Spatial and temporal patterns of recreational use at Ningaloo Reef, north-western Australia

This thesis is presented for the degree of Doctor of Philosophy in the School of Environmental Science, Murdoch University

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DECLARATION

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary educational institution.

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Claire B. Smallwood Date

Abstract

Worldwide, studies of recreational use at fine temporal and spatial scales within marine protected areas are rare, even though this knowledge is essential for successful management with respect to biodiversity conservation, resource allocation and visitor experiences. Ningaloo, a diverse fringing coral reef extending 300 km along the coast of north-western Australia, is reserved as a multiple use marine park. Its isolation from major population centres and limited access has, until recently, shielded it from extensive tourism. However, a growing population and increased publicity have led to a growth in visitor numbers and development pressure. This study aimed to map the fine-scale patterns of recreation at Ningaloo over a 12-month period using a multi-faceted survey approach which recorded >40 000 people. Synoptic patterns were described from 34 aerial surveys, while specific activities (e.g. recreational line fishing, snorkelling and windsurfing) were characterised using 192 land-based coastal surveys. During peak months from April to October, spatial distribution and density of use increased by up to 50% and included expansion of boating activity beyond the sheltered lagoon environment. Sandy beaches were preferred sites for recreation and people were generally clustered around infrastructure such as boat ramps and camping sites. Park zonation influenced activities and recreational fishers exhibited >85% compliance with sanctuary zones. Significant relationships between user characteristics, recreational activities and adjacent land tenure (e.g. national parks and pastoral leases) were revealed through analysis of 1 208 interviews with people participating in recreational activities on the shores of the Marine Park. These geo-referenced interview data allowed tracing of travel pathways from accommodation to coastal access points (or boat ramps) and recreation sites and highlighted the node-focused nature of visitor use. Strong clustering and rapid distance decay was especially evident from beach access points, with a median distance of 100 m travelled for shore-based recreation. The robust and multi-

faceted sampling design applied in this study resulted in high spatial accuracy with strong congruency between different survey techniques and could be widely applied to other marine parks adjacent to coastlines. This study provides essential benchmark data on recreational use which can contribute to the design of cost-effective monitoring programs, enables managers to focus resources at high use sites and at peak times of year, and predict effects of coastal developments in dispersing or concentrating visitor use.

Table of Contents

Chapter 5 Characterizing fine-scale patterns of recreational use: a land-based approach

Chapter 6 Land tenure, user characteristics and their effects on patterns of recreational activity

Chapter 7 Identification and quantification of intra-regional travel networks

Chapter 8 Data integration and comparative analyses

Chapter 9 Applications and conclusions

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The financial support from CSIRO and the Wealth from Oceans Ningaloo Collaborative Cluster program was instrumental in the completion of this project; enabling the ambitious 226 day fieldwork program and contributing to many other costs associated with a project of this magnitude. I would also like to acknowledge the financial support of Murdoch University for their research and completion scholarships and the School of Environmental Science for PhD running costs.

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Chapter 1 General introduction

1.1 Introduction

Australia is an island nation and its beaches, coastal and marine environments are national icons; represented in a beach culture of 'sun, sea, surf and sand' which are highly valued by many Australians (James, 2000; Huntsman, 2002). These environs are easily accessible by the 80% of Australians who reside in coastal regions (Short and Woodroffe, 2009) and are the focus of many outdoor recreational activities such as swimming, surfing, fishing, boating and relaxing (Zann, 1995). Coastal waters are also economically important, supporting offshore oil and gas production, shipping, commercial fishing, aquaculture and tourism (Ward and Butler, 2006).

Recreational activities within these environments support one of the fastest growing facets of the tourism industry (Orams, 1999; Newsome *et al.*, 2002), providing a diverse range of experiences for domestic and international visitors. Activities 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 marine environment, such as reef walking or sunbaking on the beach (Orams, 1999). Coastal tourism developments (i.e. accommodation and restaurants) and their associated infrastructure (i.e. marinas, roads and boat ramps) which support these activities are also facets of marine tourism (Hall, 2001). These visitors within, and to, Australia spend ~$20 billion per annum on activities in coastal and ocean ecosystems (Ward and Butler, 2006) while providing employment for >0.5 million people (ABS, 2006a). Although some definitions of tourism and recreation vary, they share the same resources, use the same facilities and exert similar impacts (McKercher, 1996), and are therefore used in concert throughout this thesis.

While there are economic benefits to the communities who support these recreational activities, the coastal and marine environments in which they occur are under increasing threat from a wide variety of human pressures and environmental change (Hall, 2001; Sanderson *et al.*, 2002; Ban and Alder, 2008; Tolvanen and Kalliola, 2008). The major impacts from tourism can be summarised as those arising from land-based development (marinas, roads and resorts), marine-based infrastructure (moorings or pontoons), boat-induced damage (anchoring, littering and waste discharge), water-based activities (diving, fishing and reef walking) and wildlife activities (fish feeding, whale watching or swimming with whale sharks) (Harriott, 2004). These impacts have been well documented and include marine pollution, habitat damage, decline in the breeding success of wildlife, shoreline modification causing erosion and exploitation of aquatic organisms (Ban and Alder, 2008; Lloret *et al.*, 2008). Erosion of sand dunes and destruction of vegetation may also occur in the coastal environment by people accessing the beach on foot or via 4WD (off-road) vehicles for recreation (Newsome *et al.*, 2002). There are also social impacts which can include overcrowding, user conflicts and safety concerns (Crawford *et al.*, 1994; 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).

Ecological impacts are particularly pertinent for coral reefs, where the diversity of marine life and structural complexity attract many visitors (Newsome *et al.*, 2002; Davenport and Davenport, 2006). As well as threats from the aforementioned anthropogenic disturbances, coral reefs are also susceptible to natural stressors such as cyclones, diseases and introduced predators which impact on coral reefs at various spatial and temporal scales (Hughes and Connell, 1999; Hughes *et al.*, 2003). Although

coral reef systems have the capacity to recover from these natural disturbances, humans not only introduce new impacts but can exacerbate the effects of natural ones, thereby affecting the resilience of reefs to these effects (Nystrom *et al.*, 2000).

There has been significant research focused on these natural stressors and also on identifying the impacts from these anthropogenic pressures. However, to comprehensively protect and manage marine resources, an understanding of patterns and density of visitation and recreation must also be developed. This is essential for supporting management decisions, and providing rewarding experiences for visitors to coastal areas (Roggenbuck and Lucas, 1987; Ormsby *et al.*, 2004). However, in both terrestrial and marine environments, there are few locations where sufficient data have been collected to develop this understanding (Newsome *et al.*, 2002; Cole and Wright, 2004; Ban and Alder, 2008; Griffin *et al.*, 2008; Fernandes *et al.*, 2009). Integrated or multi-faceted approaches to data collection, which can be used to identify suitable methods for monitoring recreational activity, are also rarely considered in survey designs (Manning and Vaske, 2006).

Previous studies into recreational use of natural environments have been dominated by research in North American terrestrial settings and, it has only been in recent years, that the focus has shifted to coastal and marine environments. Many concepts developed in terrestrial settings, such as carrying capacity (originally an ecological term now adapted to tourism management), the recreational opportunity spectrum and limits of acceptable change, have been transferred to marine environments with some success. Setting descriptions, based on standard recreational opportunity spectrum classifications, were applied to recreation sites by the Great Barrier Reef Marine Park Authority in the Whitsunday Islands (GBRMPA, 2008). The concept of carrying capacity has also been

applied in specific marine locations, such Kaneohe Bay in Hawaii (Lankford *et al.*, 2006), or for specific activities, such as diving (Hawkins and Roberts, 1997; Zakai and Chadwick-Furman, 2002).

Recent management frameworks have developed from these early concepts to embrace the idea that protected areas should not only conserve ecosystems but also provide a range of opportunities for the different experiences sought by the diverse range of visitors (Ormsby *et al.*, 2004). These multiple use frameworks (which may also permit commercial and exploitative uses) have been widely implemented in Australia since the 1990s when a plan to establish a National Representative System of Marine Protected Areas was formulated. The primary aim of this system was to "establish and manage a comprehensive, adequate and representative system of Marine Protected Areas (MPAs) to contribute to the long term ecological viability of marine and estuarine systems, to maintain ecological processes and to protect Australia's biological diversity at all levels" (p.15) (ANZECC, 1999). Secondary aims included the management of human activities and the recreational needs of both indigenous and non-indigenous peoples, in accordance with this primary goal. Standard IUCN definitions of protected areas also allowed for multiple objectives of ecosystem protection and recreation (Laffoley, 2008).

MPAs are currently considered the foremost management option for conservation of marine biodiversity, fisheries and other human uses of the ocean. They not only control against overexploitation of resources (McClanahan and Mangi, 2000) and resolve user conflicts (Agardy, 1993; Lynch *et al.*, 2004) but also provide connective networks from which larvae and adult marine organisms can disperse to adjacent areas and enhance ecosystem resilience (Nystrom *et al.*, 2000; Hughes *et al.*, 2003; Almany *et al.*, 2009). Most Australian states have either gazetted, or are moving towards the implementation

of, these MPA networks. Both of Australia's iconic coral reef systems, the Great Barrier Reef (GBR) (in Queensland) and Ningaloo Reef (in Western Australia), are located within multiple use MPAs (Figure 1-1). Both these MPAs comprise >30% sanctuary (no-take) areas and, combined with other management initiatives, such as reduced bag limits for recreational fishing, aim to ensure the sustainability of these ecosystems in the face of increasing human and environmental pressures. However, this is complex, with a diversity of perspectives and goals within management systems which are often in conflict (Crosby *et al.*, 2000).

