zoning boundaries, habitats or other natural characteristics, to enhance the quality of any management outputs (Kopperoinen et al., 2004).

Several conceptual models have been developed to describe various itineraries and visitor flow patterns (Campbell, 1966; Matley, 1976; Mings and McHugh, 1992; Lew and McKercher, 2002). McKercher and Lew (2004) summarised itinerary types into four main categories. The first type comprises those with a single destination, which may or may not involve side trips. The second type involves a transit leg to a destination area, after which the visitor conducts a circle tour, undertaking activities and stopping overnight at different places. The third type is a circle tour from which multiple side trips, overnight stays and recreational day trips can be incorporated. The fourth is a hub-and-spoke type, for which recreational (day) trips are the main element of the journey, forming a radial pattern from a destination area. This pattern is likely to be one of the most commonly exhibited patterns at Ningaloo with visitors, as well as residents of Exmouth and Coral Bay, travelling to (or within) the Marine Park on day trips.

Investigating the intra-regional movement of people once they have arrived at a destination area can provide additional insights into visitor behaviour (Murphy and Keller, 1990; Kramer and Roth, 2002; O'Conner et al., 2005; Gimblett et al., 2007; McKercher and Lau, 2008). Pearce and Kirk (1986) originally linked the tourism system with various coastal components by describing visitors as moving between the hinterland (accommodation and service areas), transit zone (coastal interface) and recreational activity zone (coastal and marine environment). Ningaloo Marine Park (NMP) not only fits well within these frameworks for both inter- and intra-regional movement patterns but also offers a unique perspective as it is an isolated attraction, not adjacent to any large population centre, with limited coastal access restricting interactions with people visiting from nearby destinations.

Collecting data on intra-regional movement patterns can be challenging because of potentially large numbers of people, unconstrained choices and the need for accurate tracking of movements without affecting normal behaviour (O'Conner et al., 2005). Mapping techniques, whereby an interviewee traces their travel routes along roads or waterways, which are then digitised into a Geographic Information System (GIS) framework, have been applied widely in North America using mail and on-site survey approaches (Falk and Gerner, 2002; Sidman et al., 2004; Sidman et al., 2006; Gimblett et al., 2007). It is also possible to collect information on travel routes without maps by using face-to-face interviews to gather data on destinations visited and exit and entry points (Murphy and Keller, 1990; Tideswell and Faulkner, 1999). Techniques such as aerial surveys (Deuell and Lillesand, 1982), image recording (Sacchi et al., 2001) and GPS tracking devices on both land (O'Conner et al., 2005) and water (Deng et al., 2005; Pelot and Wu, 2007) have been used to document movement patterns. Secondary datasets from external sources, such as traffic counters, may also prove useful.

Information required from travellers' itineraries to investigate visitor flows includes data on entry and exit points to the destination region, associated arrival and departure times, length of stay and location of places of recreation and time spent at each (Cole, 2005a; Gimblett et al., 2007). This information also meets some of the requirements for gravity models (Leung et al., 2006) or programmes such as RBSim which allow managers to improve planning and development by simulating movement patterns (Itami et al., 2000; O'Conner et al., 2005; Gimblett et al., 2007). The recreation modelling environment is currently restricted to movement along a linear travel network (such as roads, trails or rivers), so its application to

boat-based recreational activity in the marine environment (where the travel network is diffuse) is not likely to be appropriate.

Although travel to and from a boat launching site can be described using road networks, once on the water, the most effective way to define the distribution of boaters is to identify areas where vessels are more likely to travel, as the decision process is affected by attributes such as navigation aids, shoreline morphology and bathymetry (Sidman and Flamm, 2001; Sidman et al., 2004). This type of analysis lends itself to raster or grid-based techniques such as trend surface analysis. When combined with these spatial features a representative boating network may be developed based on information digitised from respondents, including departure locations, destinations and travel routes (Pelot et al., 2004; Sidman and Fik, 2005). As with land-based travel routes, being able to determine the movement patterns of boats assists with modelling, evaluating management strategies and determining likely areas of impact from the activities associated with these boats.

Currently, no data exist on visitor flows or movement patterns of people participating in recreational activities within NMP. Although access points and infrastructure are known to influence the distribution of visitors (Holt and Kearsley, 1998; Coombes et al., 2009) there are few studies that quantify travel distance or dispersion between different coastal components (e.g., from an accommodation location to a beach access point) or within a marine park (e.g., from boat launching site to recreation location). These could be highly specific to a study area but would provide useful data to support management decisions (Zhang et al., 1999).

The main aim of this study was to investigate the movement patterns and geographic range of people participating in shore-based and boat-based recreational activities throughout NMP. This was achieved by identifying and quantifying the travel networks of recreational participants as they dispersed by vehicle from accommodation to beach access points or boat launching sites, by foot from beach access points to recreation locations or by boat from launching sites to offshore recreation locations.

8.3 Methods

Face-to-face interviews were conducted with people participating in recreational activities along the shore of the NMP during a 12-month period from January – December 2007 and were purposively selected using quota-based sampling (Smallwood 2009). The geographic location of the respondent as well as where he/she had accessed the beach were recorded as well as the location of their accommodation the previous night. Respondents were also asked to identify the major road used to reach their accommodation and the reason why they stayed at their particular accommodation site.

There are nine main access roads from which to enter or exit coastal regions adjacent to the NMP (Figure 8-1). From these, there exist many subsidiary roads and tracks from which recreation and camping areas can be accessed. These were mapped during fieldwork using a data logger and imported into ArcGIS 9.3 where attributes such as road type, road surface and length (km) were added. In total, 1 007 km of roads and tracks were mapped along the coastline

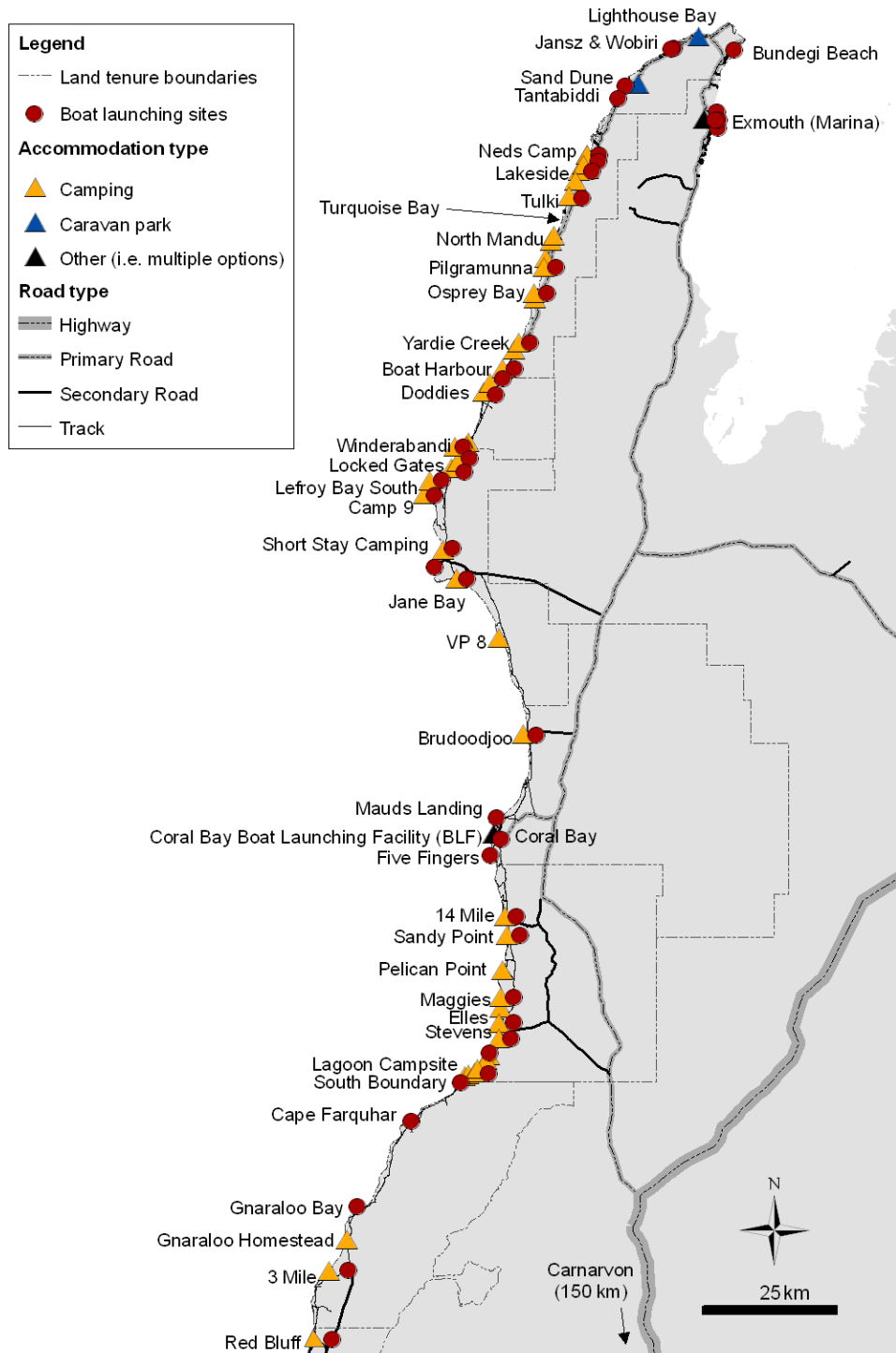


Figure 8-1. Location of main access roads [classification adapted from ICSM (2006)], accommodation and boat launching sites situated adjacent to Ningaloo Marine Park, north-western Australia.

adjacent to the NMP and they were classified according to their function, level of traffic and surface type (Table 8-1).

Table 8-1 Road type classification at Ningaloo as an attribute for network analysis [adapted from ICSM (2006) and WAPC (2004)]. Note: Speed reflects official speed limits and * indicates value derived during fieldwork.

Road type	Description	Speed (km/hr)
Highway	Major connecting roads between cities and towns which are the principal avenue for high volume traffic (i.e. North-West coastal highway). Sealed.	110
Main road	Distributes traffic between highways and are principal avenues for mass traffic movement. Split into primary roads (sealed) and secondary roads (gravel).	40 – 80
Track	Unimproved vehicular road of minimal construction connecting other roads or leading to a feature. Sand or gravel.	40*
Beach	No fixed road, vehicle travels along a sandy beach if tides permit. Sand.	20*

Beach access points were defined as any location or track at which an individual could gain access to the beach on foot or by vehicle and such points generally originated at the end point of a road (i.e. path leading from a car park). The 336 beach access points recorded during the survey were dominated by designated car parks and sand or gravel tracks which were developed either formally (by management) or informally (by users). This distinction was the basis for a classification of beach access types at Ningaloo which was adapted from Leung and Marion (1998) (Figure 8-2. Number, and description, of formal and informal beach access locations recorded during the survey [adapted from Leung and Marion (1998)], as well as fixed and non-fixed beach access locations along the Ningaloo coast.). Two additional beach access types entitled ‘formal (marine)’ and ‘non-fixed’ were also identified. Formal (marine) locations are similar to formal accesses in that they are structures constructed with management approval, extend into the marine environment and are used to access the water for recreational activities (i.e. boat ramps or jetties used for fishing). Non-fixed locations are movable features, such as campsites and vehicles from which respondents are able to directly access the beach for recreation. This category was created because of the proliferation of camping or driving directly onto the beach in many sections of the Ningaloo coast. Beach access points were all geo-referenced during fieldwork and, together with the geo-referenced interview location, were used to determine the distribution of people participating in shore-based recreation.

Accommodation was distributed at 87 locations along the coastal strip adjacent to the NMP and in nearby service centres such as Exmouth and Coral Bay. Seven generic accommodation categories included coastal camping, caravan parks, hotels, chalet/self-contained units, backpackers, safari tents and private residences. The service centres had several different accommodation options available to visitors and these were aggregated so that all respondents staying in these locations were considered to be travelling from the same central geographic reference point (i.e. the 15 accommodation options in Exmouth were combined to a single location). In total, accommodation locations were condensed into 56 locations (comprising all accommodation types). Although the majority of coastal camping areas were demarcated at some level (such as an informal sign erected by pastoral leaseholder), because of the

undeveloped nature of large tracts of the coast, some camping did occur at other locations and these locations were individually geo-referenced during surveys.









Track type (n)	Description
Formal (56)	Roads and tracks created by management using some form of demarcation, normally bitumen or compacted gravel. <div style="display: flex; justify-content: space-around; margin-top: 10px;">   </div>
Informal (67)	Tracks, with no camping at the endpoint, which were created and perpetuated by uncontrolled and unmanaged visitor use. <div style="display: flex; justify-content: space-around; margin-top: 10px;">   </div>
Formal (marine) (4)	A fixed access location such as jetty or constructed boat ramp which extends partway into the water, i.e. Bundegi Jetty, Coral Bay Boat Ramp, Exmouth Marina. <div style="display: flex; justify-content: space-around; margin-top: 10px;">   </div>
Non-fixed (209)	A non-fixed location such as campsite or car from where interviewees could directly access the beach. <div style="display: flex; justify-content: space-around; margin-top: 10px;">   </div>

Figure 8-2. Number, and description, of formal and informal beach access locations recorded during the survey [adapted from Leung and Marion (1998)], as well as fixed and non-fixed beach access locations along the Ningaloo coast.

During the study, 45 places were recorded where vessels could be launched. These were mostly beaches with no constructed facilities but also included four constructed boat ramps at Exmouth Marina, Bundegi, Tantabiddi and Coral Bay Boat Launching Facility (BLF). The Coral Bay BLF was completed partway through the survey with boats launching directly off the beach adjacent to the townsite of Coral Bay prior to October 2007.

In addition to questions about access points, accommodation and roads used, interviewees using boats were asked questions relating to their boat type and characteristics (length, engine size and fuel tank capacity) as well as the furthest distance travelled from their primary launch location. They were able to answer this question by providing a destination name (number of respondents = 73), a travel direction and distance (number of respondents = 82) or a travel radius (number of respondents = 51). These data were standardised to travel radius (km) and imported into ArcGIS 9.3 where a circular polygon (with the launch location as the central point) was derived based on this distance. Respondents also indicated whether or not they had remained inside the sheltered lagoon environment during their boating trips. The distance respondents travelled from accommodation to the launch location was also calculated.

Network analysis was used to determine the distance travelled from accommodation to beach access point or accommodation to boat launching site. This type of analysis is constrained to linear networks, such as roads, which can be described as a series of connected links that are terminated or joined by nodes (Leung and Marion, 1998; Cole, 2005a). These links and nodes can be assigned attributes, such as road length, road surface type or type of facility (day use recreation sites, overnight accommodation, shopping facilities and attractions). In this study, road length (km) was used as the primary attribute, thereby identifying the shortest route in terms of distance between two locations. Time (minutes) was a secondary attribute based on the speed limit for gazetted roads and speeds averaged from track logs collected during fieldwork for non-gazetted roads. Barriers were also used to indicate roads that could not be used due to road closures or limited access (i.e. authorised personnel only). The distance travelled by following the road network between accommodation, beach access points and boat launching sites was determined using ArcGIS 9.3 with Network Analyst Extension.

Network analysis was also used to calculate the distance travelled from a beach access point to shore recreation location and network distance calculated from the Mean High Water Mark (MHW) was selected as the most appropriate as it could accommodate convoluted sections of the coast. The final analysis of shore activity was to overlay the travel routes from beach access points to shore recreation locations to identify which areas were most likely to be exposed to high pressures from recreational use in off-peak and peak periods.