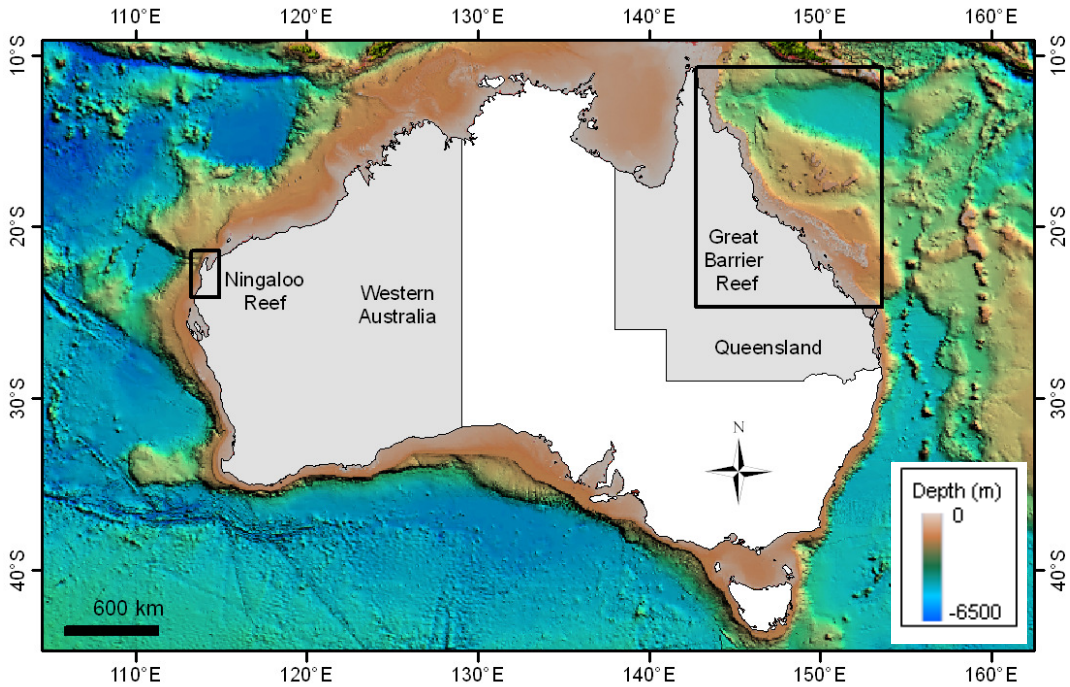


Figure 1-1 Bathymetry of waters surrounding the Australian landmass (Petkovic and Buchanan, 2002) along with location of Ningaloo Reef, in Western Australia, and the Great Barrier Reef, in Queensland, which are both gazetted multiple use marine parks.

Although the biological diversity of these two coral reef systems is comparable (Lough, 1998; CALM and MPRA, 2005), their structure, and that of the surrounding environment, is vastly different. The GBR covers an area ~12 times larger than Ningaloo. However, at 300 km in length, Ningaloo is one of the largest fringing reef systems in the world (Wilkinson, 2008)and is easily accessible from the shore while the

reef crest provides a coastal environment sheltered from large swells. Unlike the GBR, Ningaloo is isolated from large population centres and limited coastal development enables remote coastal camping opportunities in many locations. It is also one of the few places in the world which supports an industry based on whale shark interactions (worth ~$12 million per annum) (Davis *et al.*, 1997), in addition to other opportunities to encounter manta rays, turtles and whales. These attractions (and others) support a tourism industry which provides for ~200 000 visitors annually (CALM and MPRA, 2005) which, although considerably less than the 1.9 million visitors to the GBR (GBRMPA, 2006), is increasing annually.

Although Ningaloo Reef is in a relatively healthy condition (Wilkinson, 2008), in recent years there has been coral mortality caused by bleaching, pollution and cyclones as well outbreaks of *Drupella* (a marine snail which feeds on coral tissue) (Beeton *et al.*, 2006). Commercial harvesting of whales and turtles also occurred in the early 20th century, and while these have since ceased (Storrie and Morrison, 2003), commercial fishing still occurs along sections of the coast (Fletcher and Santoro, 2008). Offshore production of oil and gas, worth $16 billion to the state government, has also been developed on the nearby North-West Shelf, which extends to the north and east of Ningaloo. The frequency of bleaching and cyclones are predicted to increase in the future (Wilkinson, 2008)and, combined with increasing visitation and development, are expected to place further pressure on the reef system.

To address concerns regarding the unsustainable use of protected areas by visitors, monitoring programs should be used to document these patterns, to provide warning of abnormal conditions, support management initiatives (Wilkinson *et al.*, 2003; Bennetts *et al.*, 2007) and evaluate their effectiveness (Hockings *et al.*, 2000). Topics requiring

research to establish baseline data and greater understanding of relevant processes should be supported, although care should be taken to ensure these findings are communicated to management (Agardy, 2000; Cole, 2006; Simpson *et al.*, 2008). Challenges for research into recreational use stem from its variability, as it operates over broad spatial and temporal scales (as do the biophysical processes and ecosystems with which these activities interact). Therefore, access to current, comprehensive and reliable spatial information is necessary for informed decision-making in managing recreational activities in coastal and ocean environments (Smith, 1990; Canessa *et al.*, 2007).

The recent and widespread use of GIS has facilitated a spatial context to the collection of data, providing a powerful data analysis tool (McAdam, 1999). The incorporation of geo-referenced data is essential for replication, site revisitation and developing an understanding of the spatial complexities of systems. However, there are still datasets which lack this geo-referenced context and, there is rarely standardisation of spatial scales, with many different dimensions used for data reporting which can result in loss of resolution and difficulties in comparing data between studies (Eastwood *et al.*, 2007). The temporal context of activities should also be considered, with factors such as weather and holidays likely to affect the level of participation. Many previous studies have been cross-sectional rather than longitudinal in scope (Hammitt *et al.*, 2001) and expanding survey-based research into this context has several benefits in allowing more in-depth analysis of visitor trends (Legare and Haider, 2008) and a greater understanding of usage patterns.

Recreational use should also be placed within the context of the wider geographic area, with a high degree of connectivity between land and the adjoining coastal and marine environment (IUCN, 1999). Early studies investigated travel networks between

destinations (Campbell, 1966; Mings and McHugh, 1992) while recent research has focused on intra-regional travel networks of people within a destination area (McKercher *et al.*, 2008), although these are rarely quantified. Various coastal components which can be applied to these pathways were described by Pearce and Kirk (1986) as the hinterland, transit zone and recreational activity zone. This representation of the tourism system and coastal environment is appropriate for Ningaloo, with service centres (which provide accommodation and facilities) along with limited access gateways located in the hinterland (or coastal strip) adjacent to the Marine Park. From these locations, people move to the transit zone (sand dunes) and thence into the recreational activity zone (beach and sea). This thesis will utilise these components to provide a framework for understanding the recreational travel networks within the Ningaloo region. It will also provide a fine-scale spatial and temporal context to understanding patterns of recreational activities and coastal use which are required to meet monitoring and management needs.

1.2 CSIRO Wealth from Oceans Ningaloo Collaborative Cluster

This research was funded by the Ningaloo Collaborative Cluster, which contributes to a larger Commonwealth Scientific and Industrial Research Organisation (CSIRO) Wealth from Oceans Flagship program entitled, "Marine Nation: Regional Marine Development and Growth". The overall aim of this cluster is to describe the key processes whereby humans and the reef interact with particular focus on the ecological, social and economic values of the Ningaloo Marine Park. Several components contribute to this research initiative (Figure 1-2). These components are being undertaken by a number of research institutions across Australia, with the outputs from each of the first four projects contributing to the development of an integrated ecosystem and socio-economic model created within a management strategy evaluation

framework (Project 5). This PhD research project was conducted under the umbrella of Project 2 entitled, "High resolution mapping of reef utilisation by humans", with fieldwork directly contributing data to the project milestones.

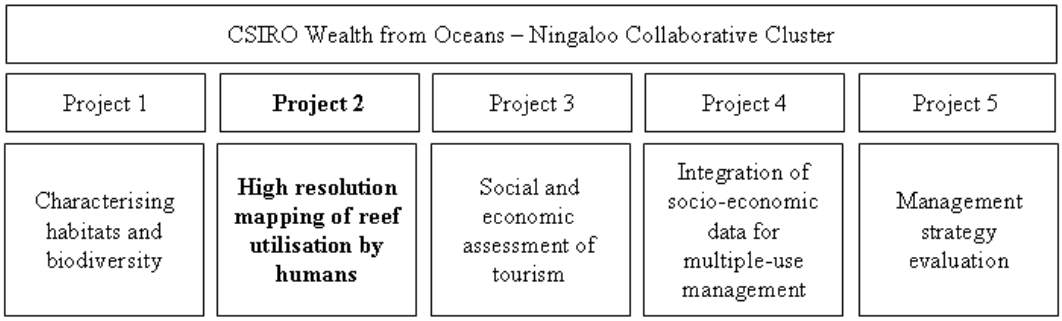


Figure 1-2 Diagrammatic representation of the various Ningaloo Collaborative Cluster components.

1.3 Research aims

The overarching aim of this research was to describe the spatial and temporal patterns of recreational use in the Ningaloo Marine Park. This broad research objective was addressed through several focused objectives, including:

a) determining the patterns of recreational use using different survey techniques,

b) describing the characteristics of recreational participants,

c) identifying and quantifying the intra-regional travel pathways of recreational participants,

d) testing the congruency of data from all survey techniques and determining their effectiveness in identifying nodes of recreational pressure,

e) identifying and discussing the major factors influencing the distribution and characteristics of recreational use; and

f) linking the outcomes of these objectives to management and monitoring.

1.4 Thesis structure

This thesis consists of nine chapters. Chapter 1 sets the research context and establishes the study objectives. Chapter 2 describes the study area and identifies current knowledge gaps in recreational use patterns at Ningaloo.

Chapter 3 discusses the broader survey design as well as each of the techniques (aerial surveys, land-based coastal surveys and on-site interviews) used to collect geo-referenced data on recreational use. Chapter 4 provides a synoptic description of use patterns that were identified using aerial surveys while Chapter 5 focuses on case studies of specific recreational activities utilising data collected during land-based coastal surveys.

The next two chapters feature the results from the on-site interviews with people participating in recreational activities along the shoreline. Chapter 6 focuses on demographics, visit attributes and activity participation with respect to the various land tenures associated with the coastal strip adjacent to the Marine Park. Chapter 7 describes the intra-regional travel networks of these recreationalists and identifies areas which are likely to be exposed to the highest levels of use.

Chapter 8 explores the level of congruency between the survey approaches and explores comparative analyses against an index of tourism pressure. Importantly, in this chapter, are comparisons of results obtained from all survey methods discussed previously in the thesis. Chapter 9 is the concluding chapter and describes how results from this study can be applied in monitoring, management and future research at Ningaloo and marine protected areas elsewhere.

Chapter 2 Ningaloo Reef: attributes and literature review

2.1 Study area

2.1.1 Physical and environmental attributes

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 (Wilkinson, 2008)(Figure 2-1). Extending ~300 km along the coastline, it is also the only extensive reef system of its kind situated along the western side of a continent (Collins *et al.*, 2003). Its proximity to the shore is due to both the aridity of the region, which results in extremely low levels of run-off, and the warm southward flowing Leeuwin current (CALM and MPRA, 2005).

The physical structure of a fringing reef system differs from a barrier reef as a shallow lagoon (<5 m deep) is formed along the coast, as opposed to a wide expanse of deeper water, such as at the Great Barrier Reef (Spalding *et al.*, 2001). At Ningaloo, the lagoon environment varies in width between 0.2 – 7 km, with an average distance of 2.5 km (CALM and MPRA, 2005) (Plate 2-1). This reef crest also shelters the coast from the prevailing southerly swell, attenuating up to 90% of wave energy (Sanderson, 2000). However, at the southern and northernmost limits of the reef, the lagoon disappears and the reef forms a discontinuous ridge adjoining the coast creating expansive intertidal reef platforms (Plate 2-2).

The coastal geomorphology of Ningaloo Reef is highly variable. The coastline adjacent to the northern extent of the Reef is dominated by sandy beaches with isolated patches of mangroves and intertidal platforms, backed by a coastal plain and elevated limestone ridge (Plate 2-1). This ridge, known as Cape Range, has a maximum height of ~450 m,

contains an extensive cave system and is dissected by numerous deep gorges (CALM, 2005). Cape Range dissipates to the south of Yardie Creek and the southern extent of the Ningaloo coast is characterised by complex dune systems, rocky shores, intertidal platforms and limestone cliffs interspersed with pockets of sandy beaches (Payne *et al.*, 1987) (Plate 2-2).

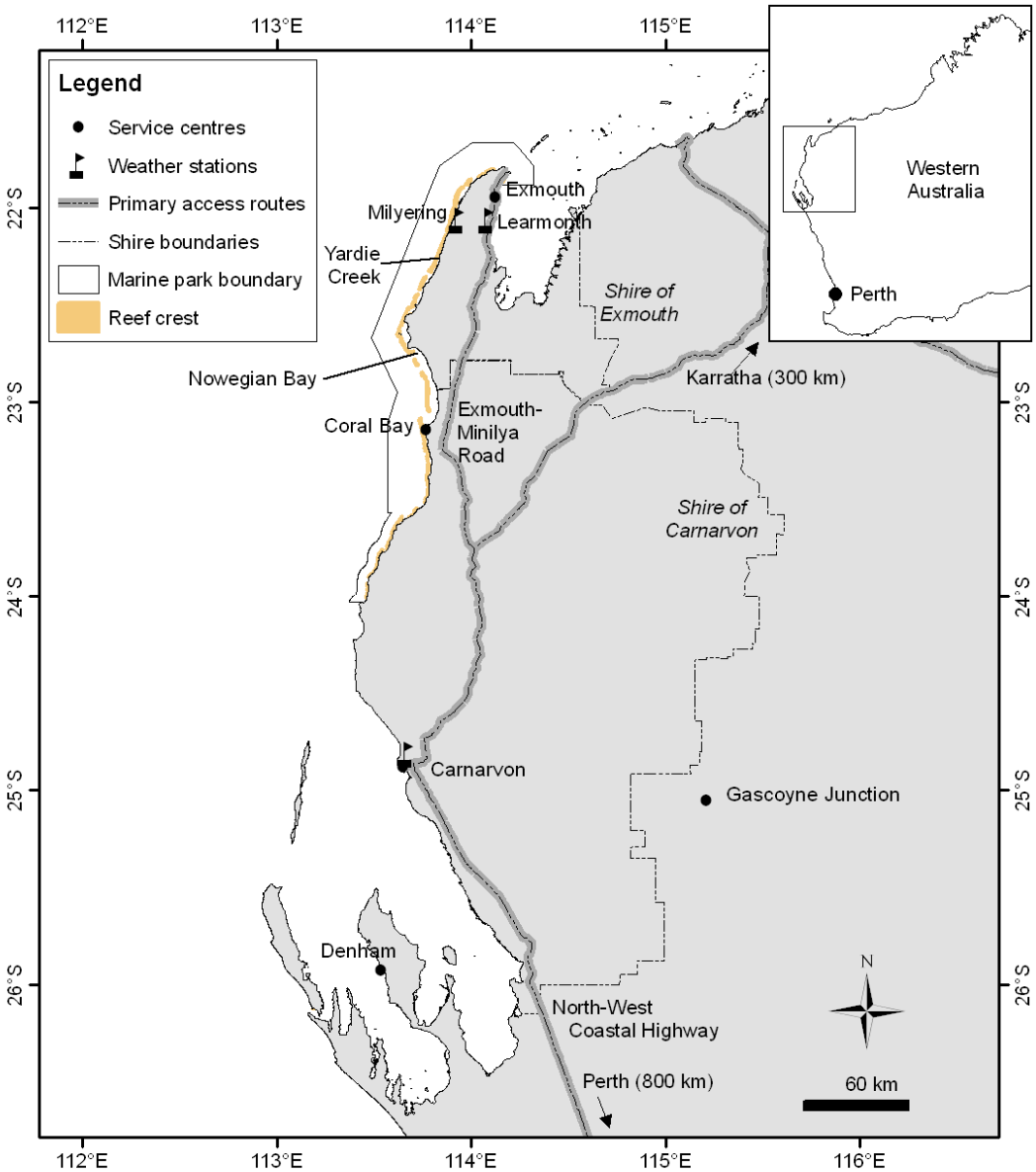


Figure 2-1 Gascoyne region of Western Australia, identifying the location of shire boundaries, major settlements, primary access routes, marine reserve boundaries, Ningaloo reef crest and weather stations (source: Bureau of Meteorology/Australian Institute of Marine Science, 2007).

Plate 2-1 Aerial view of the northern extent of Ningaloo Reef highlighting the fringing reef crest, sheltered lagoon and sandy beach environments flanked by a coastal plain and elevated limestone ridge known as Cape Range (source: C. Smallwood, 2007).

Plate 2-2 View of Red Bluff, located at the southern extent of Ningaloo Reef, highlighting the intertidal reef platforms and cliffs interspersed by sandy beaches (source: C. Smallwood, 2007).

Water movement in the lagoon is controlled by tidal flow, wave action and wind driven circulation (Collins *et al.*, 2003). Water enters the lagoon through the action of waves pumping over the reef crest (D'Adamo and Simpson, 2001) while irregular passages that intersect the reef crest allow water from the lagoon to return the oceanic environment. Large-scale currents also influence Ningaloo Reef and are dominated by the southward flowing Leeuwin current, which is strongest in autumn and winter (Pearce and Griffiths, 1991), and the northward flowing Ningaloo current, which is strongest in spring and summer (Taylor and Pearce, 1999; Woo *et al.*, 2006). Tides are also variable along the Ningaloo coast, decreasing southwards from a maximum range of 2 m and changing from semi-diurnal (e.g. 2 highs and 2 lows per day) to mixed (but still predominantly semi-diurnal) along this same gradient (Commonwealth of Australia, 2002).

The climate of Ningaloo Reef is arid, with a hot summer from October to April and mild winter for the remaining months (BOM, 2009). The hottest and coolest months in the region are January and July, respectively, and there are wide variations in the air temperatures experienced along the length of the coast (Figure 2-2). These variations are caused by factors such as weather systems crossing the coast in the southern half of Western Australia and the blocking influence of the Cape Range. There are also variation in the wind patterns, with stronger mean wind speeds between October and May especially at Carnarvon (Figure 2-3). These wind conditions are dominated by south-easterly trade winds during the morning and south-westerly seabreezes in the afternoon (BOM, 2009), especially during the summer months at Learmonth and Milyering (Figure 2-4a,b). However, there is a higher proportion of southerlies in the Carnarvon area, especially from September to May (Figure 2-4c). The average annual rainfall of between 200 - 300 mm is caused by either the occurrence of cyclones (from

November to May), or the influence of cold fronts crossing the coast during the winter months.

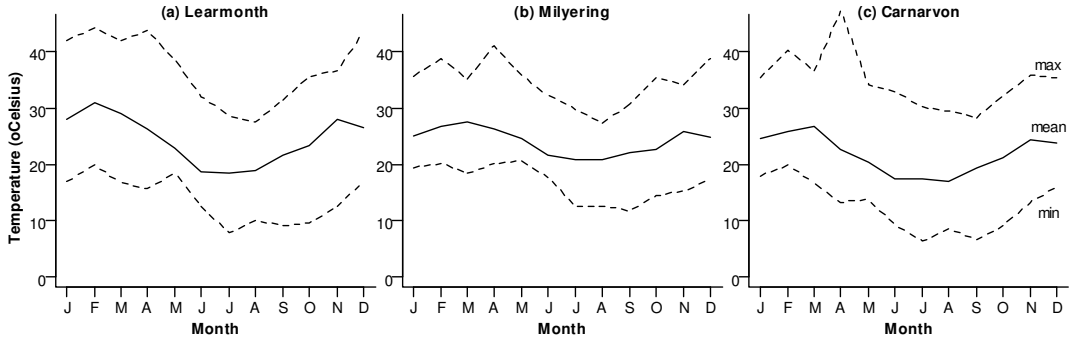


Figure 2-2 Monthly minimum, mean and maximum temperatures (in °Celsius) in 2007 for weather stations in the (a) northern (Learmonth), (b) middle (Milyering) and (c) southern (Carnarvon) extents of the Ningaloo coast (source: Bureau of Meteorology/Australian Institute of Marine Science, unpublished data).

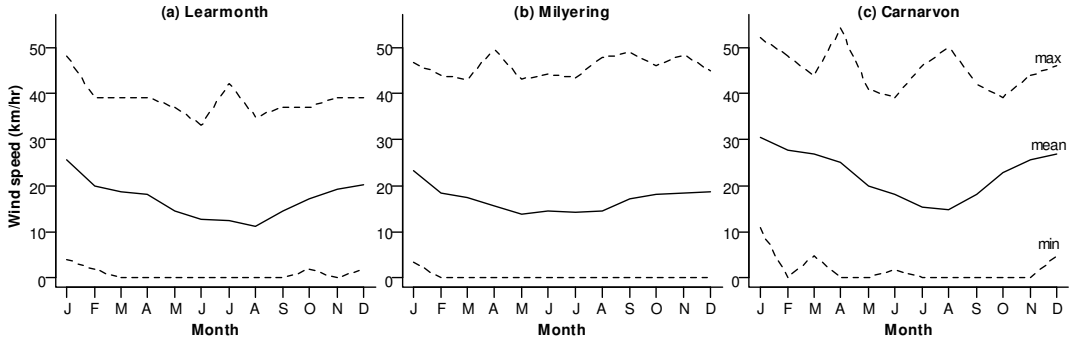


Figure 2-3 Monthly minimum, mean and maximum wind speeds (km/hr) in 2007 for weather stations in the (a) northern (Learmonth), (b) middle (Milyering) and (c) southern (Carnarvon) extents of the Ningaloo coast (source: Bureau of Meteorology/Australian Institute of Marine Science, unpublished data).