Travel routes for boats from a launching site to a recreation location could not be calculated using network analysis as vessel movements are not restricted to linear features. A raster-based technique was thus applied using information collected during interviews. The maximum possible distribution of each vessel was calculated as a polygon based on the radius travelled from their primary launch location. These polygons were overlaid by a 1 km² grid to determine areas where vessels were likely to occur, similarly to the method applied by Ward-Geiger et al. (2005) in North America.

Data on accommodation locations, beach access points and interview locations comprised geographic co-ordinates stored in an Access database, which were linked to ArcGIS 9.3. The analysis of these data sources used the distances calculated for each interview (i.e. via road from accommodation to a beach access point) as the dependent variable and independent variables such as length of stay, group type, boat length and origin to test this effect on distance travelled. Analysis of Variance (ANOVA) was used for these analyses and, where necessary, a square root transformation was used to correct for non-normality. In situations with multiple factor levels, *post-hoc* tests were used to identify those responsible for these effects.

8.4 Results

8.4.1 Accommodation to beach access points

Of the 336 beach access points documented during the survey, 321 were used by respondents to access the shoreline. Formal tracks were the dominant track type, used by 56.9% of respondents, and were most common around North-West Cape (NWC) and in Cape Range National Park (CRNP). Informal tracks were also abundant at NWC and CRNP, as well on Gnarlou and Quobba Stations (GN/Q) (Figure 8-3). Coral Bay (CB) had <10 beach access points which were all categorised as formal. Formal (marine) locations were only in NWC and on Cardabia Station (CS) and were used by 5.9% of respondents while the remaining 17.6% accessed the beach directly from a campsite or vehicle (non-fixed). These non-fixed locations were mostly on pastoral leases, particularly Warroora Station (WS), Ningaloo Station and Department of Defence land (NS/DoD) due to the wide availability of camping on the beach.

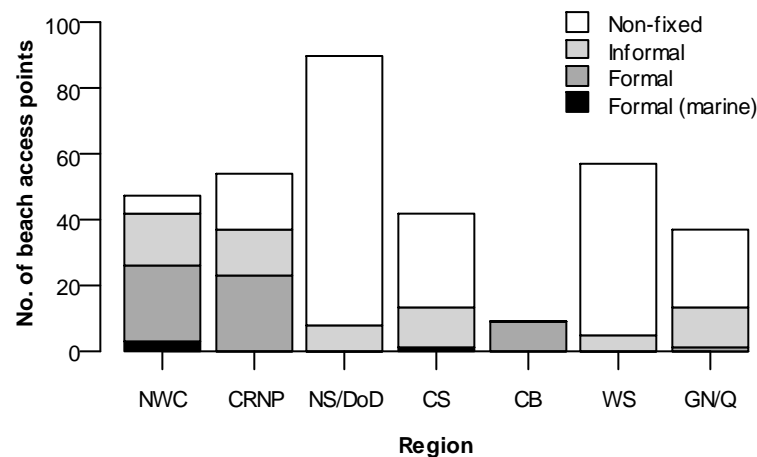


Figure 8-3. Number and type of beach access points within each region of the Ningaloo Marine Park (number of beach access points = 336).

There were 237 different pathways between 48 accommodation locations and 103 beaches (with 321 access points) documented during the survey which highlighted several trends in the distribution of respondents (Figure 8-4). Those staying in the northern part of the NMP (in Exmouth and NWC) dispersed to a wider number of beach access points (47 and 40,

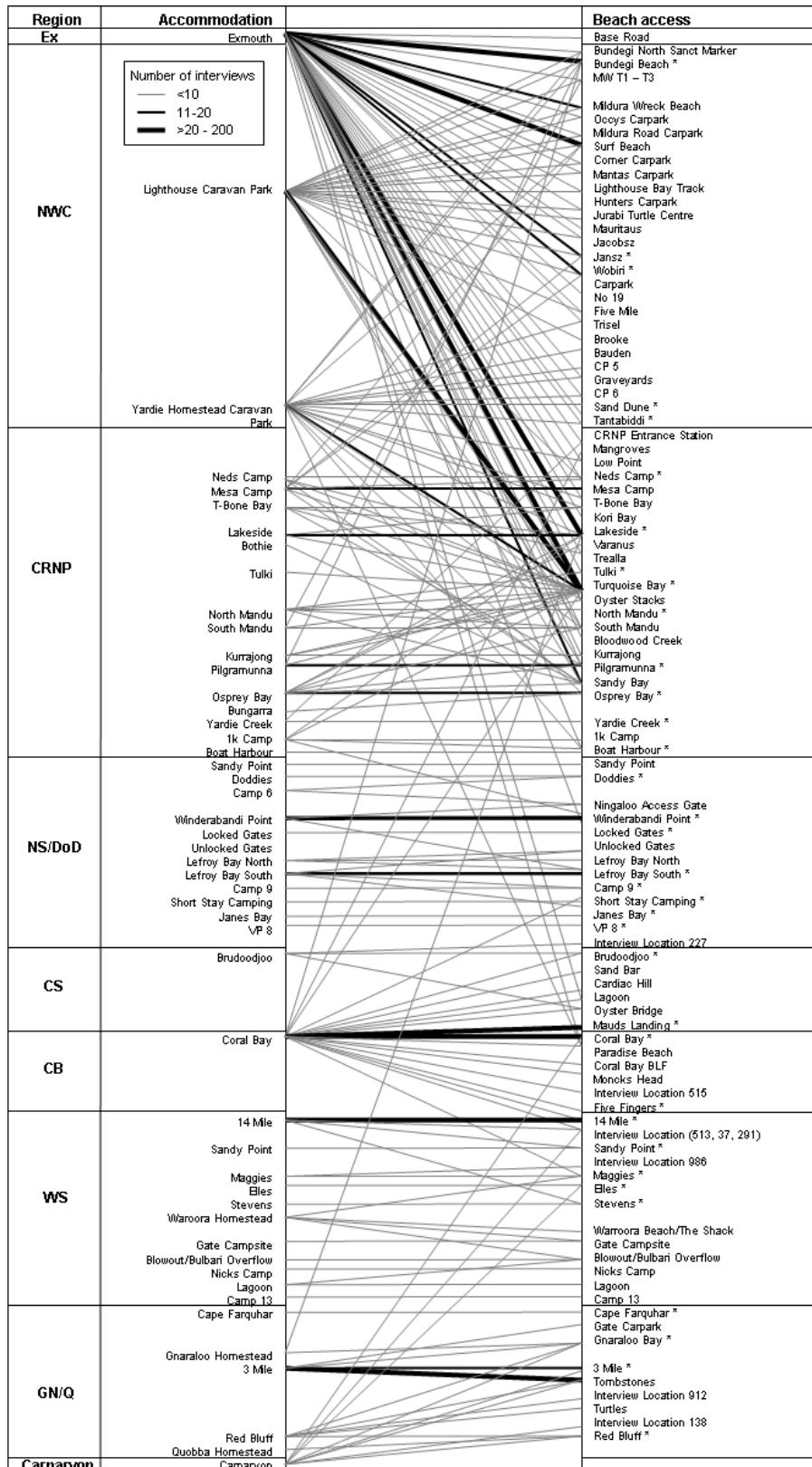


Figure 8-4. Travel flows and their frequency between accommodation and beach access points for interviewees on their current trip to Ningaloo Marine Park (number of interviews = 1 188). Note: * indicates shown in Figure 8-2

respectively) when compared to those staying in the south. From the northern regions the most frequently visited beaches were Bundegi and Surf Beaches, Lakeside and Turquoise Bay. The only exception in the southern part of the NMP was Coral Bay, with respondents travelling to 20 different beach access points, the most popular being Coral Bay and Maud's Landing. The highest number of beach access points used from an accommodation area on a pastoral lease was five at 14 Mile (WS) and Red Bluff (Q).

Travel flows between accommodation and beach access points were utilised differently by residents, repeat visitors and first time visitors to the NMP. Residents were interviewed in the greatest numbers at Jansz, Wobiri, Bundegi and Surf Beaches located along NWC, which is the closest region to the service centre of Exmouth. Interestingly, Bundegi Beach, Turquoise Bay and Coral Bay were frequented by a similar number of first time and repeat visitors. Tombstones (located to the south of 3 Mile on Gnaraloo Station) and Surf Beach (located within Lighthouse Bay) were popular for repeat visitors while Lakeside, a well advertised location in CRNP, was frequented by first time visitors.

At the time of interview, 66.5% of respondents had travelled away from their accommodation location for shore recreation. The remaining 33.5% of respondents were more sedentary when choosing a site for shore recreation, particularly in the southern regions of the NMP. There were 16 accommodation areas from which, at the time of interview, no respondent had travelled away from to undertake recreation. All but one of these locations (Boat Harbour in the southern CRNP) were situated on NS/DoD (Locked Gates, Jane's Bay and Doddies) and WS (Steven's, Elle's and Maggies).

The distance travelled by an interviewee along the road network between accommodation and beach access point was calculated to be a median of 6.8 km (SD = 25.2 km) with a maximum distance of 192.7 km (Figure 8-5). In terms of travel duration (which takes into account speed limits associated with road quality), this equated to a median trip of 7.8 minutes (SD = 18.2 minutes) by vehicle. The distribution had a strong positive skew towards interviewees travelling < 20 km with subsequent exponential decline with increasing distance, although a secondary peak was evident at ~70 km (Figure 8-6). The mean distances of these pathways for each NMP region were significantly different (assuming unequal variances, $F(1, 1153) = 192.84$, $p < 0.05$). Visitors from Carnarvon and Exmouth travelled a mean distance of 90.9 km and 40.7 km, respectively, compared to <3 km travelled by visitors staying at NS/DoD, CS and WS.

The calculation of distance travelled between accommodation and beach access location via a road network also permitted further investigation with respect to user characteristics. There were significant differences between distances travelled by first time and repeat visitors (assuming non-equal variances, $F(1, 1160) = 15.83$, $p < 0.05$). First time visitors travelled further ($\bar{x} = 22.3$ km) than those who had visited previously ($\bar{x} = 16.4$ km). The effects of visitor origin on distance travelled to a beach access location were also significant (assuming non-equal variances, $F(4, 1157) = 6.53$, $p < 0.05$). *Post-hoc* testing revealed longer distances were

travelled by international visitors ($\bar{x} = 23.6$ km) and residents ($\bar{x} = 23.3$ km) when compared to intra-state visitors from Perth ($\bar{x} = 17.0$ km) and regional WA ($\bar{x} = 13.9$ km). Univariate analysis of variances showed there was no interactive effect between these two variables of visitor origin and first trip to the NMP ($F(1, 4) = 1.44, \rho > 0.05$).

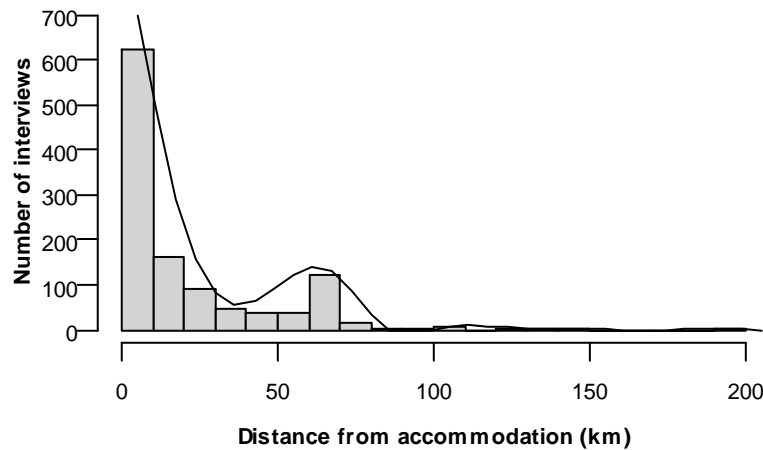


Figure 8-5. Distance travelled by road from accommodation to beach access point by interviewees in Ningaloo Marine Park with an interpolated spline representing the distance decay curve (number of interviews = 1 163).

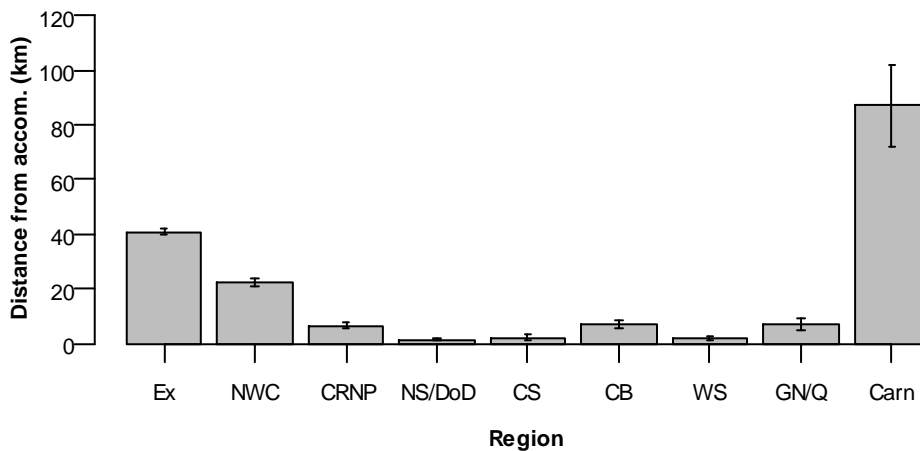


Figure 8-6. Mean distance travelled from accommodation to beach access points for respondents in each coastal region of the Ningaloo Marine Park ($\pm 95\%$ CI) (number of interviews = 1 163).

Type of tourist group was significant when compared to the distance travelled to a beach access point (assuming non-equal variances, $F(1, 1156) = 9.23, \rho < 0.05$). A Games-Howell *post-hoc* test showed respondents travelling on their own produce significantly different results from other group types at the 0.05 level. Individuals travelled a mean distance of 8.9 km, the shortest distance of any group type, while commercial tours and school groups travelled the greatest mean distance ($\bar{x} = 34.8$ km).

There was a significant difference between the distance travelled to a beach access point when compared to length of stay (assuming unequal variances, $F(1, 1056) = 6.77, \rho < 0.05$). *Post-hoc*

testing identified interviewees staying for 1-3 days ($\bar{x} = 24.5$ km) travelled greater distances than those staying longer. Residents on day trips were excluded from this length of stay analysis, however, their mean distance travelled was 29.2 km, which was greater than that for visitors ($\bar{x} = 18.4$ km) or residents on extended stays in the Marine Park ($\bar{x} = 4.8$ km).

The main activity for which respondents visited the beach with respect to distance travelled was also significantly different (assuming unequal variances, $F(17, 1143) = 11.79, p < 0.05$). *Post-hoc* testing identified that significantly greater distances were travelled by visitors participating in snorkelling ($\bar{x} = 32.4$ km), wildlife viewing ($\bar{x} = 27.4$ km) and sightseeing/spectating ($\bar{x} = 27.1$ km) than other activities.

Interviewees were asked to identify the furthest location for shore recreation to which they had travelled from their accommodation. From the 48 accommodation locations there were 123 sites recorded as furthest places travelled to by respondents. Sites were matched against the location at which the interview took place and revealed that 38.0% of respondents were at their furthest travelled beach access point, of which 15.7% were also at their place of accommodation. The median furthest distance travelled was 18.9 km (SD = 31.7 km). There was a strong positive skew towards visitors who had not travelled far from their accommodation for recreation and an exponential decline in people travelling greater distances was evident (Figure 8-7). A secondary peak was still evident at ~70 km from accommodation.