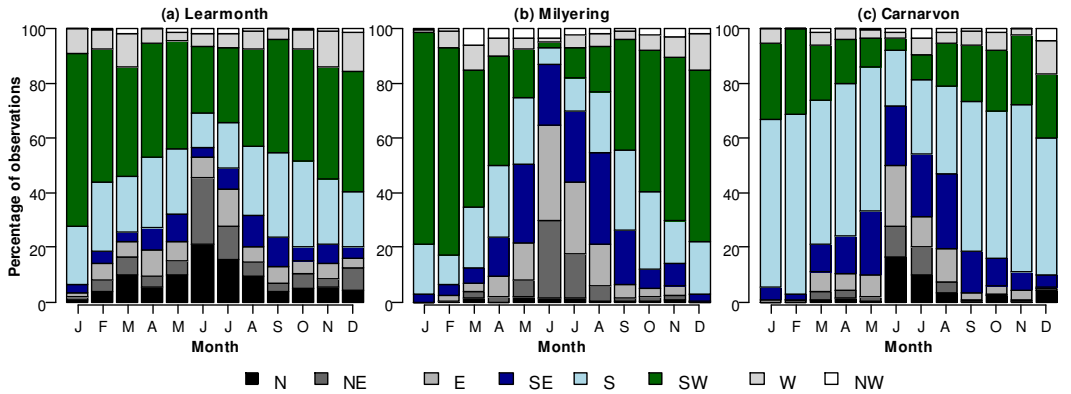


Figure 2-4 Percentage of time for each wind direction within each month of 2007 for weather stations in the (a) northern (Learmonth), (b) middle (Milyering) and (c) southern (Carnarvon) extents of the Ningaloo coast (source: Bureau of Meteorology/Australian Institute of Marine Science, unpublished data).

2.1.2 Biological attributes

Ningaloo Reef has traditionally been described as located within the West Coast Overlap Zone; an area where southern temperate biota overlap with those from the tropical north (Morgan and Wells, 1991). More recently, as part of the integrated marine and coastal regionalisation of Australian waters, Ningaloo has been assigned to its own region based on its unique ecological and physical features (Commonwealth of Australia, 2006). This classification identified the high level of complexity, abundance and diversity of Ningaloo, which is comparable to that of the Great Barrier Reef (Lough, 1998).

The diverse array of marine life documented at Ningaloo includes >900 fish species, 250 coral species (including representatives of all 15 families of hard or reef-building coral) and ~600 mollusc species (Hutchins *et al.*, 1996; Storrie and Morrison, 2003; Fox and Beckley, 2005). This diversity is further enhanced by the narrowness of the continental shelf, which is located only 6 - 10 km from the shore (Taylor and Pearce, 1999). This results in oceanic species such as migrating humpback whales, whale sharks and pelagic fishes being found extremely close to the shore. Manta rays are found within the lagoon area of Ningaloo Reef all year round and, along with whale sharks (which visit from April to July), are popular attractions for visitors. Turtles are also a popular attraction, with the sandy beach environments providing nesting locations for several species between December and March, especially at the northern end of Ningaloo Reef (Waayers and Newsome, 2006). Seagrass habitats throughout the region support small populations of dugongs (Preen *et al.*, 1997; Gales *et al.*, 2004) and play a key role in primary production and habitat for invertebrate fauna, as do macroalgae beds (CALM and MPRA, 2005).

The richness and diversity of coastal vegetation at Ningaloo is also indicative of the unique geomorphological and climatic characteristics of the region, with ~600 species of flora recorded (CALM, 2005). As with marine organisms, this includes a diversity of both temperate and tropical species. The aridity of the region supports predominantly low lying vegetation associations, such as perennial shrubs and grasslands, along with a high proportion of annual (short-lived) species (Keighery and Gibson, 1993). The coastal strip adjacent to the Reef also supports a high diversity of native terrestrial animals, including the black-flanked rock wallaby, which is the focus of wildlife watching activities by visitors (CALM, 2005), along with rare subterranean stygofauna (Knott, 1993). However, there are also a number of exotic species introduced to the region by early settlers including domestic stock (i.e. sheep and goats), feral animals (i.e. foxes, cats, rats and rabbits) and weeds (i.e. buffel grass, a drought resistant perennial native to Africa).

2.1.3 Social attributes

Human associations with the Ningaloo coast began with the inhabitation of the Cape Range peninsula ~30 000 years ago by aboriginal tribal groups (Morse, 1993), with evidence of shell collecting for jewellery found in a rock shelter dating back to this time (Balme and Morse, 2006). Although commercial whaling and pearling was undertaken along the Ningaloo coast throughout the 19th century, European settlement did not occur until the 1880s, with the demarcation of several pastoral leases along the coast (Brandis, 2008). The construction of facilities (not associated with pastoral leases) began along the northern Ningaloo coast with the establishment of a Royal Australian Air Force station and bombing range in World War II. This was followed by the construction of a US Naval Communication Station (in 1963) around which the town of Exmouth was

built. Oil exploration and fishing were other key industries supporting the small local population during this time.

Commercial whalers became successful with a greater understanding of humpback whale migrations and this cumulated in the 1913 development of a shore-based processing station at Norwegian Bay, a mid-point of Ningaloo Reef (Figure 2-1). It remained open until 1955, when the station moved south to Carnarvon, before finally closing in 1963 (Storrie and Morrison, 2003). Turtle fishing was a major industry on the reef in the 1960s, with catch rates of 90 - 100 turtles per day, until it was terminated in 1972 (CALM and MPRA, 2005). Commercial diving for western rock lobster was permitted along the reef for many years (which has now been discontinued), however, commercial demersal line and prawn fisheries still operate in the region (Fletcher and Santoro, 2008).

Tourism along the Ningaloo coast was restricted for many years due to limited coastal access, although this did not prevent the reef being exposed to intense fishing pressure during the 1960-70s (Weaver, 1998; Mack, 2003). Some locations along the southern part of Ningaloo, such as Red Bluff, were also discovered as good surfing locations during these years (Wootton, 2007). The main road to Exmouth from the south was sealed in 1980 and this, as well as the creation of additional access roads to the northern part of Ningaloo, further increased fishing pressure. It was not until the US Navy withdrew in 1992, that a tourism industry centred on the natural features of the area was created. This was initially based fishing charters, but has since diversified into diving, coral viewing, whale watching and interactions with whale sharks or manta rays.
The current population of the Gascoyne is the lowest of all regions in Western Australia with ~10 000 residents concentrated in the towns of Carnarvon, Exmouth, Denham,

Coral Bay and Gascoyne Junction (Figure 2-1). This population is boosted in the winter months with ~276 000 domestic and international visitors spending between a few days to over 6 months in the region (GDC, 2006). Approximately 200 000 of these visitors travel to the Ningaloo coast (CALM and MPRA, 2005), forming the basis of a tourism industry which has grown rapidly in recent years and is now the largest contributor to the region's economy ($172 million per annum) (GDC, 2006). The tourism industry is focused on the Gascoyne region's unique natural attractions, such as Cape Range National Park (CRNP) and Ningaloo Reef. There are >40 tour companies, based in the service centres of Exmouth and Coral Bay, offering a wide range of opportunities for tourists to experience the natural environment and interact with wildlife such as manta rays and whale sharks. Agriculture and fishing have traditionally been the dominant industries in the region, and still support Western Australia's major trawl fisheries (prawns and molluscs) ($53 million per annum), pastoralism ($21 million per annum) and horticulture ($32 million per annum) (GDC, 2006).

The Gascoyne region covers >600 km of coastline, including that adjacent to Ningaloo Reef, which falls under the jurisdiction of two local government entities, the Shire of Exmouth and Shire of Carnarvon (Figure 2-1). The Western Australian waters of the Reef, which extend 3 nautical miles (nm) offshore, were originally gazetted as the Ningaloo Marine Park (NMP) in 1987; stretching from Bundegi in the north to Amherst Point in the south (Figure 2-5a). This was subsequently expanded southwards to Red Bluff in 2004, to include all Ningaloo Reef and cover an area of approximately 263 300 hectares (ha) (CALM and MPRA, 2005) (Figure 2-5b). It is a multiple use marine park that fits within an IUCN Category VI protected area classification (Laffoley, 2008) and contains designated sanctuary, recreation and general use zones, as well as special

purpose areas for shore-based activities (SBA) and benthic protection (BP). A general description of each zone type is provided in Table 2-1 while the specific permissible activities are listed in Table 2-2.

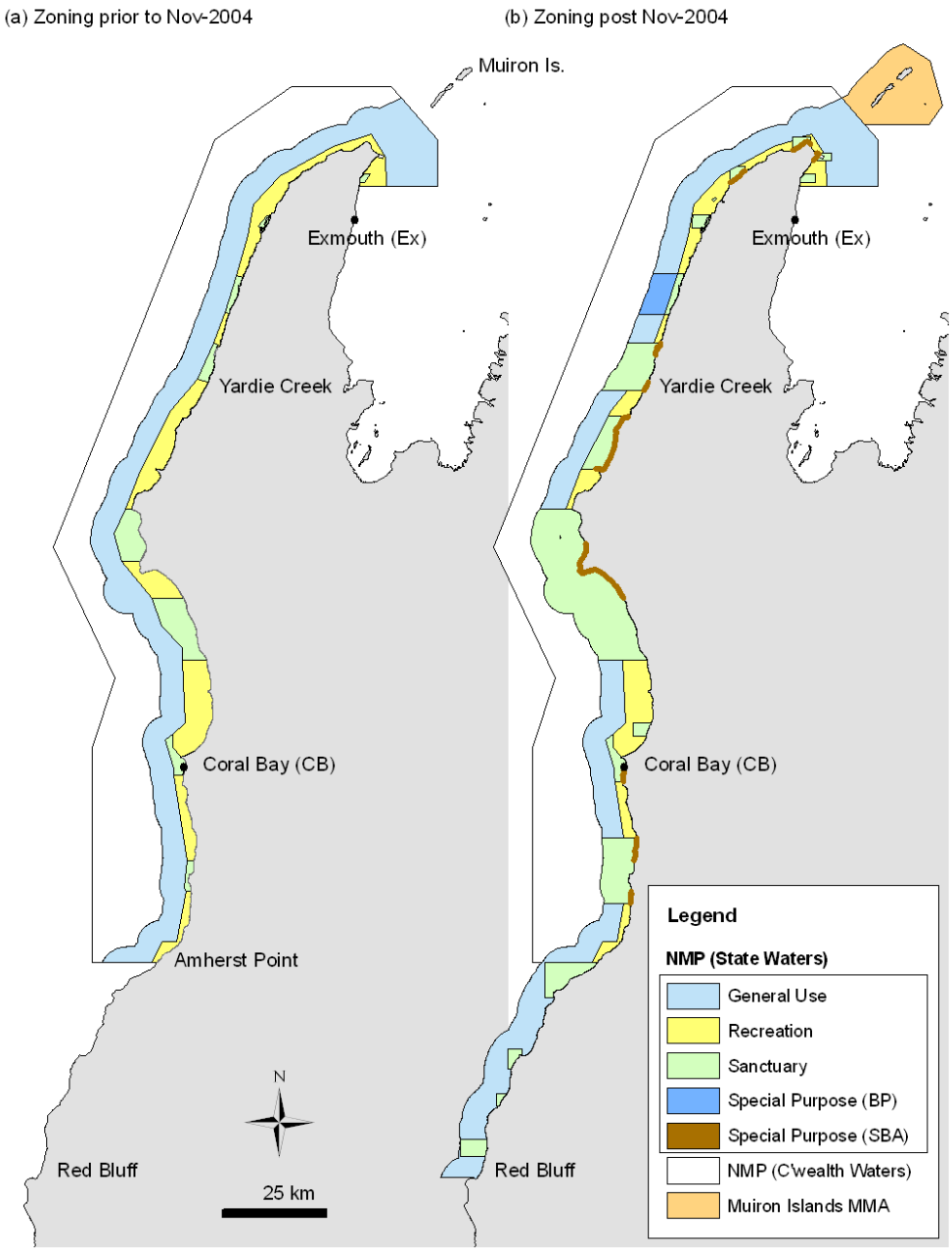


Figure 2-5 Marine parks and associated zoning boundaries enacted at Ningaloo Reef from (a) 1987 to Nov-2004 and (b) post Nov-2004 to present.

Table 2-1 General description of each zone type in the Ningaloo Marine Park, [adapted from CALM & MPRA (2005)].

Zone type	***General description***
Sanctuary	Managed for protection and conservation of marine biodiversity by excluding human activities that are likely to have adverse environmental impacts.
Recreation	Managed for conservation and recreation, including fishing and commercial tourism operations, where these activities are compatible with conservation values.
General use	Areas where conservation of natural values still a priority but activities such as commercial and recreational fishing, aquaculture and petroleum exploration may be permitted provided they do not compromise ecological values.
Special purpose zones	
Shore-based activities (SBA)	Managed for a particular purpose, such as fishing or seasonal event (i.e. wildlife breeding). Uses incompatible with the specified purpose are not permitted.
Benthic protection (BP)	Prioritised as a conservation area for benthic habitat.

The expansion of the Marine Park included an increase in sanctuary zones to 34% (from <10%) of the total area (CALM and MPRA, 2005). The NMP (state waters) is managed by the Western Australian Department of Environment and Conservation (DEC), formally known as the Department of Conservation and Land Management (CALM), on behalf of the Marine Parks and Reserves Authority in accordance with the *CALM Act 1984 (WA)* along with the Western Australian Department of Fisheries (DoF), who are responsible for the management of fisheries resources. The seaward extent of the NMP (state waters) is 3 nautical miles (nm) while the landward boundary is the high water mark, except for adjacent to, a pastoral lease (40 m above high water mark), Department of Defence land (low water mark), the navy pier (an exclusion zone for the Department of Defence) (Figure 2-6), and from Amherst Point and Red Bluff (low water mark) (CALM and MPRA, 2005).

Table 2-2 Description of permitted activities in each zone type in the Ningaloo Marine Park (state waters) [adapted from CALM & MPRA (2005)].

Activity	*Zone type*				
	General Use	*Recreation*	*Special purpose (shore)*	*Special purpose (benthic)*	*Sanctuary*
Commercial activities					
Trawling	Y/Limited	N	N	N	N
Beche de mer fishing	N	N	N	N	N
Long line fishing	N	N	N	N	N
Aquarium & shell collecting	Y/Limited	N	N	N	N
Collect coral, live sand & rock	N	N	N	N	N
Wet lining	Y/Limited	N	N	N	N
Rock lobster fishing	N	N	N	N	N
Mud crabbing	N	N	N	N	N
Beach seine	N	N	N	N	N
Trap fishing	N	N	N	N	N
Pearling	Y	N	N	N	N
Aquaculture	Assess	N	N	N	N
Mineral exploration	Assess	Assess	Assess	Assess	Assess
Drilling & mineral development	N	N	N	N	N
Pipelines	Assess	N	N	N	N
Charter vessels (fishing)	Y	Y	N	Trolling	N
Charter vessels (other)	Y	Y	Y	Y	Y
Recreational activities					
Boating	Y	Y	Y	Y	Y
Surface water sports	Y	Y	Y	Y	Y
Rock lobster fishing	Y	Y	N	N	N
Line fishing	Y	Y	Y (beach only)	Trolling	N
Netting (shore-based)	Y/Limited	Y/Limited	Y/Limited	N	N
Netting (throw net)	Y	Y	Y	N	N
Spearfishing	Y/Limited	Y/Limited	N	N	N
Collecting	N	N	N	N	N
Mud crabbing	Y	Y	N	N	N
Diving & snorkelling	Y	Y	Y	Y	Y
Wildlife interaction	Y	Y	Y	Y	Y
Other activities					
Marine infrastructure	Assess	Assess	Assess	Assess	Assess
Research	Y	Y	Y	Y	Y
Dredging & spoil dumping	Assess	N	N	N	N

The Ningaloo Marine Park (Commonwealth waters) extends from the limit of Western Australian coastal waters (3 nm offshore) a further 9 nm offshore (Commonwealth of Australia, 2002) (Figure 2-5). This area consists mainly of the waters and seabed of the continental shelf and slope. The southern boundary of the NMP (Commonwealth waters) was not extended past Amherst Point to correspond with changes to the NMP (state waters) in 2004, and no sanctuary zones are gazetted. Day-to-day management of these waters are undertaken by DEC and DoF through a memorandum of understanding with the Commonwealth of Australia.

The Muiron Islands Marine Management Area was gazetted in 2004 and covers 28 616 ha of which 1 928 ha (or 7%) are conservation areas. These conservation areas are similar to sanctuary zones in the NMP (state waters), however, petroleum industry activities are permitted. The remaining unclassified area of the marine management area can be equated to general use zones in the NMP and are managed accordingly.

Land tenures currently in existence along the Ningaloo coast include Cape Range National Park (CRNP), several pastoral leases, Commonwealth Department of Defence (DoD) Learmonth Air Weapons Range (Bunderra Coastal Protection Area), Unclaimed Crown Land, freehold land and, Jurabi and Bundegi Coastal Parks (Figure 2-6). CRNP is located along the coastal plain and rangelands adjacent to the northern part Ningaloo Reef. This park was first gazetted in 1964 and has since been expanded through the acquisition of the Yardie Creek pastoral lease to cover 50 500 ha (CALM, 2005). There are 13 coastal camping areas within CRNP (comprising 109 designated sites) which are charged at a nightly rate and DEC regulations limit campers to a maximum stay of 28 days.

Pastoral leases are enacted under the *Land Administration Act 1997 (WA)* and current leases in the region are due to expire in 2015. The five pastoral stations which adjoin the coast are named Ningaloo, Cardabia, Warroora, Gnaraloo and Quobba (Figure 2-6) and their primary income is based on sheep and goats which are farmed for wool and meat. However, decreased earnings from livestock in recent years have resulted in diversification into horticulture and tourism. Tourism activity usually comprises allowing people to access coastal camping areas, or accommodation such as eco-tents, which are located on the coastal strip adjacent to the NMP. These accommodation options are charged at a nightly rate. The state government is in the process of excising a 2 km wide coastal strip from these pastoral leases during the 2015 renewal process to facilitate conservation and sustainable development within this area (WAPC, 2004).

The Learmonth Air Weapons Range (Bunderra Coastal Protection Area) is managed by the DoD and covers an area of 18 954 ha. It was intended primarily for military training and weapons testing, although it is infrequently used for this purpose. Coastal camping is permitted free of charge at several locations in undesignated sites in this area. The Jurabi and Bundegi Coastal Parks are jointly managed by DEC and the Shire of Exmouth for the purpose of recreation (Shire of Exmouth and CALM, 1999) and are 1 287 and 462 ha in size, respectively. These parks contain several beaches which are significant areas for turtle nesting and associated wildlife watching activities (Birtles *et al.*, 2005). Coastal camping is not permitted in these locations.

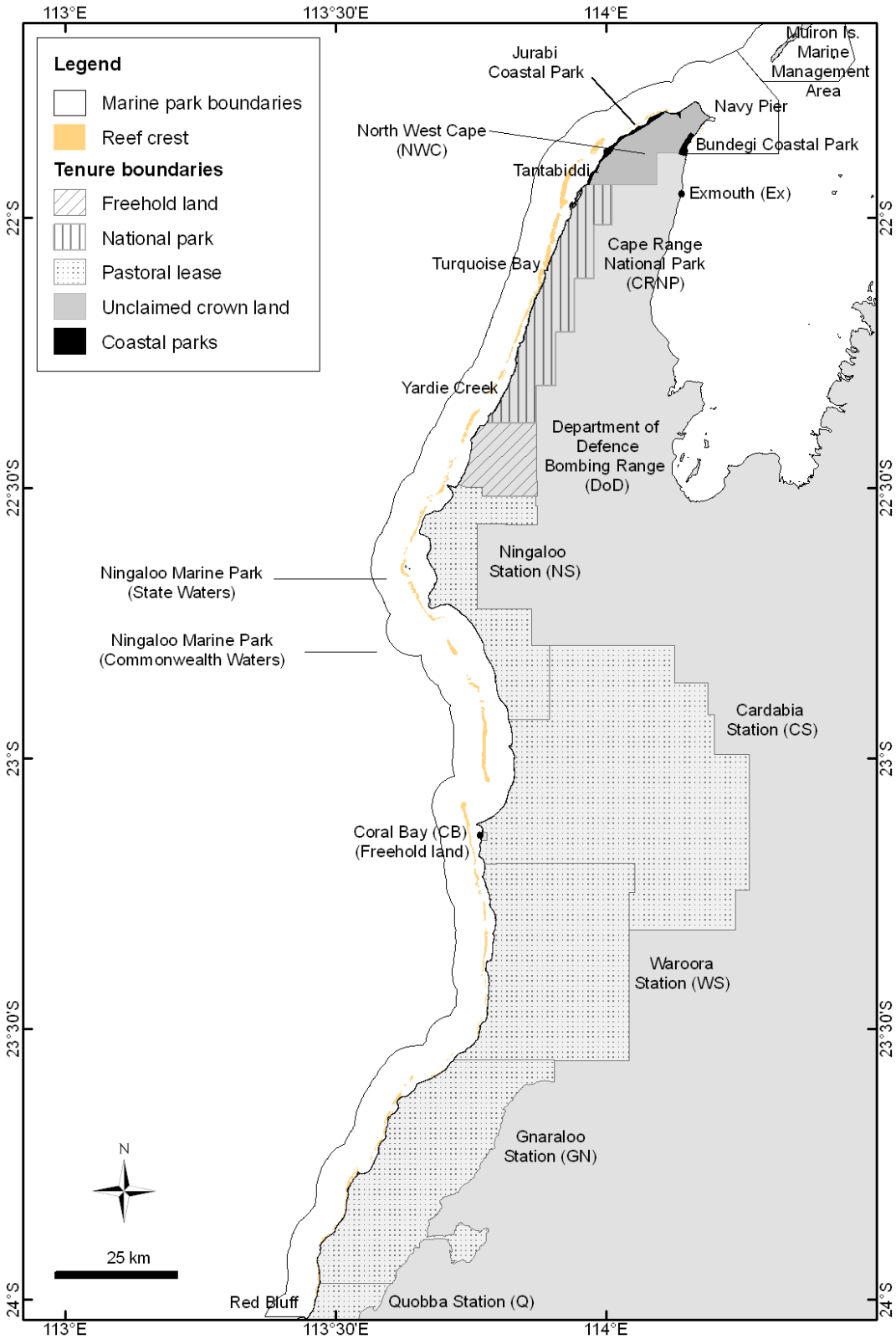


Figure 2-6 Current land tenure arrangements along Ningaloo reef and adjacent coast which include pastoral leases, freehold land, conservation areas, coastal and marine park boundaries.