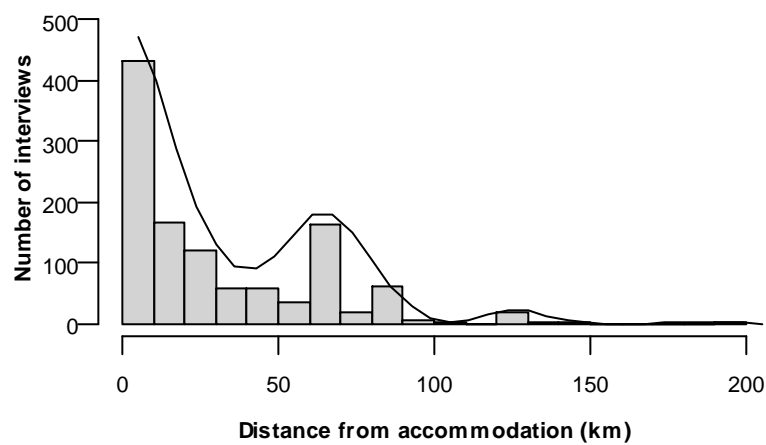


Figure 8-7. Distribution of furthest distance travelled from accommodation during a trip to Ningaloo Marine Park (number of interviews = 1 163).

8.4.2 Accommodation to boat launching site

There were 308 respondents who had brought a boat with them on their trip to the NMP, of which 293 were motorised vessels and 15 were kayaks. Data on motorised vessel length (m), engine (hp) and fuel tank size (L) showed strong positive correlations between each of the variables with correlation coefficients of 0.79 – 0.87 (Figure 8-8). The majority of vessels were 3 - 4 m in length with engines <50 hp and fuel tanks <50 L in size.

There were 59 different pathways documented from accommodation to launch site for the 267 motorised vessels which had been launched by respondents at the time of interview (Figure 8-9). The 41 respondents who had not yet launched their boats were excluded from this analysis. Of the 45 boat launch sites located between Red Bluff and the Exmouth Marina, 30 were used by respondents on their current trip. The majority of respondents (83.0%) launched their vessels at only one site, with four the maximum number of sites used during a trip to the NMP (by 1.8% of respondents). At the time of interview, 58.1% of respondents had not travelled away from their accommodation location to launch their vessels. As with shore recreation, this trend was strongest in the southern regions of the NMP (i.e. to the south of Yardie Creek in CRNP).

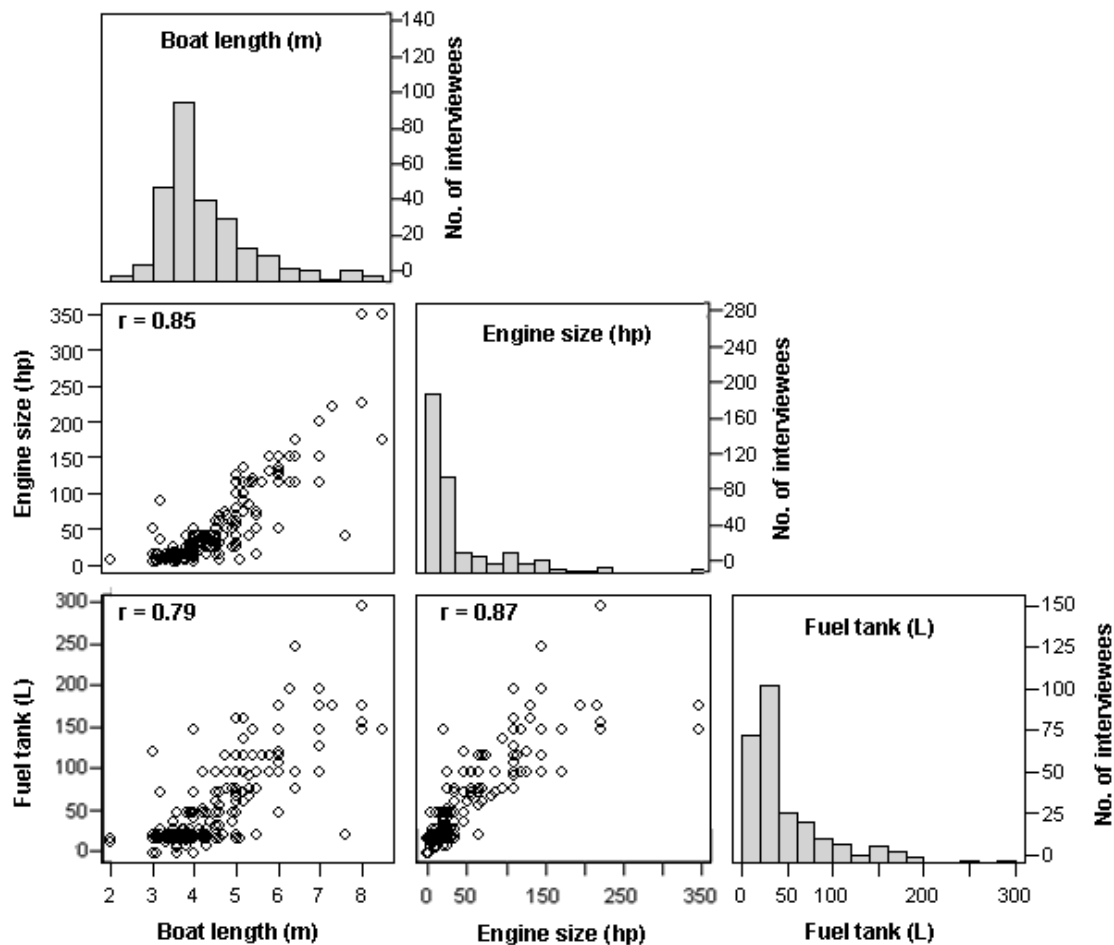


Figure 8-8. Characteristics of vessels provided by interviewees at Ningaloo (diagonal) and scatterplots with correlation coefficients (r) (bottom left panels) between each of the boat characteristics (number of interviews = 267).

The median distance travelled between accommodation and boat launching sites along the road network by respondents with motorised vessels was 1.8 km (SD = 18.6 km), equating to a median trip length of 2.1 minutes (SD = 13.9 minutes). The distribution had a strong positive skew towards interviewees travelling <10 km with a subsequent exponential decline (Figure 8-108-10). There was also a secondary peak evident at ~40 km. The furthest distance travelled (86.8 km) was by respondents staying in Exmouth and launching their vessels at Yardie Creek. Respondents staying in Exmouth also launched their vessels at the widest range of sites (14)

with the most frequently utilised being the Exmouth Marina, Bundegi and Tantabiddi boat ramps which were located 1.8 km, 15.7 km and 38.3 km by road from Exmouth, respectively.

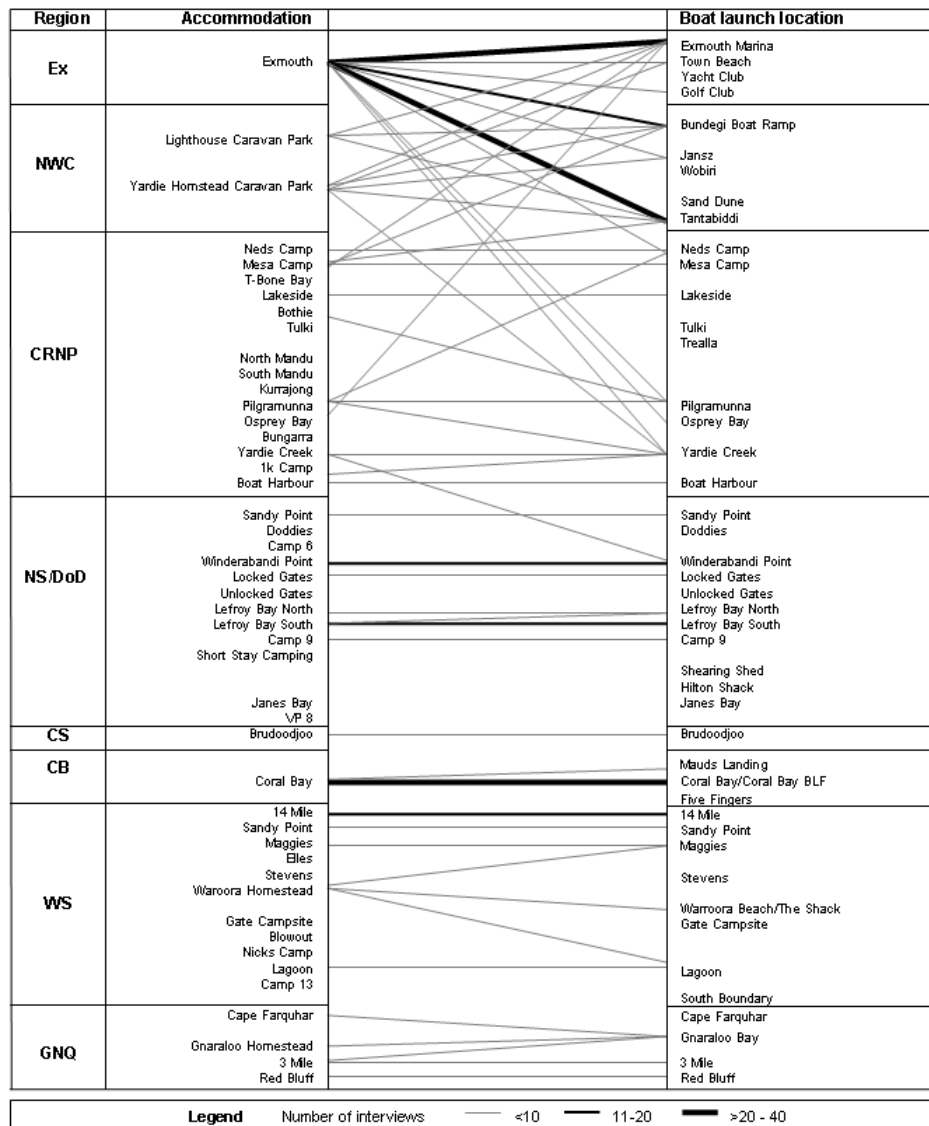


Figure 8-9. Travel flows between accommodation and boat launch locations, and their frequency, for interviewees with motorised vessels on their current trip to the Ningaloo Marine Park (number of interviews = 267).

There were 34.5% of respondents who did not travel away from their accommodation to launch their motorised vessels. When summarised by the different regions, this was significant for respondents staying on pastoral leases (NS/DoD, CS, WS and GN/Q) (assuming unequal variances, $F(1, 256) = 38.75, p < 0.05$). Respondents on these pastoral leases exhibited the shortest mean distances travelled (<6.3 km), except for CB, which had a mean travel distance of 1.0 km (Figure 8-11). Unsurprisingly, significant differences were found between the type of boat launching site and vessel length (assuming equal variances, $F(1, 262) = 24.76, p < 0.05$), with vessels launched at sealed ramps having a greater mean length ($\bar{x} = 4.8$ m).

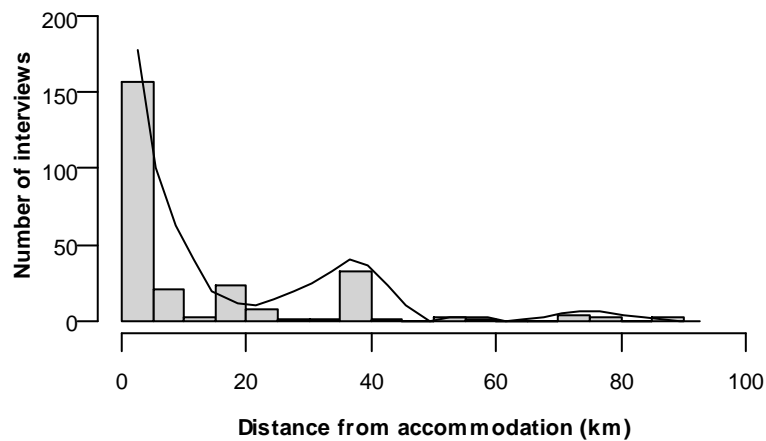


Figure 8-10. Distance travelled by respondents with motorised vessels from their accommodation to boat launch locations at Ningaloo with an interpolated spline representing the distance decay curve (number of interviews = 267).

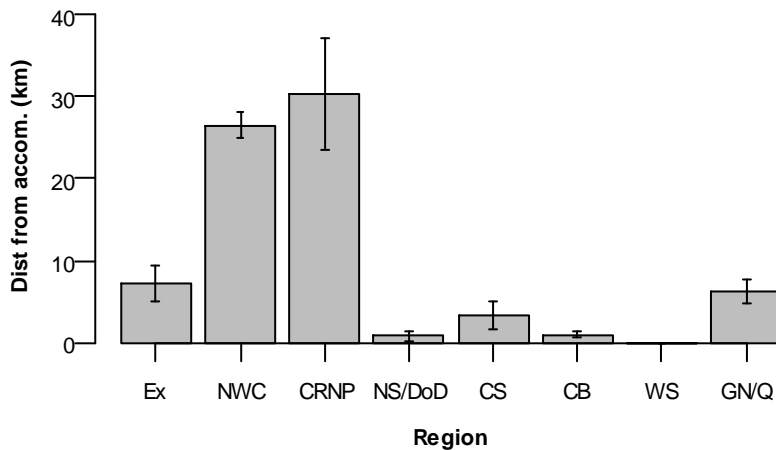


Figure 8-11. Mean distance travelled from accommodation to a boat launch location for motorised vessels by respondents in each region of the Ningaloo Marine Park ($\pm 95\%$ CI) (number of interviews = 267).

8.4.3 Beach access to shore recreation location

There were 321 beach access points used by respondents to access their shore recreation location in the NMP (out of a total of 336 documented access points). Respondents were highly clustered around beach access points and the majority had walked a mean distance of <0.1 km along the beach, which was calculated based on network distance (Figure 8-12). Once again, rapid distance decay was evident. The maximum distance walked by an interviewee from an access point for shore recreation was 4.7 km although this was treated as an outlier and excluded from Figure 8-12. The mean distance of these pathways for each region was significantly different (assuming unequal variances, $F(1, 1171) = 6.50, p < 0.05$) with visitors staying at NS/DoD walking furthest from access points to recreation locations (0.2 km) (Figure 8-13).

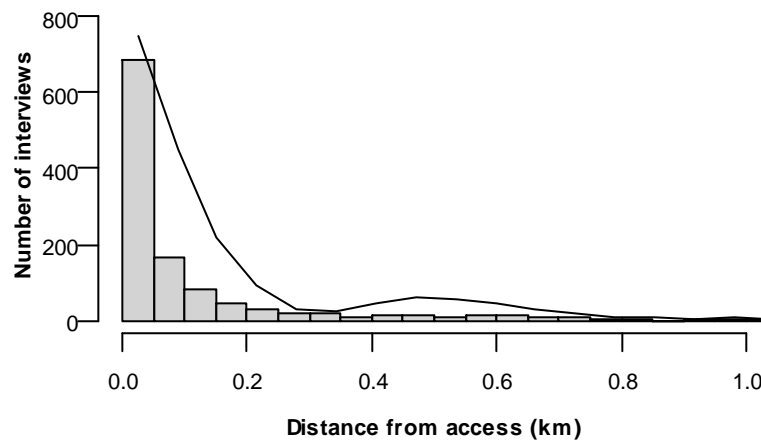


Figure 8-12. Distance walked from beach access point to shore recreation location by respondents in Ningaloo Marine Park with an interpolated spline representing the distance decay curve.

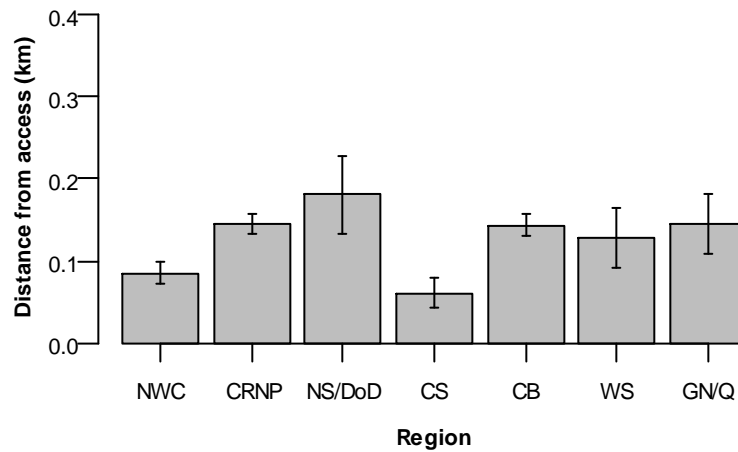


Figure 8-13. Mean distance walked from beach access point to shore recreation location in each region of the Ningaloo Marine Park ($\pm 95\%$ CI) (number of interviews = 1 163).

Mapping the sphere of influence for visitors from these access points for shore recreation highlighted areas which were most likely to be exposed to pressures from visitors. These were identified based on actual distance walked by respondents in off-peak and peak months with both found to influence 51.1% of the coastline. Areas such as Lighthouse Bay, Bundegi Beach, Turquoise Bay, Coral Bay and Maud’s Landing recorded high levels of use in both periods (Figure 8-14).

The distance travelled on foot between beach access points and shore recreation locations with respect to various user characteristics revealed different trends to those from accommodation to beach access point. When comparing the distance walked from a beach access location, there were no significant differences between first time and repeat visitors (assuming equal variances, $F(1, 1176) = 3.497, \rho > 0.05$), visitor origin (assuming equal variances, $F(1, 1173) = 2.42, \rho > 0.05$), group type (assuming equal variances, $F(1, 1172) = 1.60, \rho > 0.05$) or length of stay (assuming equal variances, $F(1, 1171) = 0.89, \rho > 0.05$). However, the distance walked by people participating in different activities was significantly different (assuming unequal variances, $F(17, 1159) = 7.45, \rho < 0.05$). *Post-hoc* testing identified that significantly greater

distances were covered by visitors walking ($\bar{x} = 0.4$ km) or participating in beach games ($\bar{x} = 0.2$ km) than other activities, such as surfing ($\bar{x} = 0.03$ km).

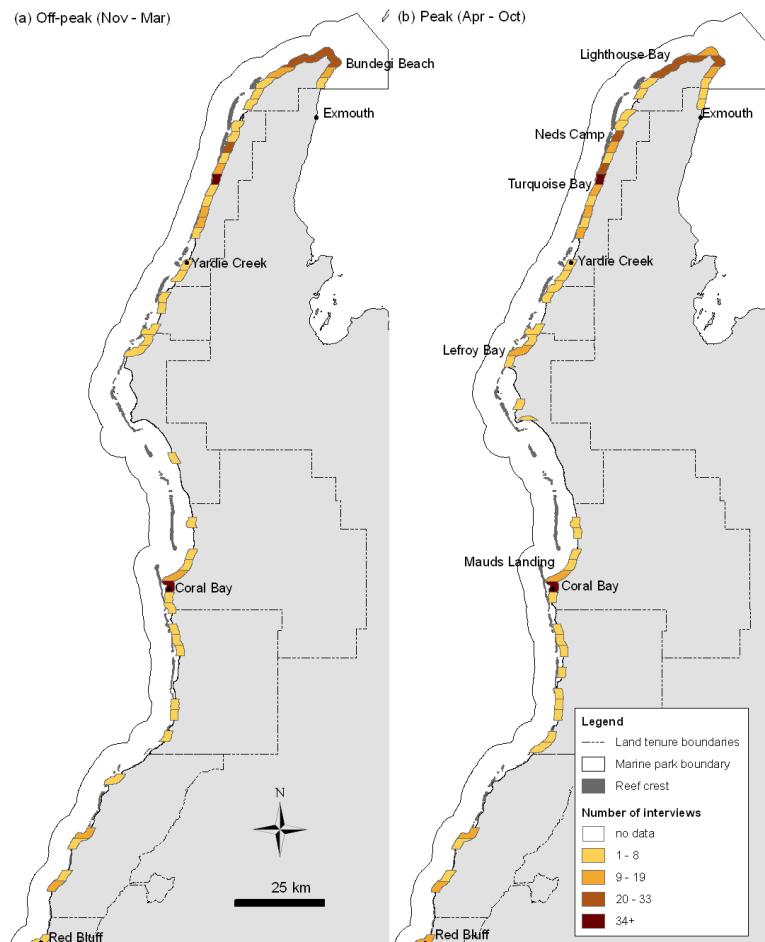


Figure 8-14. Coastal areas of Ningaloo Marine Park exposed to the highest density of recreational usage by interviewees travelling on foot from a beach access point to shore recreation location based on the distance calculated from the interview location in (a) off-peak and (b) peak months (number of interviews = 1 208).

8.4.4 Boat launching site to boat recreation location

There were 210 respondents with motorised vessels who nominated a furthest travelled location for recreation and they had launched from 30 different sites. Boats dispersed up to a maximum median radius of 4.6 km (SD = 15.9 km) to a recreation location. However, there was also a rapid decline in the number of vessels travelling >10 km from their launch location (Figure 8-15). There was a positive relationship between boat length and distance travelled from a launch site with larger vessels travelling further. A non-parametric correlation test showed this relationship was statistically significant (Spearman’s rho = 0.512, $\rho < 0.05$). There were also effects of the reef crest involved with a significant result obtained when comparing boat length and whether the vessel travelled outside the lagoon (assuming unequal variances, $F(3, 204) = 12.72$, $\rho < 0.05$). The results of a Games-Howell *post-hoc* test indicated the significant

differences were associated with a smaller mean boat length ($\bar{x} = 3.9$ m) inside the lagoon compared to outside the lagoon ($\bar{x} = 4.9$ m).

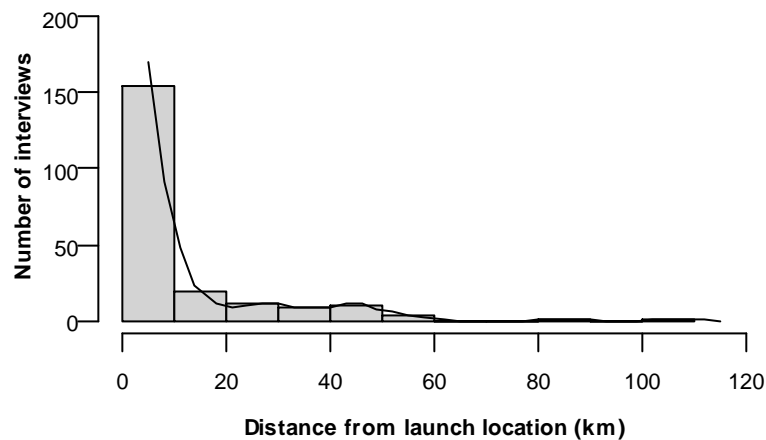


Figure 8-15. Radius travelled by motorised vessels from boat launch location to furthest recreation location in Ningaloo Marine Park with an interpolated spline representing the distance decay curve (number of interviews = 210).

The radii of furthest distance travelled by boats were represented as polygons centred on their nominated launch site and it was clear that many vessels did not move far from these locations (Figure 8-16). However, based on the positive correlation between travel distance and boat length, the furthest radii are likely to be larger vessels (>5 m in length). These boats covering greater distances generally travelled from sealed boat ramps at Exmouth Marina, Tantabiddi and Coral Bay BLF.

These radii were converted to a density of boats per 1 km² grid cell by overlaying all polygons and counting the number of vessels within each cell to indicate which areas are expected to have the highest boat use. Information supplied by respondents on whether or not they remained within the lagoon when boating was used to clip the travel radius and provide a more accurate representation of boating areas (Figure 8-17). The highest use was located around Exmouth and Tantabiddi, extending south into both the Exmouth Gulf and towards Yardie Creek. Although there is a fringing reef crest located along this latter section of the coast, it did not curtail the distribution of boats in this area. Additional boat use occurred around Winderabandi Point, Lefroy Bay, Coral Bay and 14 Mile. These sections displayed different patterns to the north, with higher densities of boat activity clearly concentrated within the sheltered lagoon environment.

8.5 Discussion

This study used a questionnaire to collect information on travel pathways and geographic extent of recreational participants within the NMP. Although a map-based approach could have provided additional data, because of the limited number of access routes that can be travelled to a particular site in the NMP, little additional information would have been garnered. This is especially true in the northern extent of the NMP as there is only one access road from Exmouth to North-West Cape and CRNP, with subsidiary roads leading to each beach.

Although extensive proliferation of informal tracks has occurred in regions to the south of Yardie Creek, the number of possible travel routes to a destination is still restricted.

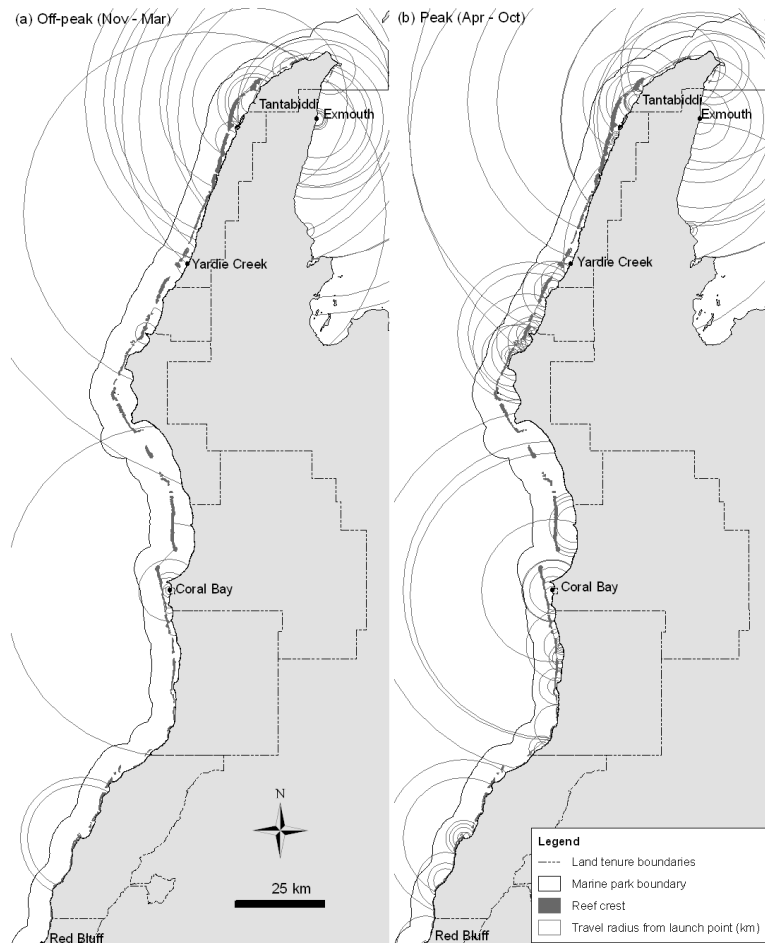


Figure 8-16. Maximum travel radii of boats from nominated launch sites in Ningaloo Marine Park without clipping to the fringing reef crest (number of interviews = 210).

The four itinerary types identified by McKercher and Lew (2004) encompassed entire trips. Visitors to Ningaloo can be classified as being on any of these trip types, i.e. single destination trip from a point of origin (i.e. Perth) or a circle tour stopping at multiple locations around Australia. Although the focus of this study was on intra-regional travel patterns, some general conclusions can be drawn about the travel itineraries of visitors to Ningaloo. For example, 61.4% of respondents stated they were staying at a single location while visiting Ningaloo, and were therefore not participating in a transit trip type, which has multiple overnight stops at different locations. From this single accommodation location, respondents would then choose whether or not to undertake day trips for recreation.

The questionnaire data revealed that 33.5% of respondents had not travelled away from their accommodation for shore recreation during their entire trip (up until the time of interview), while 34.5% had not travelled away to launch their motorised vessels. These groups were therefore undertaking a single destination trip, whereas the remaining 66.5% were following a hub-and-spoke type itinerary by travelling on day trips for shore recreation to (or within) the

NMP. Spatial variation was also evident in the distribution of respondents for recreation from boats and the shore with those staying in the northern regions of the Marine Park, such as Exmouth or along North-West Cape likely to travel greater distances than those on the southern pastoral leases, such as Ningaloo Station.

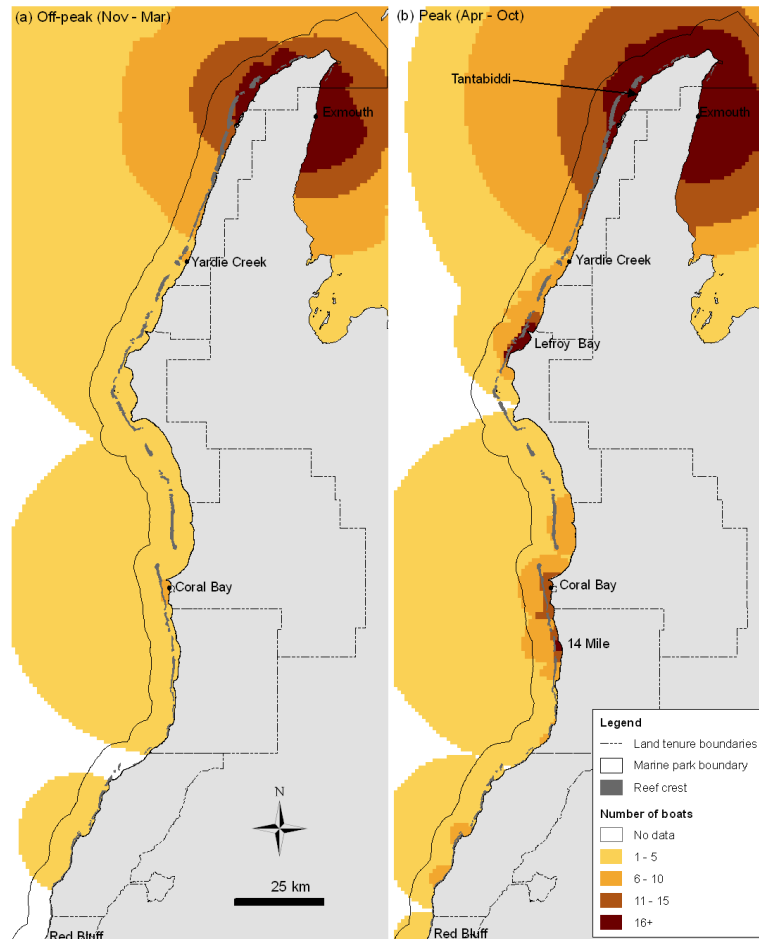


Figure 8-17. Areas with highest potential level of usage by recreational boats in Ningaloo Marine Park, based on respondents indicating their furthest travel radius from a boat launching site to recreation location and adjusted to take the fringing reef crest into account (number of interviews = 210).

Many factors influence the spatial flow and distribution of visitors conducting recreational activities from boats and the shore and this, in turn, may affect the shape of the theoretical distance decay curve. Factors investigated in this study included the proximity of recreation sites to access points (Van Wagtenonk, 1980; de Ruyck et al., 1997; Skov-Petersen, 2001), transport networks (Murphy and Keller, 1990; Tideswell and Faulkner, 1999), previous experience or visitation (Murphy and Keller, 1990; Darnell and Johnson, 2001) as well as length of stay and group type (McKercher, 1998). Other factors not included in this study, but identified in previous research worldwide include the dominance of key usage nodes, visitor motives and information availability (Husbands, 1983; Tideswell and Faulkner, 1999).