2.1.4 Coastal access and infrastructure

The proximity of Ningaloo Reef to the coastline greatly increases its accessibility to visitors. However, this is restricted by the limited number of roads and tracks in the region, many of which are only accessible by 4WD (off-road) vehicles. The main gateway to the Marine Park is via the North-West Coastal Highway, which extends southwards, through Carnarvon, to Perth and northwards to Karratha and Darwin (Figure 2-1). The Exmouth-Minilya Road links the North-West Coastal Highway to Exmouth. Coral Bay is an additional central accommodation and supply node between Exmouth and Carnarvon which also provides access to the coast. These roads are sealed and suitable for access by 2WD vehicles, as is the Yardie Creek Road which extends southwards along the length of CRNP to Yardie Creek. Yardie Creek is a natural barrier that limits access to the DoD Bombing Range, Ningaloo and Cardabia Stations to 4WD only (CALM, 2005). The remainder of the access roads to the NMP are through the pastoral leases and consist mainly of gravel or sand tracks, of which the majority are only accessible by 4WD vehicles.

The main service towns for the Ningaloo coast are Carnarvon, Exmouth and Coral Bay. Carnarvon is the local government centre for the Gascoyne region and, unlike Exmouth or Coral Bay, employment is not dominated by tourism and its associated industries. It is located ~120 km from the southern tip of the NMP, and is not generally used as a base for day trips to the Reef. Coral Bay is a small community, with ~150 residents, which is dominated by the tourism and hospitality industries. Accommodation in the town is provided for ~1 850 visitors in two caravan parks, a hotel, backpackers and rental accommodation (WAPC, 2004). Exmouth has a population of ~2 000 people (ABS, 2006b) and is also dominated by the tourism and hospitality industries. There are

several caravan parks, hotels and self-contained units throughout the town supplying accommodation for >4 000 visitors during the peak months (Shire of Exmouth, 2007).

2.2 What are the knowledge gaps in recreational use patterns?

The first visitor survey was conducted at Ningaloo by DEC in 1982-83 along North-West Cape, prior to the Marine Park being declared in 1987. Since then, a number of studies have been completed by government agencies and research institutions. These have generally been cross-sectional, with a narrow temporal focus and at broad spatial scales, with little geo-referenced data collected (Table 2-3). Gnaraloo and Quobba Stations were only incorporated into the Marine Park in 2004, so little research was focused on these areas prior to this time. Regulated industries, such as charter boat operators, who are required to fill in logbooks as part of their licence requirements, provide some ongoing data sources. Although limited in time and space, these studies provide some understanding of recreational activities along the Ningaloo coast and have been used to provide background information and identify the knowledge gaps in recreational use patterns for this current study.

There are no accurate estimates of the total number of visitors to the NMP. This is difficult to calculate due to the open access and diffuse nature of the marine environment, large number of undesignated coastal camping areas and location of service centres, such as Exmouth, outside the NMP boundary which are used as a base for day trips. The current NMP management plan estimated there were ~200 000 visitors to Ningaloo in 2004 (CALM and MPRA, 2005) while the regional development strategy reported that this number of visitors has been attained annually since 1996 with a record number of domestic visitors (280 000) in 1999 (WAPC, 2004). Tourism Western Australia figures provide an average of 96 700 visitors annually to the

Table 2-3 Timeline, survey method, sampling frequency and spatial extent of human use studies and monitoring undertaken in the NMP and along the coastal strip from 1982 - 2007.

Year	*Area of interest (reference)*	*Fieldwork method and sampling frequency*	*Fieldwork location (based on land tenure shown in Figure 2-6)*									
			Ex	*NWC*	*CRNP*	*DoD*	*NS*	*CS*	*CB*	*WS*	*GN*	*Q*
1982	Visitor survey (DEC, unpublished)	Workshop and interviews; unknown	■	■			■	■	■	■	■	
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990	Environment-toursim relationships (Dowling 1991, 1993)	Interviews; Jan, July, Oct		■	■							
1991	Environment-toursim relationships (Dowling 1991, 1993)	Interviews; Apr		■	■							
1992	Recreational fishing (DoF, unpublished)	Interviews; Apr - Oct	■	■	■	■	■	■	■	■	■	■
1993												
1994												
1995	Camping surveys (DEC, unpublished)	Aerial flights; ongoing; 2 flights per year (Apr, Jul)			■	■	■	■	■	■	■	■
	Whaleshark logbooks (Wilson *et al.* , 2007)	Logbooks; ongoing	■	■	■			■	■			
1996												
1997	Tourism surveys (Wood, 2003a,b)	Interviews, mail surveys; Apr 1997, 2000-2002, July 2002					■	■	■	■	■	■
1998												
1999	Recreational fishing (Sumner and Williamson, 1999)	Boat ramp and access point survey; 12 months (3-12 days/month)	■	■	■	■	■	■	■	■	■	■
2000	Human use review (Cary, 2000)	Desktop study	■	■	■	■	■	■	■	■		
	Fisheries compliance (DoF, unpublished)	Observations, interviews; Ongoing	■	■	■	■	■	■	■	■	■	■
2001	Resident survey (Hollet, 2001)	Door-to-door survey; April (8 days)	■									
	Unmanaged camping survey (Remote Research, 2002)	Interviews; Aug (4 days)				■	■	■				
2002	Charter fishing (DoF, unpublished)	Logbooks; ongoing	■	■	■	■	■	■	■	■	■	■
	Unmanaged camping survey (Remote Research, 2002)	Interviews; May (4 days)				■	■	■				
2003	Vehicle counters (DEC, unpublished)	Vehicle counters; ongoing			■							
	Pastoral station survey (Galloway and Northcote, 2003)	Interviews; July					■			■	■	
	CRNP visitor surveys (Moore & Polley, 2007)	Interviews; July			■							
2004												
2005	Coral Bay boating survey (Worley Parsons, 2006)	Interviews; June, July, Aug, Oct (6 days/trip)							■			
	Resident socio-economic surveys (Ingram, 2005)	Mail surveys; Sept	■						■			
2006	Coastal camper survey (Northcote and McBeth, 2007)	Interviews; July, Aug			■		■			■		
	Coral Bay boating survey (Worley Parsons, 2006)	Interviews; Jan, Apr (6 days/trip)							■			
	Trip log book (Hughes and Mau, 2006)	Observations; intermittent	■	■	■	■	■	■	■	■	■	■
2007	Recreational fishing (DoF, in preparation)	Boat ramp and access point survey; 12 months (3-12 days/month)	■	■	■	■	■	■	■	■	■	■
	Human use study (current project)	**Observations, interviews; 12 months (20-22 days/months)**	■	■	■	■	■	■	■	■	■	■

Shire of Exmouth, based on data collected between 2005 and 2007 (Tourism WA, 2008b) and it has been assumed in previous research that most visitors to Exmouth would be likely to visit the Marine Park (Northcote and Macbeth, 2008). During this same time period, the total number of visitors to the Shire of Carnarvon was calculated to be 128 200 people (Tourism WA, 2008a). However, due to the greater distance from the NMP (~120 km to the southern extent) the assumption that all visitors to Carnarvon are likely to visit the Marine Park cannot be made.

Estimates of visitation to CRNP have been made annually for each financial year (July – June) since 1994-95 based on data collected from ticket sales, entry/camping fees and vehicle counters. Based on these data, total number of visitors to CRNP has been increasing in recent years (Figure 2-7). Vehicle counters are located at the northern and southern entrances to the National Park and at the entrance to Turquoise Bay. The vehicle counter data from Turquoise Bay show that ~50% of visitors to CRNP also travelled to this well-known (and publicised) location (DEC, unpublished data). When summarised by month, higher visitation to CRNP is evident between April and October (Figure 2-8).

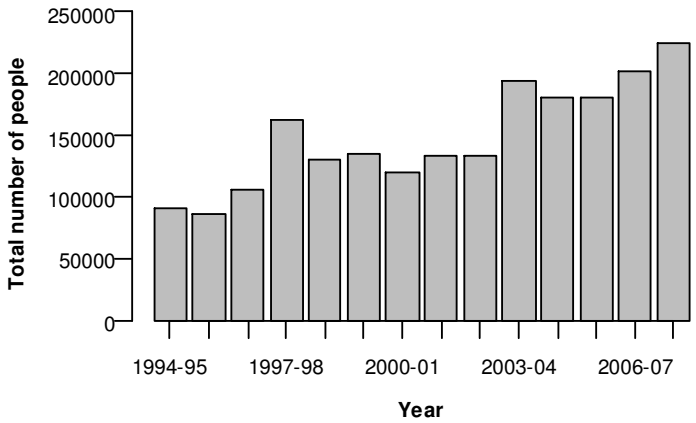


Figure 2-7 Total number of people visiting CRNP each financial year, based on aggregated information from ticket sales, camping/entry fees and vehicle counters (source: DEC, unpublished data).

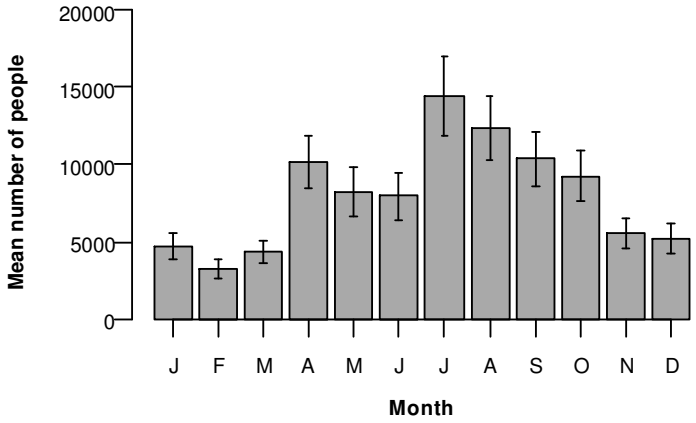


Figure 2-8 Mean number of people visiting the CRNP per month calculated using vehicle counter data from 2003 – 2007 (±95% CI) (source: DEC, unpublished data).