Distance decay curves in the current study (represented as lines interpolated from quantitative interview data) all exhibited rapid exponential decline with increasing distance from origin.

However, travel from accommodation to beach access points and boat ramps were not reflective of the theoretical distribution due to a secondary (more distant) peak in number of interviews. A secondary peak is known to result from both the uneven spatial configuration of resources and the level of appeal of a particular attraction to visitors (Fotheringham, 1981; Hanink and White, 1999). Therefore, even though locations in close proximity to a point of origin were more likely to be visited, highly attractive or publicised locations, such as Turquoise Bay (for coral viewing) and Tantabiddi (for boat launching), were selected as a destination, even though they were further from accommodation.

The preference for recreation locations further from accommodation is highly dependent on choice of accommodation location, with those staying in Exmouth travelling further when compared to those in the southern extent of the NMP. Sedentary behaviour by people choosing a location for recreation (especially in the southern regions of the NMP) may be due to a number of factors. Visitors who travel long distances to reach Ningaloo (i.e. from Perth, located 1 200 km to the south) are more likely to minimise travel once they arrive at their accommodation, as are those who invest significant time accessing a remote coastal camping location. This is especially relevant for domestic respondents staying in the southern pastoral regions (where sandy 4WD tracks are dominant) who did not travel for recreation. This concept of balancing or maximising time spent at a location against travel time has been previously identified in travel patterns (McKercher and Lew, 2004) (Lew and McKercher, 2006) (Lucas, 1990a). These characteristics, along with external factors, such as increasing fuel prices or unfavourable road conditions caused by flooding from cyclones or winter cold fronts, may also affect the distance travelled by visitors.

At Ningaloo, analyses of user characteristics (e.g. visitor origin) revealed no significant relationship with the distance walked on foot from a beach access point for shore recreation. However, many of these same characteristics were significant when compared to distance travelled by vehicle from an accommodation location which, although highly clustered, had a secondary peak in the distance decay curve. Easy connections facilitate higher visitation and distance from the nearest access point (Jimenez et al., 2007; Coombes et al., 2009) and road networks (Reed-Anderson et al., 2000) have been found to be strong predictors of recreational use. This study also found similar results at Ningaloo, with the distribution of recreation closely linked with both the road and track network as well as beach access points.

The notion of transport connections also links with information availability as the most popular sites, e.g. Turquoise Bay and Coral Bay (which are heavily advertised in guide books and brochures), are also those with sealed roads and some public transport (or charter tours) available. The amount of information provided to recreational users of protected areas will affect their behaviour, and the use of maps and brochures selling the attributes of a particular area are commonplace (MacLennan, 2000). The type of transport, which can be linked with group type, also affects movement patterns, with increased mobility and flexibility associated with private vehicles (Cooper, 1981; Connell and Page, 2008). The wide range of road conditions found adjacent to the NMP also limits the distribution of visitors based on vehicle type, i.e. only 4WD vehicles can negotiate many of the sandy tracks on pastoral leases, which account for ~60% of tracks within the Ningaloo region.

The restricted number of travel routes at Ningaloo could be useful for obtaining data on visitor numbers, with a minimal number of locations required to capture the majority of movement patterns. Vehicle counters have been in place at the access gateways to CRNP and at the entrance to Turquoise Bay (since 2003). These data suggest that, of all the traffic that enters CRNP, almost 50% visit Turquoise Bay. This is similar to results from this study, with interviewees within the CRNP, and from locations >100 km away, visiting Turquoise Bay either on the day of interview or as their furthest travelled location for shore recreation. Furthermore, Turquoise Bay is a day use site only and the closest accommodation is located 5.2 km away at Tulki camping area. Of the six respondents staying at this location, three cited its closeness to Turquoise Bay as the main reason for staying at this particular camping area.

The effect of transport type on movement patterns is also true of boat-based activities, as the type of boat (i.e. motorised, self-powered or wind-powered) will affect how it moves around an area (Pelot and Wu, 2007). Sidman et al. (2004) found the greatest differences in boat distribution were caused by boat draft, with smaller vessels able to access more areas. The analyses for Ningaloo found that smaller vessels travelled shorter distances and remained inside the sheltered lagoon environment. However, this may be a trade-off against the fact that these smaller vessels can launch at a higher number of beach locations, and therefore impact on a greater proportion of the Marine Park.

The capacity of boat launching sites to support vessels of increasing size is another factor which affects the spatial extent of recreational activity. At Ningaloo, larger vessels launched from Exmouth Marina, Tantabiddi and Coral Bay BLF which are all sealed ramps. At Coral Bay, prior to construction of the BLF in October 2007, a tractor was available to launch and retrieve large vessels from the beach. However, the construction of the Coral Bay BLF may still impact the distribution of boats from this node as this ramp has the capacity to launch bigger boats and, although these will be limited by environmental factors such as water depth and reef passages, they can travel further for recreation.

The distribution of vessels at Ningaloo was influenced by the fringing reef crest which provided a sheltered lagoon environment for boating, and also by vessel characteristics, such as boat length. Sidman et al. (2004) identified the most frequent reasons for boaters selecting a preferred departure site were that it was close to home or a favourite boating locale or had easy launching and retrieval. Similarly, they found the most cited reasons for selecting a travel route were easy access to favourite boating locale, scenic beauty and avoiding shallow water or congested areas. These are similar to reasons cited by respondents at Ningaloo for choosing a place to stay which included easy access to boat launching locations, close to a favoured recreational activity site and located near features such as safe anchorages or reef passages. This contributes to the low median distance (4.6 km) travelled to their launch sites within the NMP. Although some vessels travelled >100 km, the median distance was substantially less than the 20 km assumed to be the maximum distance travelled in one day by small recreational vessels within the Shark Bay Marine Park in Western Australia (Bruce and Eliot, 2006). Furthermore, in Florida, research on the time spent travelling from a place of residence to boat launching location, showed that the mean travel time was 26 minutes (Sidman et al., 2004), which is again considerably longer than the < 5 minutes documented in this study in the NMP.

Some variation in the distance travelled by respondents can be explained by the level of previous experience and familiarity with the NMP, with residents and repeat visitors travelling less distance for recreation than first time visitors, and also visiting different shore recreation locations. Those visitors less familiar with the region (i.e. first time visitors) were more likely to be found at more well known (or advertised) locations such as Turquoise Bay or Coral Bay and also Bundegi Beach, which is located close to the town of Exmouth. This was similar to the results obtained by Murphy and Keller (1990) on Vancouver Island, Canada. The short distances walked from beach access points to a recreation location by respondents in the Ningaloo study complements the findings by Chhetri and Arrowsmith (2008) that recreationists, when provided with several options, would willingly walk between 200 and 500m.

Previous studies have found that increased length of stay resulted in more dispersed activity (Oppermann, 1994) and that visitors on package tours are less spatially active than independent travellers (Oppermann, 1992). However, neither of these trends was supported in the current study, with respondents on commercial tours travelling greater distances to a beach access point (on average) than all other group types. These respondents were also more likely to be first time visitors to Ningaloo.

There are several benefits to developing an understanding of movement patterns and visitor flows. These include the ability to implement initiatives to control, redirect and disperse usage patterns to minimise impacts, conflicts and sustain coastal resources (Kramer and Roth, 2002; McVetty, 2002; Swett et al., 2004). These initiatives include changing the focus of information provision and marketing to de-emphasise heavily used sites and potentially promote others, limiting the sale of tickets to attractions, issuing a limited number of permits to visitors, and redirecting visitors once they have arrived to areas if overcrowding is occurring (e.g., at Turquoise Bay where there are a limited number of car parking bays). Furthermore, this information can be used as a means of influencing visitor activities through education (MacLennan, 2000), especially provision of pre-visit information (Newsome et al., 2002). The data can also be used for assessing infrastructure needs, determining economic pressures (Swett et al., 2004), evaluating effectiveness of zoning plans (Bruce and Eliot, 2006), risk assessments (Pelot et al., 2004), forecasting and prediction (Higham et al., 1996; Gimblett et al., 2007) as well as accessibility modelling (Skov-Petersen, 2001; Bruce and Eliot, 2006) and simulation modelling of visitor movements (Itami et al. 2000).

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9. A MODEL OF SHORE-BASED RECREATIONAL USE OF NINGALOO MARINE PARK, NORTH-WESTERN AUSTRALIA, RELATIVE TO SPATIAL, TEMPORAL AND ENVIRONMENTAL VARIABLES

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9.1 Summary

The shore-based human usage of the Ningaloo Marine Park was modelled based on data collected by aerial and coastal surveys throughout 2007. The number of recreational users in 26 activity categories, as well as additional indicators of recreational use were grouped by location and time of observation. Environmental variables, such as geomorphology, infrastructure, accommodation availability, road accessibility, management regulations and zoning were obtained from both the survey data and external information sources. Principal Coordinate Analysis of Neighbourhood Matrices revealed significant spatial (39.3 %) and temporal (2.3%) structures in the recreational use, which were largely co-explained by the known environmental variables, leaving a spatial and temporal auto-correlative component. A multivariate multiple regression model of the environmental variables plus auto-correlative components explained 55.3 % of the recreational use. Two variables, namely the presence of camping and accessibility by charter bus (i.e. road paved), explained 28% of the variance. The model was used to predict the effects of building a new road (i.e. reducing transport impedance) to the southern part of the park on recreational usage in the area. The prediction shows a year-round increase in recreational use at the beaches serviced by the simulated paved road.

9.2 Introduction

Marine parks are generally accepted as marine protected areas that, in addition to their important role in biodiversity conservation, also allow for tourism and recreational use (Dudley, 2008). Visitors for these purposes require effective management, and it is thus fundamental to have an understanding of the spatio-temporal patterns of recreational activities in marine parks and the factors influencing these activities.

Ningaloo Reef is a remote, fringing reef which extends for about 300 km along the coast of north-western Australia (22° - 24°S). It supports a high diversity of corals (Veron and Marsh, 1988), fishes (Fox and Beckley, 2005) and other biota including charismatic seasonal migrants like whale sharks, turtles and humpback whales (Sleeman et al., 2007). The multiple-use Ningaloo Marine Park (state waters) (NMP), which was established in 1987, and expanded in 2004, protects the full length of the reef (Figure 9-1). The current regulatory framework of the NMP is the 2005-2015 management plan (CALM & MPRA, 2005), which includes a system of zoning whereby areas are demarcated as sanctuary (“no-take”), recreation, general use and special purpose zones.

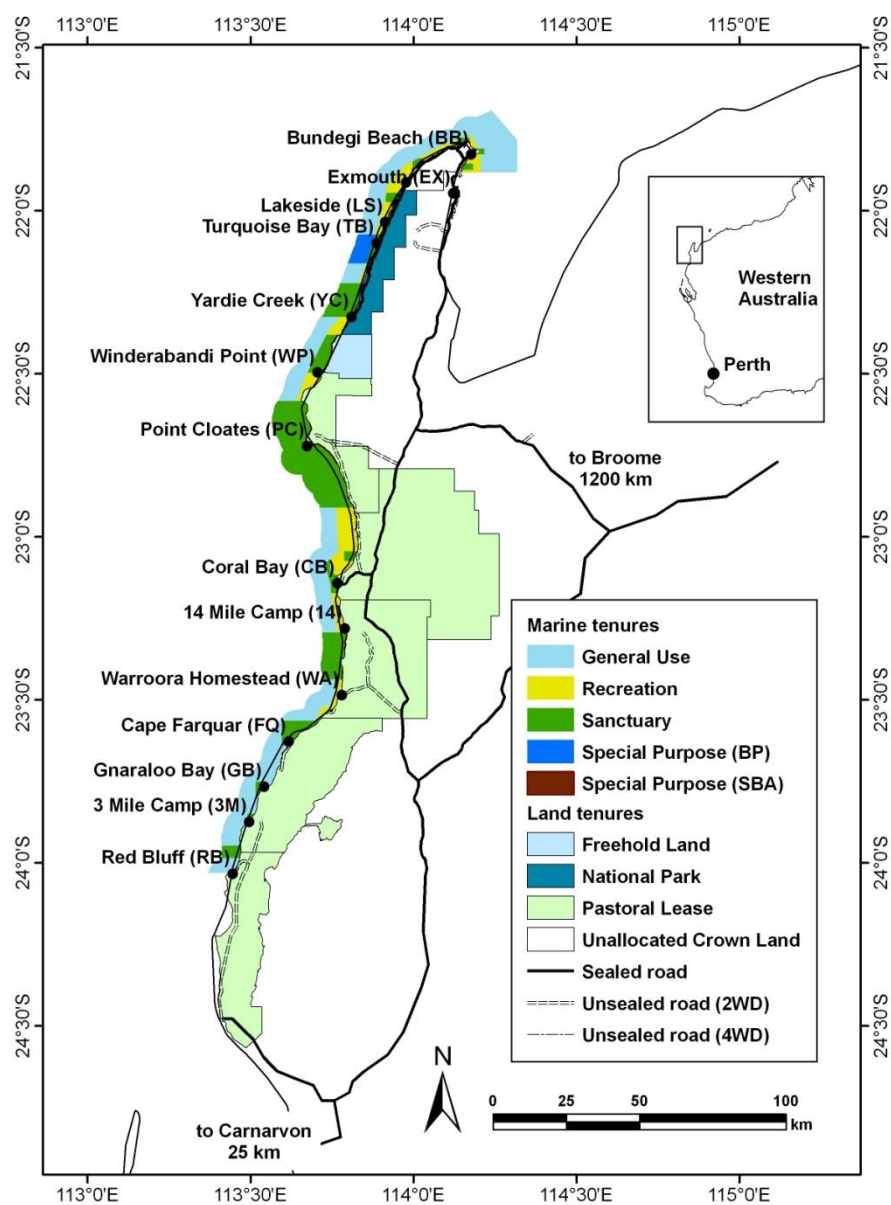


Figure 9-1. A map of the Ningaloo Marine Park, Western Australia showing the coastline from Red Bluff (RB) to Exmouth (EX), the park zoning, access roads and adjacent land tenure. Abbreviations in brackets after place names are used in subsequent figures.

The Ningaloo region has high social importance, particularly for its Aboriginal history, nature-based tourism and recreational opportunities. Tourists usually visit the region by road (1200 km from the city of Perth) or fly into the small town of Exmouth adjacent to the northern extent of the Ningaloo Marine Park. Accommodation, in the form of hotels, caravan parks and backpacker establishments is concentrated in Exmouth and Coral Bay but there is also extensive coastal camping in suitable locations along the length of the park (Smallwood 2009). Land tenure along the coast adjacent to the NMP is varied and includes Cape Range National Park (CRNP) where camping is restricted to managed camping sites of limited capacity, as well as several pastoral stations, where considerable coastal camping also occurs. There is a limited formal road network of paved and gravel roads suitable for two-wheel drive vehicles (2WD) but a vast labyrinth of four-wheel drive (4WD) coastal tracks exists, particularly on the pastoral

stations. These roads and tracks are used to access coastal camping sites and locations for recreational activity. Using 2WD vehicles, only Coral Bay and the route along the north-west Cape and CRNP, from Exmouth to Yardie Creek, are easily accessible. Access to the southern part of NMP is generally along the road from Carnarvon but road conditions usually preclude 2WD access and the time needed for the trip generally discourages Carnarvon-based recreational users from day trips to Gnaraloo. On the landward side of the reef crest there is a sheltered lagoon environment well-suited for a range of recreational activities. Some natural bays, such as Coral Bay or Turquoise Bay, provide north-facing sandy beaches, which in turn offer shelter from the south-westerly winds dominating most afternoons.

Relatively little historical spatial information exists about human use of the region for recreational activity, though various tourism surveys have highlighted the importance of Ningaloo for a range of pursuits ranging from swimming with whale sharks to snorkelling and fishing (CALM and MPRA, 2005; Wood and Dowling, 2003). In 1998/99, a survey of recreational fishing in the Gascoyne region (which includes Ningaloo) was undertaken whereby boat-based anglers self-reported the geographical location of their fishing trip in 5 nautical mile grid cells (Sumner et al., 2002).

A recent, extensive field-based study systematically surveyed recreational usage of NMP over its full spatial extent throughout 2007 (Smallwood, 2009). Stratified, random, aerial surveys were used to provide a synoptic overview of spatio-temporal patterns in usage of NMP. These surveys were of 4 hours duration and the southbound flight was from Exmouth to Red Bluff with the northbound flight the return trip. Land-based, 4WD, roving coastal surveys provided similar coverage but, because of the distances involved and nature of the sandy coastal tracks it took three days to cover the entire length of the marine park. These surveys enabled the spatial distribution of recreational activities conducted in the Marine Park to be determined as well as opportunities for questionnaire surveys of the people engaged in these activities.

Numerous factors influence the distribution of people using the marine environment for tourism and recreation. At Ningaloo, these can include biodiversity (e.g., presence of coral reefs, whale sharks etc), physical conditions (e.g., waves and currents), coastal geomorphology (e.g. sandy beaches), marine park zoning (e.g., sanctuary areas), access roads (e.g., only 4WD) and location of accommodation (e.g., hotels, caravan parks and camping areas).

The aim of this study was to examine a range of factors as potential drivers of the observed spatio-temporal patterns in recreational use of the NMP, quantify their contribution to the explained variation and create a regression model that could then be used to predict variation in recreational use after changing one of the factors.

9.3 Methods and model development

9.3.1 Data structure and treatment

The approach used to develop the model of the shore-based recreational use of NMP from the aerial and coastal surveys is shown in Figure 9-2. The number of people observed engaging in each recreational activity at each geographic location during the 34 aerial and 192 coastal surveys throughout 2007 (Smallwood, 2009) was used as a measure of human usage along the

shoreline of the NMP. A two-sided shore buffer of 500 m width either side of the Mean High Water Mark along the 300 km of coastline from Exmouth to Red Bluff was used to envelop the geographic locations of the activities. The shore buffer was divided into shore segments of 1 km length.

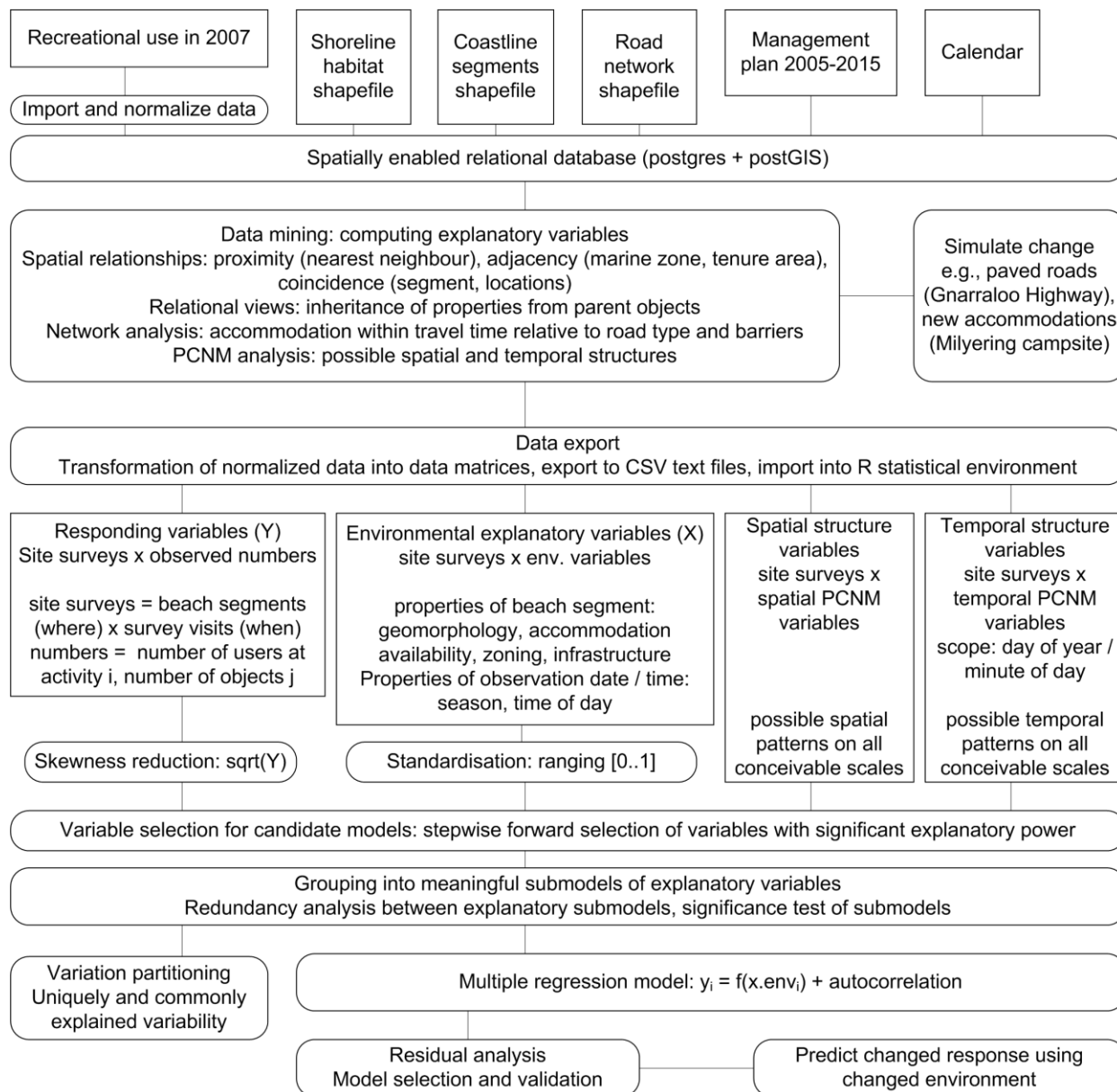


Figure 9-2. The approach used to develop the model of shore-based human usage data of the NMP collected in 2007 by aerial and coastal surveys. Raw data sets were processed in a spatially enabled Postgres database, mined using postGIS and ArcGIS and exported to the statistical package R. Principal Coordinate Analysis of Neighbourhood Matrices (PCNM, Borcard et al., 1992) yielded additional sets of explanatory spatial or temporal structure variables.

Unique combinations of beach segment and survey were termed site surveys, i.e. the survey data for each 1 km segment per sampling visit over the 12 months of 2007. All observations within a site survey were viewed as quasi-instantaneous counts of recreational user abundance.

Site surveys resemble species abundance profiles where the number of recreational users conducting an activity is treated like the number of individuals of a species at a site. The data were imported, together with features such as shoreline habitat, zoning plan and road networks, and processed in a spatially-enabled, relational database (Postgres / postGIS). Data were mined using postGIS and ArcGIS and exported to the statistical package R. Data for analysis were aggregated and exported as matrices of site surveys by activities as well as site surveys by different sets of explanatory variables. The software packages used in the analyses and modelling are listed in Table 9-1.

Table 9-1 Software used to model recreational use of the Ningaloo Marine Park. * PCNM: Principal Coordinate analysis of Neighbourhood Matrices

Software	Version	Source	Task
Postgres	8.3	http://www.postgresql.org/	data handling
PostGIS	1.3.7	http://postgis.refrains.net/	spatial analysis
ArcGIS	9.2	http://www.esri.com/	network analysis
R statistical package	2.10	http://www.r-project.org/	statistical analysis
R vegan library	1.15	http://cc.oulu.fi/~jarioksa/	redundancy analysis
R PCNM* library	1.9	http://r-forge.r-project.org/	PCNM analysis
R packfor library	0.0-7	http://r-forge.r-project.org/	forward selection

9.3.2 Response variables

To simplify further analysis and preserve explanatory power for the most frequently observed activities, the optimal set of observed activities to include in the analyses was determined following Legendre and Birks (2010). Firstly, a principal component analysis (PCA, Hotelling, 1933) was conducted on the set of response variables (e.g., number of recreational users per activity). Then, the PCA was repeated excluding the least frequently observed activity. This step was repeated, until the smallest eigenvalues of the PCA changed, which indicated that the last omitted activity conveyed a significant amount of information.

The surveyed activities were relaxing, walking, fishing, snorkelling, swimming, surfing, beach games, motoring, wildlife interaction, sightseeing, kayaking, sailing (including wind- and kitesurfing), boating, off-road driving, education, collecting and netting, wildlife viewing, spearfishing, exercise, park management, sandboarding, bike riding and jetskiing as well as unidentified activities. If boats were observed inside the 500 m buffer zone of a segment, the people on it were included in the analysis, since they were interacting with the environment at the time of the observation.

Additional, indirect indicators of human usage were recorded for each beach segment, namely, the numbers of cars, quad-bikes, buses and boat trailers present, the numbers of boats at boat ramps and on commercial and recreational moorings or in marina pens, the numbers of commercial and recreational boats on the beach, the numbers of tenders at moorings and on the beach as well as the number of overnight camps in the beach segment.

The remoteness and limited accessibility of the NMP manifests itself in low numbers of recreational users over wide stretches of its coast line. The response data are therefore skewed

with many observations of none or few users and some observations of many users at a few sites. The data were square-root transformed to reduce skewness. Linear spatial trends are the manifestation of processes acting on a larger spatial scale than the study extent and generally cannot be modelled from a data set of smaller spatial extent than the scale of the process. They appear as linear gradients in the response data along their geographical coordinates and were removed by canonical trend surface analysis (Legendre and Legendre, 1998).

9.3.3 Explanatory variables

A set of explanatory variables, expressing infrastructure, accessibility, geomorphology, accommodation availability and management zoning scheme (see below), was created to hold information about the properties of each of the 292 beach segments. Similarly, further explanatory variables including season, holidays and date for each day of 2007 were assembled. Mirroring the site surveys in the response data, which comprise unique combinations of location, date and time, a matrix of explanatory variables was formed. All explanatory variables were ranged to an interval of [0;1] to remove their physical units (Legendre and Legendre, 1998).

Geomorphology was represented by the length of sandy, rocky, mangal and salt marsh habitats within the beach segments (CALM and MPRA, 2005). Visual interpretation of high-resolution, aerial, hyperspectral imagery (HyVista) of the Ningaloo coast (Kobryn et al., in prep.) was used to determine the presence of north-facing and, therefore, wind-protected sandy beaches, within or adjacent to a coastal segment.

The infrastructure and accessibility were described by the number of car parks, boat ramps, and commercial and recreational moorings in the beach segment. As indicators of accessibility, the observed presence or absence of campsites directly within the beach segment, charter buses and quad-bikes as well as the number of car parks and boat ramps were determined from the observational data of Smallwood (2009). For example, a beach segment was treated as being accessible to camping, if a camp was observed there at any time during 2007.

In order to facilitate modelling the response of recreational use to the number of, and distance from, accommodation facilities, accommodation availability for every coastal segment was expressed by a number of separate variables. These variables were derived from a network analysis using ArcGIS with the Network Analyst extension. The location and extent of camping areas (Smallwood, 2009), a road network shapefile (digitized from aerial photography by H.T. Kobryn, unpublished data), known barriers (such as the river crossing at Yardie Creek or permanently locked farm gates) and appropriate road speed limits were used. For every beach segment, polygons of travel distances were calculated as the area which could be reached from each beach segment as a starting point within an interval of driving time (e.g., between 2 and 2.5 h) regarding the speed limits on the different road surface types (bitumen, gravel, sand). The intervals of travel time were 15, 30, 45, 60 min and 1, 1.5, 2, 2.5, 3, 3.5 and 4h. This was done both for 2WD and 4WD vehicles. Subsequently, the number of accommodation sites (providing space for a tent, caravan or camper van) and areas (managed units of several sites or hotels) within each travel distance polygon were calculated. These estimates were conservative, since some unpaved roads allow for higher driving speeds, depending on road condition and vehicle type. As a result, every beach segment received 32 variables, such as “number of accommodation sites within 2 to 2.5 h travel time using a 2WD vehicle” (see Appendix 9-1).

The area of different NMP zone types (sanctuary, general use, recreational use or special purpose) inside a coastal segment, the type of adjacent land tenure (national park, freehold or pastoral lease) and the opportunity for coastal camping were determined from the management zoning scheme and land tenure shapefiles (Department of Environment and Conservation, unpublished data).

A group of temporal explanatory variables showed coincidence with school and public holidays and whale shark season (April – July). Furthermore, the month [1;12], day of month [1;31], day of year [1;365], hour of day [0;23] and minute of hour [0;59] of the observations were used as additional explanatory variables. This separation of date and time allowed the determination and partitioning of temporal effects on different scales, from diurnal to seasonal.

This set of explanatory variables, split into the above-mentioned five groups, is referred to in the text as environmental explanatory variables, as it represents the environment, both man-made and natural, of the observed recreational use.

9.3.4 Spatial and temporal structure of recreational use

Principal Coordinate Analysis of Neighbourhood Matrices (PCNM) (Borcard et al., 1992) was used to quantify spatial and temporal structures in the response data. PCNM analysis is “a spectral decomposition of the spatial relationships among sampling sites, creating variables that correspond to all the spatial scales that can be perceived in a given data set, and finds the scales to which the data set responds” (Borcard et al., 2004). Spatial PCNM variables were calculated from the centre coordinates of the 292 coastal segments. Temporal “coordinates” of observations (date and time) spanned the year 2007 and had an individual resolution in the range of minutes. To reconcile coverage with resolution, the temporal coordinates were broken down into two sets of nested scope and resolution, one set containing the days of year (*doy*) as integer numbers from 1 - 365, the other set containing the minutes of day (*mod*, 1 - 1440). For these three sets of spatial and temporal coordinates, PCNM variables were calculated using the statistical software R (R Development Core Team, 2009) with the PCNM library. In PCNM analysis, the smallest detectable structure is determined by the widest gap in the analysed coordinate set. For the spatial PCNMs from the beach segments, the smallest detectable structure was 2.096 km, for *doy* PCNM variables it was 1.000 days and for the *mod* PCNM variables it was 1.000 minutes. Matrices of sites by PCNM variables (spatial, temporal *doy* and temporal *mod*) were constructed by matching the PCNM variables to the beach segment or observation date and time, respectively. In combination, these matrices represented all possible spatial or temporal patterns and served together with the known environmental variables as explanatory matrices (Appendix 9-2).

9.3.5 Variable selection and variation partitioning

Stepwise forward selection (Miller and Farr, 1971) was used in a permutation test (999 permutations, R library *packfor*; see Table 9-1) to identify environmental, spatial and temporal PCNM variables, which significantly explained variation in the response data (see Figure 9-2). The unique and common contributions of those significant explanatory (environmental, spatial PCNM and temporal *doy* and *mod* PCNM) variables to the variation in the response data set were quantified using variation partitioning (Borcard et al., 1992). Variation partitioning is a constrained regression method which removes known sources of variation from the data set using redundancy analysis (RDA) (Rao, 1964). Estimates of the redundancy statistic R^2 were

adjusted for multiple testing after Peres-Neto et al. (2006). Autocorrelative fractions were quantified via partial redundancy analysis (Rao, 1964; Legendre and Legendre, 1998), followed by permutation ANOVA tests (R package *vegan*, Oksanen et al., 2007).