CRNP is the only coastal area for which information on visitor numbers are available. However, the number of coastal camps adjacent to the NMP is documented twice yearly by DEC using aerial flights during school holidays in April and July. Coastal camps are defined as one (or more) tents, caravans or camper trailers which share a communal area in an identifiable clearing (Hughes and Mau, 2006). These flights have also recently been expanded to include October and January. These surveys provide some information on the level of camping along the coastal strip and support DEC vehicle counter data from CRNP with July having consistently higher numbers of camps than April (Figure 2-9).

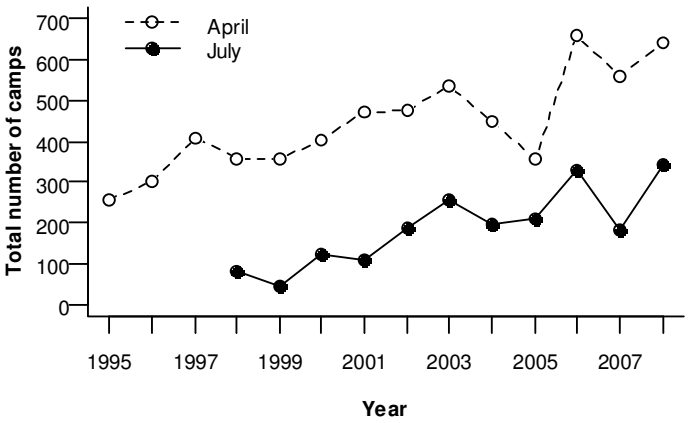


Figure 2-9 Total number of coastal camps adjacent to the NMP recorded during each aerial flight conducted by the DEC from 1995 - 2008 (source: DEC, unpublished data).

These data collected by DEC using ticket sales and vehicle counters provide an indication of inter-annual and monthly variation in visitor numbers to CRNP, along with isolated data points for the remainder of the NMP coast obtained during aerial flights. Daily variation in patterns of use have been investigated on a limited number of selected days within peak April and July school holidays periods at three locations; Bundegi Beach, Turquoise Bay and Coral Bay (Neiman, 2007). Up to 500 people were counted recreating at these locations, with the highest use occurring after noon at Bundegi Beach and Turquoise Bay, but earlier in the day (11 am – 12 noon) at Coral Bay (Figure 2-10).

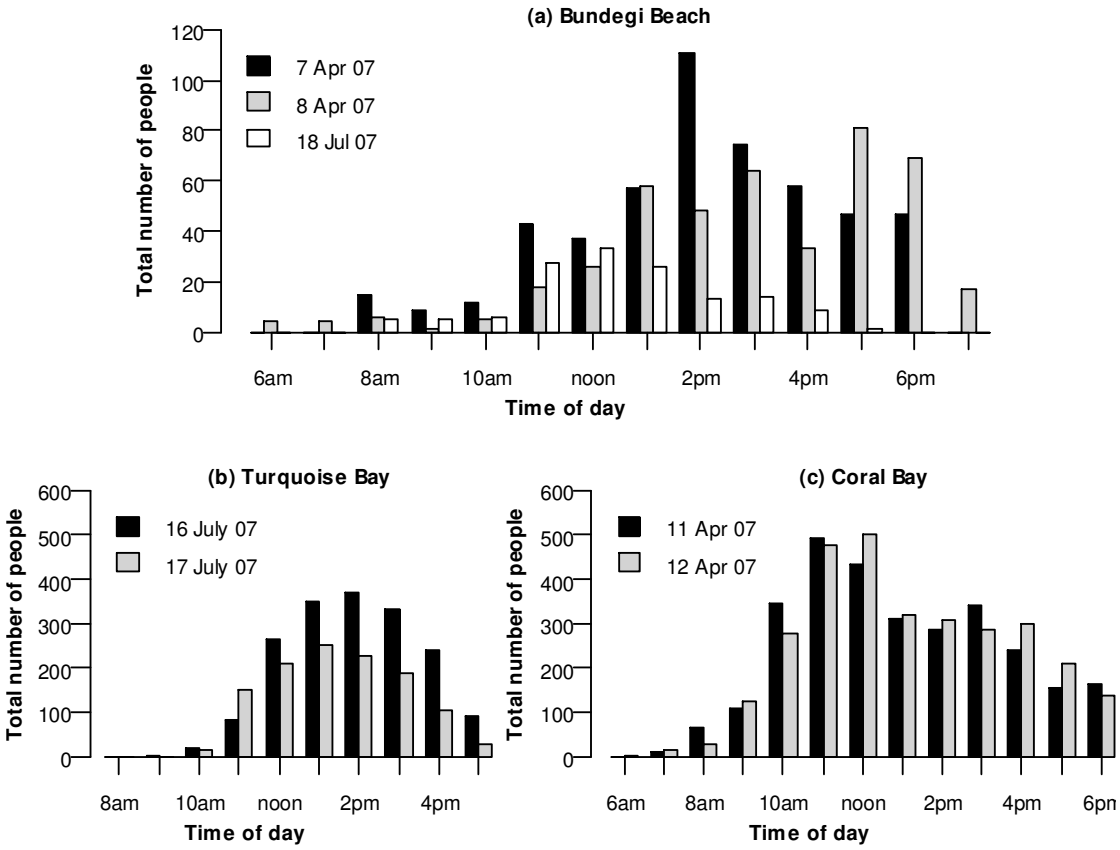


Figure 2-10 Total number of people recorded during hourly counts of beach usage at (a) Bundegi Beach, (b) Turquoise Bay and (c) Coral Bay in April and/or July 2007 [adapted from Neiman (2007)].

There are few studies where it is possible to identify spatial patterns of recreational use at Ningaloo. The DoF completed a 12-month survey of recreational fishing, from April 1998 (Sumner *et al.*, 2002) which estimated boat-based recreational fishing intensity at

5 x 5 nautical mile (nm) resolution (~80 km^2). These data on boat locations were self-reported by fishers when interviewed at boat ramps. Fishing activity from boats launched from public ramps was concentrated adjacent to Coral Bay and to the north and east of Exmouth (Figure 2-11). Estimated effort from shore fishing (in fisher days) was also calculated for broad-scale areas along the Ningaloo Coast and the highest levels were recorded to the south of Exmouth (Figure 2-11). A repeat of the original (1998/99) survey was recently conducted in 2007/08, the results of which were unavailable at the time of thesis submission.

The DoF has also collected data on recreational fishers during compliance patrols in the NMP. There have been >15 000 contacts made with shore and boat-based fishers since 2005, after the implementation of the new zoning scheme. These were classified broadly into fishing and non-fishing contacts with their recorded location based on areas corresponding to NMP sanctuary zones as well as broader spatial areas. These data indicated some non-compliance within sanctuary (no-take) areas of the Marine Park (T. Green, 2009, DoF, *pers. comm.*).

Since 2002, charter vessels operating in Western Australia have been required to submit logbook returns to the DoF as a condition of their licence. From these returns it was possible to determine that for charter vessels departing from Coral Bay and Exmouth there was a mean of 10 clients per tour (based on 2002 – 2005 data). Furthermore, ~30% of all tours were involved in fishing only and <25% of these were undertaken within, or in close proximity to the NMP (state waters), which extends to 3 nm offshore, indicating most fishing activity from these vessels is undertaken further offshore (Northcote and Macbeth, 2008).

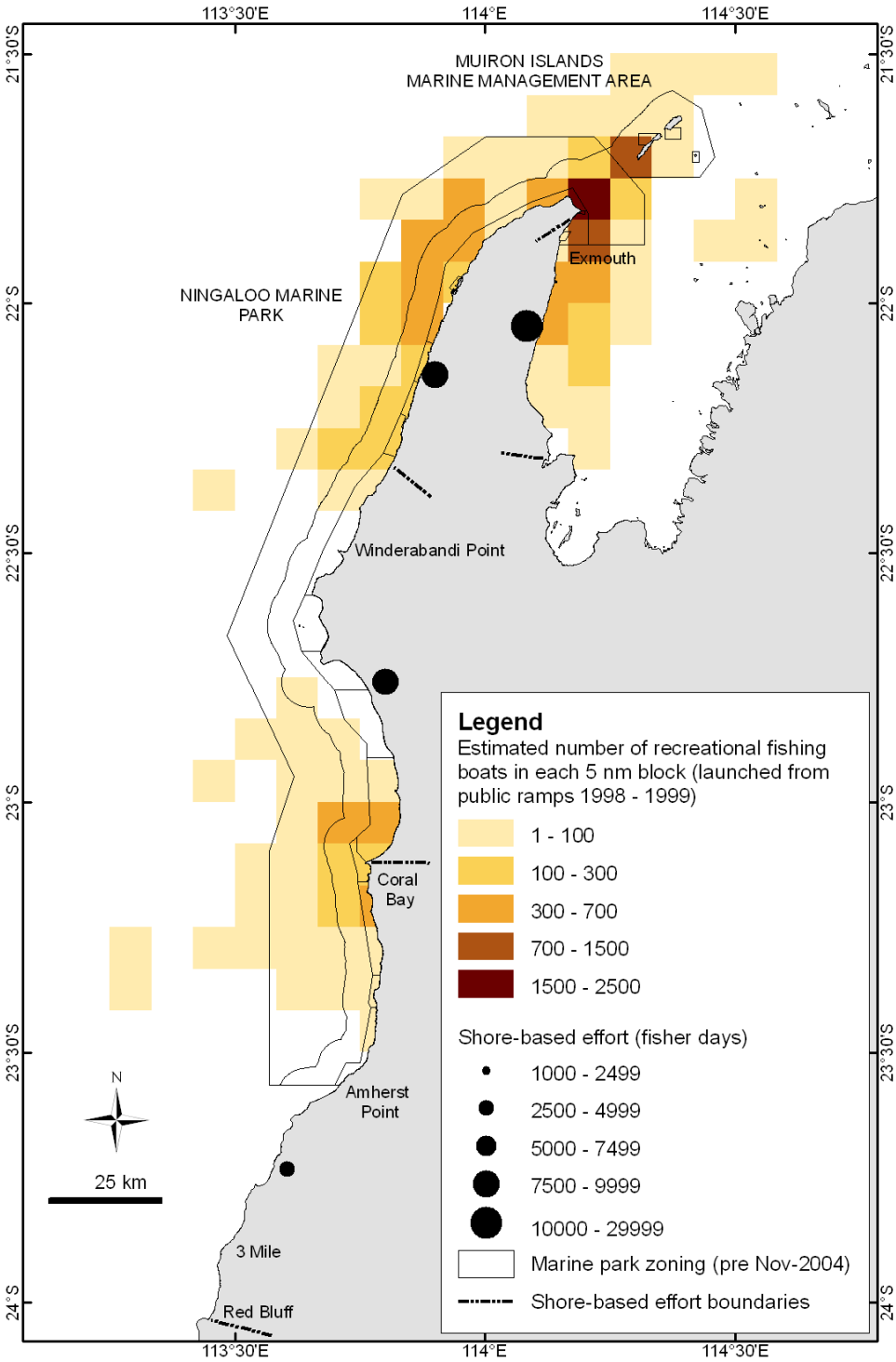


Figure 2-11 Estimated recreational fishing intensity in the Ningaloo Marine Park and Muiron Islands Marine Management Area for boats and the shore during a 12-month creel survey in the Gascoyne region conducted by the Department of Fisheries (DoF) in 1998-99 [adapted from Summer *et al.* 2002].