9.3.6 Model of recreational use

Recreational use of the NMP was modelled in a multiple regression of all selected explanatory variables plus the auto-correlative spatial and temporal components against each response variable. The model was formulated as:

$$y_i = f(x.env_i) + f(SA_i) + f(TA_i)$$

where y_i is the i -th response variable (number of users at activity i) and $x.env_i$ the i -th environmental variable from the subset of significant environmental variables chosen by stepwise forward selection. The autocorrelative components, SA and TA, denote a partial RDA model of the spatial and temporal structures in the response data, which were not co-explained by the known environmental variables.

9.3.7 Case study using the model to predict recreational use after environmental change

Based on the identified relationships between response (recreational activity) and explanatory variables, the change in recreational activity following a change in the environment (both man-made and natural) can be predicted. Gnaraloo is a pastoral station adjacent to the southern part of NMP Park from where tourists engage in recreational activities (Figure 9-1). On the station, limited chalet-style accommodation is available near the homestead and camping is permitted at 3 Mile Camp. The access road is unpaved and unsuitable for most 2WD vehicles. During the 2007 field surveys, no tourist buses were recorded at Gnaraloo. Red Bluff on Quobba station, immediately south of Gnaraloo provides a further camping area and is serviced by the same unpaved road.

It was hypothesised that paving the Carnarvon-Gnaraloo access road would decrease the transport impedance and make Gnaraloo and Red Bluff accessible to 2WD vehicles and charter buses, thereby making their beaches available as day-use sites for recreational users accommodated in the Carnarvon area. The change in recreational usage was predicted based on the Carnarvon-Gnaraloo access road effectively becoming a highway with a speed limit of 110 km h⁻¹, thus making the beaches at Gnaraloo and Red Bluff accessible to charter buses and 2WD cars. The beaches at Gnaraloo Bay, 3 Mile Camp and Tombstones were simulated to also get two additional car parks each.

Since the observational data do not evenly cover the study area and all the days of the year (2007), recreational use was predicted using the unaltered environmental explanatory variables on a regular grid, including every beach segment every three days, in order to create an interpolated baseline scenario. A second prediction on the same grid, but using the changed environmental variables incorporating the “Gnaraloo highway” scenario yielded the recreational use of the changed scenario. Therefore, the predicted (changed) user abundances can directly be compared to the interpolated user abundances of the baseline scenario.

The predictions are valid only for the impact area of the simulated changes. The prediction assumes identical user behaviour as at the time of the original survey and a linear response of

the recreational users to the environmental variables. The prediction assumes that Carnarvon provides a total of 2000 accommodation units (tents, campervan or hotel rooms), from which the beaches of Red Bluff and Gnaraloo would be accessible on day trips.

9.4 Results

9.4.1 Description of recreational use

Panel (a) of Figure 9-3 shows the total numbers of recreational users recorded in the NMP during aerial and coastal surveys during 2007 (Smallwood 2009). Higher use is clearly visible in areas of direct accommodation availability, such as Coral Bay (CB) or near Exmouth (EX), which each have approximately 2 000 accommodation units. High use also occurs in areas that are easily accessible from the Exmouth accommodation node by paved roads, such as the beaches of the Cape Range National Park like Lakeside (LS) and Turquoise Bay (TB). The higher numbers of visitors during the school holidays in April, July, October and December, which are shown as boxes in panel (c) are reflected as pulses of higher user abundances in panel (a). Many of these users are families, which are bound to the school holidays (Smallwood, 2009). Lastly, the higher abundance of users in the austral winter months from April to October is visible in the remote regions between Yardie Creek (YC) and Point Cloates (PC) as well as from 14 Mile Camp (14) to Cape Farquhar (FQ). These users are mostly the so-called “grey nomads”, retirees spending several weeks to months at these locations to escape the colder temperatures in the south of the continent (Smallwood, 2009).

9.4.2 Explanatory analysis of recreational use

Stepwise forward selection identified 39 environmental variables, 86 spatial PCNM, 5 *doy* and 4 *mod* PCNM variables that significantly explained variation in the response data. A listing of all significant environmental variables summarizing their individual explanatory contribution to the variation in the response variables is given in Appendix 9-1. Resulting from variation partitioning, the unique and common contributions to the explained variation of these sets of explanatory variables is summarised in Table 9-2.

Table 9-2. Variation partitioning of the explanatory power of environmental, spatial and temporal PCNM variables for describing shore-based recreational use at Ningaloo Marine Park. The environmental explanatory variables with an adjusted R^2 of 0.4705 are listed in detail in Appendix 9-1 and (a) indicates bimultivariate redundancy statistic (Miller and Farr, 1971).

Fractions	Df	R^2 (a)	Adj. R^2	F	p
Environmental variables	39	0.4740	0.4705		
Spatial PCNM variables	86	0.4019	0.3929		
Temporal PCNM variables	9	0.0241	0.0225		
Env + spatial PCNM	125	0.5554	0.5456		
Env + temporal PCNM	48	0.4823	0.4780		
Spatial + temporal PCNM	95	0.4167	0.4070		
All explanatory variables	134	0.5638	0.5534		
Spatial autocorrelation	39		0.0754	48.87	0.00
Temporal autocorrelation	9		0.0078	12.014	0.002

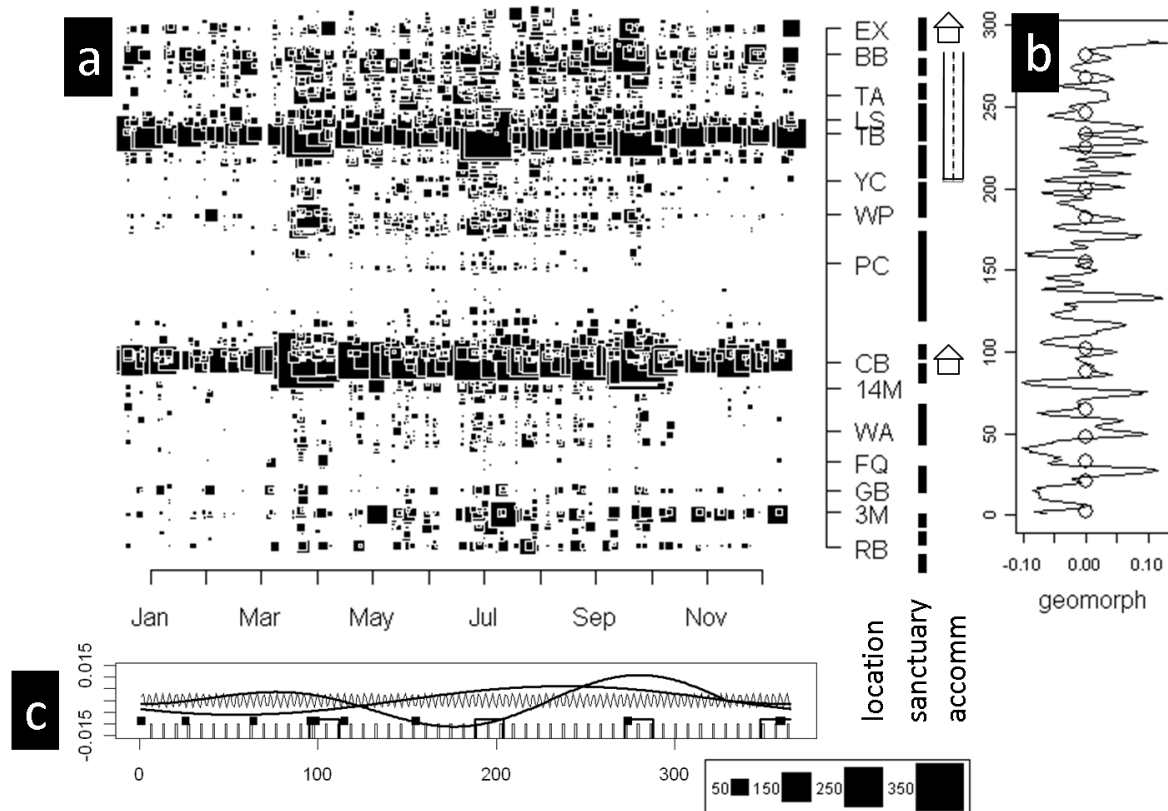


Figure 9-3. (a) Spatio-temporal distribution of total number of observed recreational users (all activities) along the rectified beach segments (y axis) from Red Bluff (RB) to Exmouth (EX) relative to the date of the observation from January to December, 2007 (x axis). The square size denotes number of people. Sanctuary zones, major accommodation nodes and the sealed road from Exmouth (EX) to Yardie Creek (YC) are indicated on the right hand side. (b) Spatial PCNM variables relating to geomorphology. The synthetic value of this variable correlates to spatial structures in the geomorphology subgroup of environmental explanatory variables. (c) Temporal PCNM variables, grouped into two seasonal (1 and 2 variables) and one weekly-scope submodels (1 variable). School holidays (boxes), weekends (ticks) and public holidays (small squares) are indicated along the days of the year on the x axis and match the months shown in panel (a).

The overlap between environmental and spatial (variation partitioning, $R^2 = 0.3185$) or all temporal (variation partitioning, $R^2 = 0.0064$) PCNM variables, respectively, represents the spatial or temporal structure of known properties such as patterns of accommodation availability (as shown in Figure 9-3, panel a, house symbols) or the coincidence of observations with holidays (as shown in Figure 9-3, panel c, boxes).

The remaining variability, which is only explained by spatial ($R^2 = 0.0660$, permutation ANOVA, $F(86,5657) = 19.917$, $p=0.005$) and temporal ($R^2=0.0077$) PCNM variables, represents spatial or temporal autocorrelation as well as spatial or temporal processes not modelled in the environmental variables. All variables combined explained 55.3 % of the variation in human use, which left the remaining 44.7 % as unexplained variation due to randomness in user behaviour and unknown or non-quantified influences of human usage (e.g. weather).

Notably, 28 % of the variation in recreational use (Appendix 9-1, variables “camps recorded” and “buses recorded”) was explained by whether accommodation (in the form of camping) is present or possible at the segment and whether a segment is accessible to charter buses. A further 13 % of variation is explained by seven more variables, and the last 7% is explained by the remaining 29 significant explanatory variables. Of the synthetic PCNM variables, 86 spatial, 4 large-scale *doy* and 5 small-scale *mod* temporal PCNM variables were significant.

The 86 spatial PCNM variables explained 39.2% of the variation in recreational use and 30.9 % of that was co-explained by the environmental variables and represents spatially structured processes and features of the NMP. Figure 9-3 (panel b) shows the spatially structured parts of one example subgroup of environmental explanatory variables, namely, geomorphology, as the sum of the respective correlating PCNM variables. The 7.54 % of variation which was spatially structured, but not co-explained by environmental variables denotes spatial autocorrelation as well as unknown spatial processes.

The significant *doy* variables were grouped arbitrarily into three additive orthogonal submodels: a seasonal component corresponding to the tourist season from April to October, a semi-seasonal component corresponding to school holidays and a weekly component, which did not correspond to the weekends and was therefore likely to denote temporal autocorrelation. Figure 9-3 (panel c) compares these *doy* submodels to the total number of observed recreational users. One diurnal *mod* variable correlated significantly to the response data and to the hour of the day. The remaining four significant *mod* variables modelled very fine-scaled temporal structures in the scope of minutes and are likely to represent temporal auto-correlation.

9.4.3 Regression model

As the temporal autocorrelation was not significant in the model (ANOVA, 999 permutations, Oksanen et al., 2007) it was not included, and the model equation was reduced to:

$$y_i = f(x.env_j) + f(SA_k)$$

where y_i is the i -th recreational activity, $x.env_j$ is the j -th environmental explanatory variable, and SA_k is the k -th spatial autocorrelative part of a PCNM variable. Every term of the regression model was significant at the 0.0001 level. The significance of the environmental explanatory variables is shown in Appendix 9-1. A permutation ANOVA (999 permutations, Oksanen et al., 2007) constrained ordination of the regression model's terms shows their significance [$F(125,5664) = 58.789, p=0.002$].

9.4.4 Case study: predicting recreational use after environmental change

After simulating the paved road to Gnarlou Bay, the difference of changed and baseline counts of recreational use, expressed as the absolute increase in total numbers of recreational users (all activities) compared to the baseline numbers is shown for the impacted part of the NMP in Figure 9-4. The total recreational activity showed a mean increase of 1.02 ± 1.49 users (mean \pm SD) and ranged from 2.32 users less than the baseline scenario to up to 11 users more than the baseline scenario throughout the whole study extent.

The non-extractive activities relaxing, walking, swimming, snorkelling, and playing beach games, which form the largest group of activities (Smallwood 2009), are highly correlated in abundance. They showed an increase of 0.51 ± 1.10 users (mean \pm SD), ranging from between 2.31 users less and 11.40 users more during the whole year. The very high relative increases translate to the presence of 1 - 10 additional users in the “Gnaraloo highway” scenario in segments where mostly zero or small groups were observed in 2007. The interpolation, which yielded fractional numbers, returned a very small number of expected recreational users in the range of 0.0001 to 0.1.

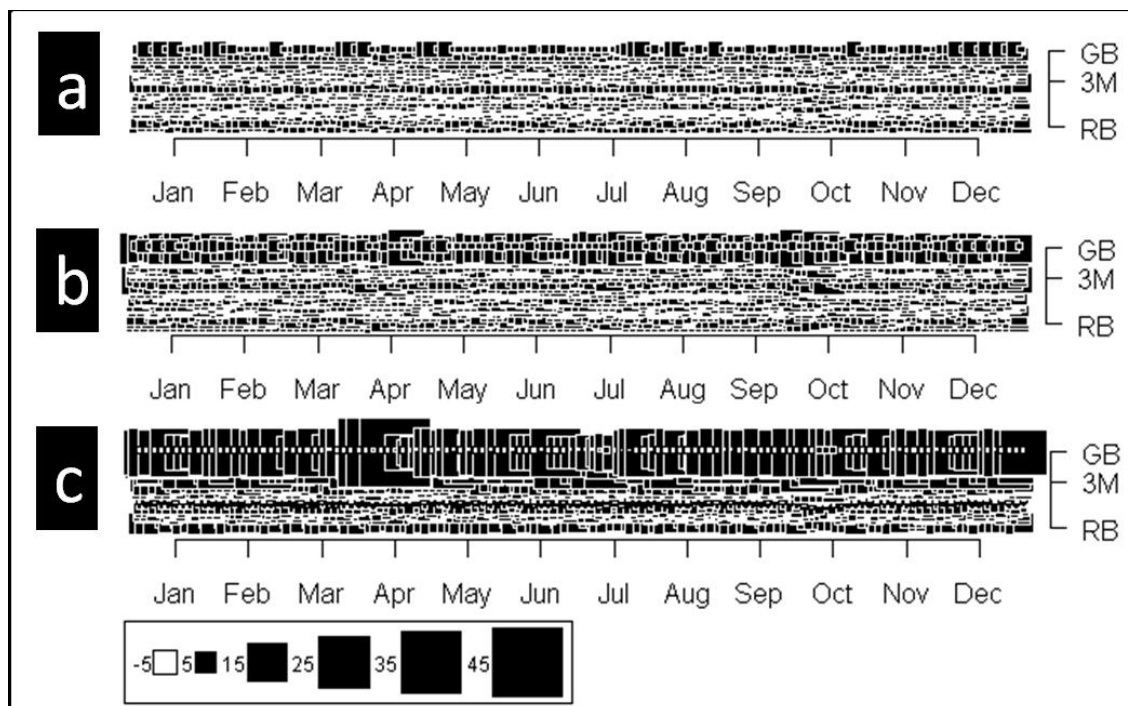


Figure 9-4. Predicted increase in total numbers of recreational users for all surveyed activities in the Gnaraloo to Red Bluff section of Ningaloo Marine Park with the “Gnaraloo highway” scenario. Square size indicates the increase in number of people relative to the baseline scenario. (a) Interpolated total numbers of recreational users in the Gnaraloo to Red Bluff section of Ningaloo Marine Park, modelled on the baseline scenario; (b) Predicted total numbers, modelled with the “Gnaraloo highway” scenario; (c) Relative increase of recreational use, expressed as percentage of the baseline numbers in panel (a).

Figure 9-5 shows the absolute and relative change in two of the most popular activities, relaxing and snorkelling. Relaxing on the beach was predicted to increase most at Gnaraloo Bay, whereas the increase in snorkelling was predicted to be more evenly spread out between Red Bluff, 3 Mile Camp and Gnaraloo Bay. Strong increases during the school holidays and little increase outside the school holidays were predicted for kayaking, boating, off-road driving and quad-biking. Fishing was predicted to increase outside the sanctuary zones year-round in Gnaraloo Bay, 3 Mile Camp and Red Bluff and, like-wise, collecting and netting would increase outside the sanctuary zones, but near 3 Mile Camp more than at Gnaraloo Bay and Red Bluff. Driven by the increase in 2WD access, water-based motorized activities and jet skiing were predicted to increase at Red Bluff during the whole year and at Gnaraloo Bay during the April school holidays.

An indirect indicator of recreational use, namely, the number of cars in car parks near the beaches was predicted to increase by 3-9 cars year-round in all impacted segments with a peak in the April school holidays. The numbers of recreational boats on the beach were predicted to increase by 1-5 boats year-round with peaks during the school holidays, thereby representing a 50- 350 fold increase.

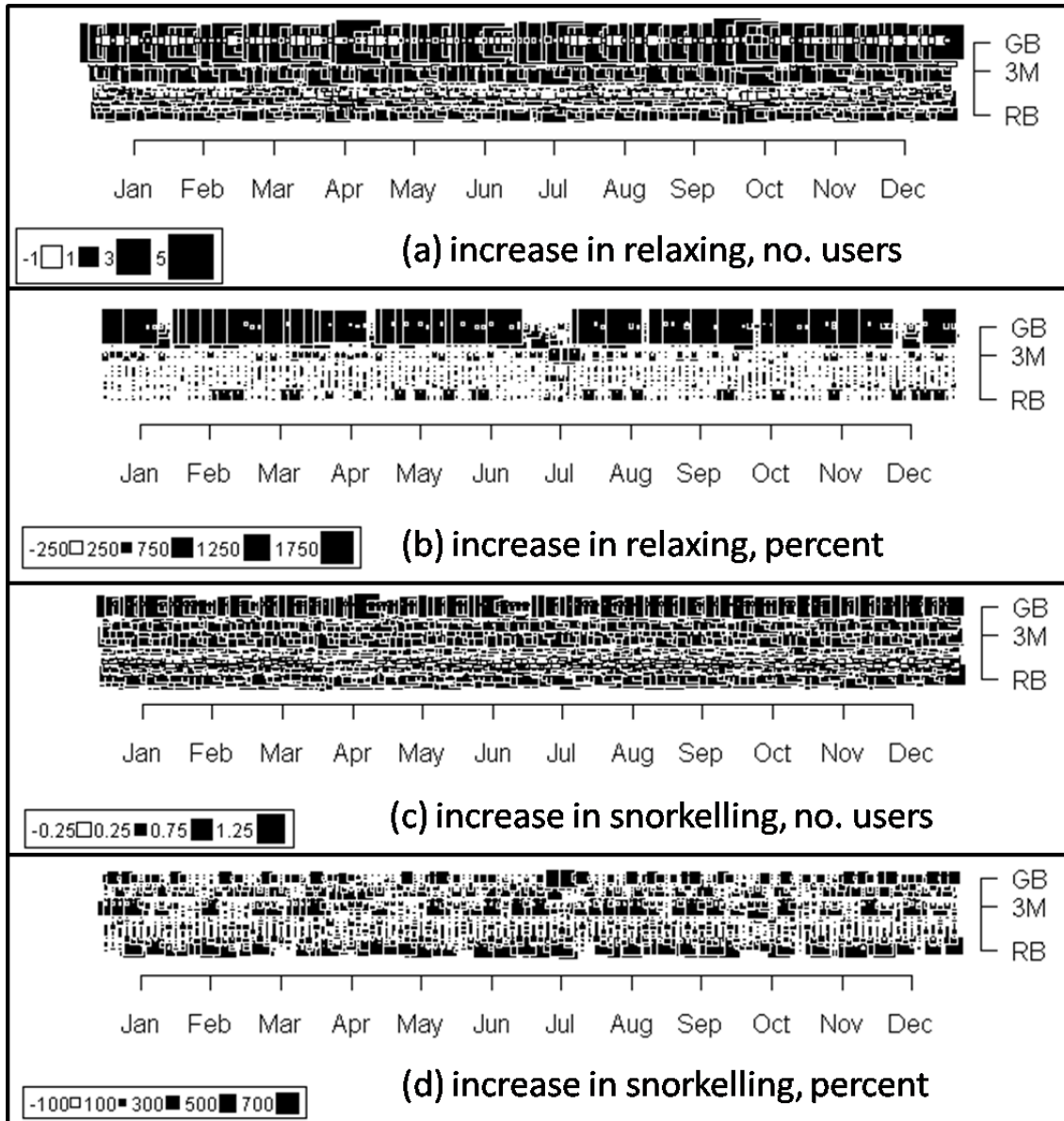


Figure 9-5. Predicted change in numbers of recreational users relaxing on the beach and snorkelling at the segments from Red Bluff to Gnaraloo Bay under the “Gnaraloo highway” scenario. Changed numbers are given as absolute numbers (a, c) and relative percentage (b, d).

9.5 Discussion

Human usage of NMP the Ningaloo Marine Park as derived from the high resolution aerial and coastal surveys in 2007 (Smallwood, 2009) was found to consist of predictable (55.3 %) and residual (44.7 %) components. The predictable part can be grouped into sub-models of accessibility, accommodation availability, marine park zoning, infrastructure, seasonal and temporal attributes as well as components of spatial and temporal auto-correlation. The major factors affecting non-extractive recreational use were accessibility by charter buses and the availability of camping (accommodation) in the direct vicinity of a beach segment. Zoning only affected extractive activities, such as fishing, and the distribution of most other recreational activities was more affected by infrastructure and accessibility. The highest density of non-extractive recreational use was, in fact, recorded in sanctuary zones in accessible areas like Turquoise Bay and Coral Bay. The least amount of recreational activity was found in the more inaccessible areas like Cape Farquhar or Point Cloates.

There are several limitations to the shore-based recreation model. For example, the daily variations in weather and sea conditions were not modelled due to the lack of sufficiently resolved data for the Ningaloo coast. It is known, however, that in the afternoons, strong south-westerly onshore sea breezes often drive recreational users towards more sheltered locations. This could, for example, be the north-facing beach at Turquoise Bay (TB) which is within close walking distance of the west-facing beach adjacent to the renowned snorkelling area. In places where camping occurs near the beach, such as on the pastoral stations or where accommodation is within walking distance to the beach, such as in Coral Bay or Cape Range National Park, users have been observed to evade the strong winds by retreating to their accommodation (Smallwood, 2009). Such user behaviour is not accounted for in this study and, together with randomness in human behaviour, contributes to the unexplained variation. Further sources of unexplained variation in recreational use at Ningaloo include the influence of tourist advertising and personal recommendations, site fidelity due to earlier experience and individually perceived, or anticipated, overcrowding, for which sufficiently resolved data were not available.

The predicted scenario of a paved Carnarvon-Gnaraloo access road revealed an increase in most activities. Non-extractive activities showed a predicted average increase of up to 12 additional users being present per 1 km beach segment throughout the year. The year-round increase in extractive activities (various types of fishing) indicates the potential for greater fishing pressure between Red Bluff and Gnaraloo Bay in the event of a road upgrade.

Several assumptions underlie these predictions. Firstly, a linear response of recreational use to changes in environmental parameters has been assumed. On the one hand, the changed variables in the “Gnaraloo highway” scenario never exceeded the range of values measured in the baseline scenario over the whole study area to which the model was fitted. The prediction also assumed the same behaviour by recreational users at all locations, particularly that users accommodated in Carnarvon would behave in a similar manner at Gnaraloo Bay to those users in Exmouth, who frequent the beaches of Turquoise Bay. Secondly, the model does not regard visitor carrying capacities, as these data were not available. Therefore, the changed recreational use was not constrained by overcrowding of beaches or overfilling of parking lots. For this reason, predictions of very large numbers of recreational users must be interpreted carefully, as the user numbers at the respective beaches will be subjected and influenced by carrying

capacities of car parks, beaches and nearby accommodation. Thirdly, as in every model, boundary effects must be observed from the access locations of Carnarvon and beyond.

Most activities in NMP are non-extractive activities, such as relaxing, walking and snorkelling. Only 8 % of the total observed activity comprised fishing. The current management plan with zoning (CALM and MPRA, 2005) appears to drive extractive use, such as fishing, but not the non-extractive use. The predictions suggest a greater increase in non-extractive use, such as swimming and snorkelling, than in extractive activities (various types of fishing). Non-extractive activities at NMP are driven by accessibility, infrastructure and accommodation availability, and do not appear to be limited by the current management plan. The results of the model suggest that non-extractive use could be controlled through limiting accessibility, infrastructure and accommodation availability, rather than by the delineation of sanctuary zones in the NMP. Increasing use of recreational sites can result in degradation, loss of recreational value and, eventually, decrease of tourism-related revenues from the recreational areas, i.e. it propagates them along the life cycle of tourist destinations (Getz, 1982),

Zoning often helps to integrate social and economic aspects relating to protected areas (Ortiz-Lozano et al., 2009) but, globally, lack of management effectiveness is often problematic (Muthiga, 2009; Qiu et al., 2009). In order to maximize the impact of regulatory measures, a thorough understanding of the driving factors of recreational use is thus needed. Furthermore, practices such as ecosystem-based management require information on the spatial and temporal distribution of recreational use (Douve, 2008; Stamieszkin et al., 2009) and this study at Ningaloo provides an example of how highly resolved usage data can be utilized by managers to understand and predict use in the event of natural or man-made changes.

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Appendix 9-1. Complete listing of significant environmental explanatory variables as selected by stepwise forward selection. Last column indicates the subgroup of the respective variable in the set of environmental explanatory variables. The prefix "no." stands for "number of".

	variable	R^2	R^2_{cum}	$adj. R^2_{cum}$	F	p	subgroup
1	camps recorded	0.1451	0.1451	0.1450	982.3946	0.001	infra
2	buses recorded	0.1315	0.2766	0.2764	1052.3702	0.001	infra
3	no. 2wd access points	0.0335	0.3101	0.3097	280.5469	0.001	infra
4	no. commercial moorings	0.0260	0.3361	0.3356	226.5267	0.001	infra
5	is north-facing sandy beach	0.0186	0.3547	0.3541	166.4866	0.001	geomorph
6	area of general use zone (km ²)	0.0137	0.3684	0.3677	125.6437	0.001	zoning
7	no. campsites 4wd 45-60min	0.0094	0.3778	0.3770	87.3909	0.001	accomm
8	no. carparks	0.0080	0.3858	0.3849	75.1432	0.001	infra
9	saltmarsh habitat (m)	0.0068	0.3926	0.3917	65.0342	0.001	geomorph
10	no. campsites 2wd 45-60min	0.0072	0.3998	0.3987	69.0589	0.001	accomm
11	length of mangal habitat (m)	0.0062	0.4059	0.4048	59.9553	0.001	geomorph
12	hour of observation	0.0041	0.4100	0.4088	39.9189	0.001	time
13	no. campsites 2wd 0-15min	0.0037	0.4137	0.4124	36.0861	0.001	accomm
14	quadbikes recorded	0.0034	0.4171	0.4157	33.8868	0.001	infra
15	no. moorings rec	0.0032	0.4203	0.4188	32.1095	0.001	infra
16	no. camping areas 2wd 3-3.5h	0.0028	0.4232	0.4216	28.4785	0.001	accomm
17	no. campsites 2wd 1.5-2h	0.0042	0.4274	0.4257	42.2016	0.001	accomm
18	is national park	0.0034	0.4308	0.4290	34.9691	0.001	zoning
19	no. campsites 4wd 30-45min	0.0033	0.4341	0.4322	33.5756	0.001	accomm
20	no. camping areas 2wd 45-60min	0.0025	0.4366	0.4347	25.8610	0.001	accomm
21	adjacent to north-facing beach	0.0026	0.4392	0.4371	26.2828	0.001	geomorph
22	length of sandy beach (m)	0.0025	0.4417	0.4395	25.4702	0.001	geomorph
23	is school holiday spring	0.0024	0.4441	0.4419	25.0681	0.001	time
24	is school holiday winter	0.0023	0.4464	0.4441	23.8188	0.001	time
25	is school holiday autumn	0.0023	0.4487	0.4463	24.3941	0.001	time
26	no. campsites 2wd 3-3.5h	0.0020	0.4507	0.4482	21.0683	0.001	accomm
27	no. campsites 4wd 1.5-2h	0.0019	0.4526	0.4501	20.4188	0.001	accomm
28	no. campsites 4wd 2-2.5h	0.0024	0.4550	0.4524	25.0499	0.001	accomm
29	no. camping areas 4wd 3.5-4h	0.0024	0.4575	0.4547	25.9886	0.001	accomm
30	no. camping areas 4wd 2-2.5h	0.0025	0.4599	0.4571	26.2530	0.001	accomm
31	no. camping areas 2wd 2.5-3h	0.0021	0.4620	0.4591	22.6332	0.001	accomm
32	no. camping areas 2wd 0-15min	0.0020	0.4640	0.4610	21.3205	0.001	accomm
33	no. campsites 4wd 2.5-3h	0.0018	0.4659	0.4628	19.8192	0.001	accomm
34	no. camping areas 2wd 3.5-4h	0.0015	0.4674	0.4642	16.6015	0.001	accomm
35	no. campsites 4wd 3.5-4h	0.0014	0.4688	0.4656	15.6842	0.001	accomm
36	area of sanctuary zone	0.0011	0.4700	0.4666	12.1075	0.001	zoning
37	area of special purpose zone ¹	0.0017	0.4717	0.4683	18.8116	0.001	zoning
38	no. camping areas 4wd 0-15min	0.0012	0.4729	0.4694	13.3177	0.001	accomm
39	length of north-facing beach	0.0011	0.4741	0.4705	12.5668	0.001	geomorph

Appendix 9-2. Technical notes on the analysis of the shore-based recreational data from Ningaloo.

Data transformation

The main difference of these activity profiles to conventional species profiles is that recreational users can, and are likely to, change the conducted activity, whereas in ecological data, individuals cannot change their species. Therefore, the assumptions, under which species profiles are transformed prior to ordination (Legendre and Gallagher, 2002, meaningful transformations) are not met in this case, and the data were merely square-root transformed to reduce skewness (Legendre and Legendre, 1998).

Processes at the scale of the spatial resolution

The effects of crowding were not tested explicitly, because the observed users' intention and history of choosing an appropriate beach segment were not surveyed for the modelled data (Smallwood, 2009). Furthermore, the scale of the smallest structure technically detectable in our analysis (2.096 km) exceeds > 99 % of the distances walked by recreational users from their vehicle to the location of their recreational activity on the beach, which was on average 100m with a range of up to 1.5 km (Smallwood, 2009). Therefore, the effect of users using the beaches directly adjacent to overcrowded beaches could not directly be analyzed.



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