Logbook returns are also submitted to DEC by charter vessels involved in whale shark tours departing from Tantabiddi and Coral Bay from April to July each year (since 1996). The number of visitors participating in these tours has been increasing in recent

years, with a mean of 16.5 people per trip (Wilson *et al.*, 2007). The location of all reported whale shark interactions are documented, and are widely dispersed to the south of Tantabiddi and north of Coral Bay (Figure 2-6).

A boating study undertaken in Coral Bay as part of a community consultation for a new boat ramp development has also been completed (Worley Parsons, 2006). Although this survey included boats undertaking all types of recreation, not just fishing, these data were also self-reported. The majority of vessels visited locations directly adjacent to Coral Bay, both inside and outside the fringing reef crest (Figure 2-12). The results from this study appear to slightly contradict the findings of the DoF survey; however, there is still a relatively even distribution of vessels to the north and south of Coral Bay.

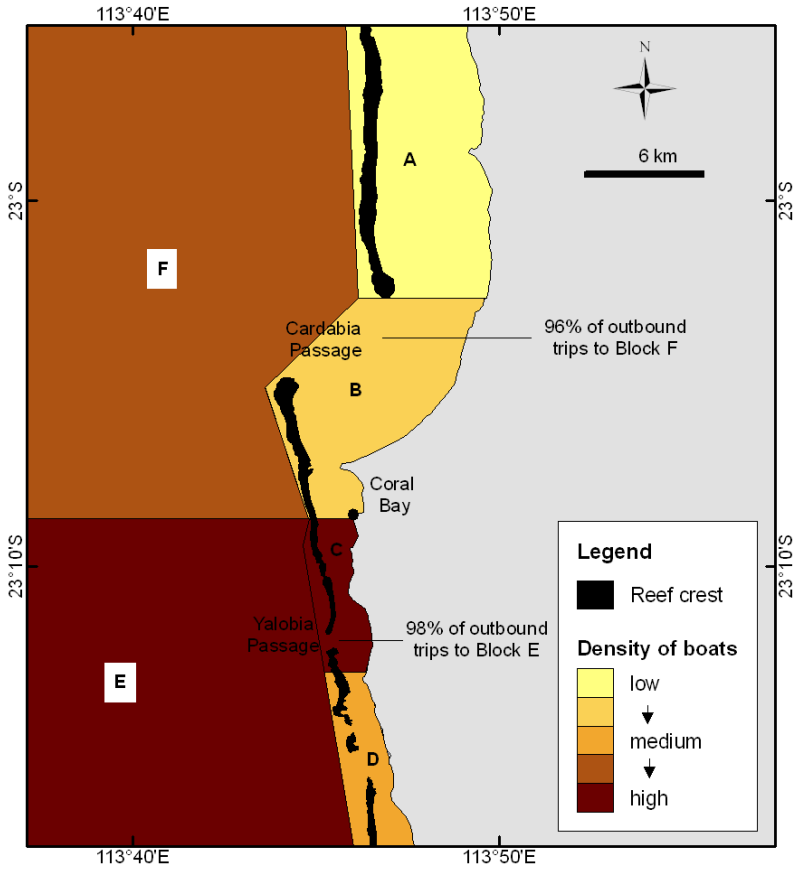


Figure 2-12 Blocks identified by boaters as where they would be spending the majority of their trip after launching from Coral Bay and passages used during outbound trips during surveys from June 2005 – April 2006 [adapted from Worley Parsons (2006)].

It was also possible to ascertain the broad spatial distribution of camps, based on land tenures, that were recorded during aerial flights undertaken by the DEC since 1995 (Figure 2-13). This same dataset was reported previously to identify more camps in the peak month of July, when compared to April. However, the variation in numbers of camps across land tenure type can also be seen, with highest mean numbers occurring on the Bombing Range/Ningaloo Station (DoD/NS), Warroora Station (WS) as well as Gnaraloo and Quobba Stations (GN/Q).

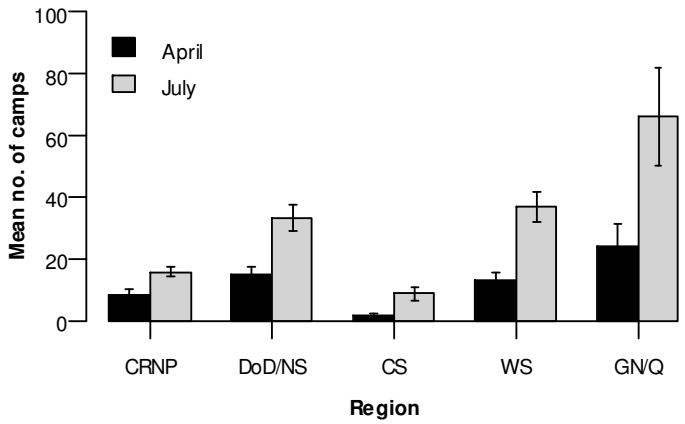


Figure 2-13 Mean number of camps per flight recorded in each region (based on land tenure) during aerial surveys conducted in April and July between 1995 – 2008 (±95% CI) (source: DEC, unpublished data).

As with temporal variability, the understanding of fine scale spatial patterns of recreational use at Ningaloo Reef is limited, with previous research undertaken at broad spatial scales. Other studies listed in Table 2-3 focused on specific land tenures, i.e. CRNP or Ningaloo Station, and results were aggregated over the entire area, thereby losing spatial rigour of the dataset for fine scale analyses of patterns with could be explored for linkages with factors such as infrastructure or benthic habitat types.

Chapter 3 Methods

3.1 Aerial and land-based coastal observation surveys

The overarching objective of this study was to determine the spatial and temporal patterns of recreational use in the lagoon environment of the Ningaloo Marine Park (NMP) and adjacent coastal strip. To this end, a comprehensive fieldwork program was designed, incorporating aerial and land-based observation surveys based primarily on techniques documented by Pollock *et al.* (1994). These techniques were originally developed for collecting data on recreational fishing activity although direct observation is also a well documented technique for broader recreation and tourism activities (Keirle, 2002; Cessford and Muhar, 2003; Arnberger *et al.*, 2005). Incorporating these approaches into a multi-faceted approach to data collection has benefits for sampling design, survey efficiency (Kemper *et al.*, 2003) and facilitating validation between datasets (Vaske and Manning, 2008).

3.1.1 Sampling design

A 12-month fieldwork program of aerial and land-based observation surveys was undertaken between January – December 2007. This consisted of 18 – 20 days sampling per month, with higher sampling intensity by aerial flights in the peak tourist season (April to October) and school holidays (April, July and October) (Table 3-1, Appendix 1). The December/January school holidays were excluded from this higher sampling intensity as they occurred in the very hot off-peak tourist season (November – March). The intensity of land-based observation surveys was maintained at a consistent level throughout the entire 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. This is a statistically robust technique used frequently to construct surveys of recreational anglers (Robson, 1960; Pollock *et al.*, 1994) although it also has widespread applications in the social sciences (Frankfort-Nachmias and Nachmias, 1992; Watson *et al.*, 2000; Neuman, 2006). This technique has been widely applied in surveys of recreational fishing (Ditton and Hunt, 2001; Sumner *et al.*, 2002; Volstad *et al.*, 2003; Smallwood *et al.*, 2006), other water-based recreational activities (Reed-Anderson *et al.*, 2000; Prior and Beckley, 2007), visitor studies (Chi and Qu, 2008) as well as fish and habitat surveys (Blackstock *et al.*, 2007; Aguilar-Perera and Appeldoorn, 2008).

Table 3-1 Total number of days surveyed in the Ningaloo Marine Park (NMP) each month within each survey type during 2007. Note: * indicates months with school holidays.

Month	***Aerial surveys***	***Land-based surveys***	***Total***
Jan *	2	16	18
Feb	2	16	18
Mar	2	16	18
Apr *	4	16	20
May	3	16	19
Jun	3	16	19
July *	4	16	20
Aug	3	16	19
Sept	3	16	19
Oct *	4	16	20
Nov	2	16	18
Dec *	2	16	18
Total	**34**	**192**	**226**

Stratified sampling assumes that a heterogeneous population can be divided into mutually exclusive groups (or strata), which cover the entire sample frame, and from which a random sample of cases are selected (Watson *et al.*, 2000; Neuman, 2006; Theobold *et al.*, 2007). Stratification was difficult in this study due to the large area

encompassed by Ningaloo Reef, which is ~300 km in length. The entire coast was divided into three different geographic strata while day type (i.e. weekend/public holidays, weekday) was taken into account in the northern extent of the study area only. Further stratification, such as time of day (i.e. morning/afternoon), which is often incorporated into survey designs, was not possible due to the large study area. The effect of this was minimal, as reversal of survey routes and multiple sampling techniques resulted in locations being visited throughout the day and covering the entire sampling frame. Another advantage of stratified random sampling is that it reduces sampling error and increases the accuracy of population estimates calculated by combining the data from all strata (Neuman, 2006). However, as the aim of this study was to determine the patterns and spatial footprint of recreational use, the priority of the survey design was to obtain data at peak times of activity and not estimate total participation; similar to the technique by Reed-Anderson *et al.* (2000) to survey boat usage on lakes in Wisconsin, USA.

As well as appropriate strata selection, there were other factors that needed to be addressed to ensure a robust sampling strategy. These were primarily due to the large study area and sandy access tracks which dominate the region; resulting in extended travel times and high associated costs (i.e. fuel, off-road equipment). Due to the multi-faceted approach to data collection, these factors were addressed differently for each survey technique, and are described below.

3.1.2 Survey design

3.1.2.1 Aerial surveys

Aerial flights are an off-site survey technique which are 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 and Lillesand, 1982; Reed-Anderson *et al.*, 2000; Sidman and Flamm, 2001; Falk and Gerner, 2002; Mapstone *et al.*, 2004; Warnken and Leon, 2006; Soiseth *et al.*, 2007). The extended coastline and linear nature of the NMP make aerial flights an ideal technique for surveying the entire coastline and lagoon area.

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 Marine Park (~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) and it took ~4 hours for a return trip covering the study area, with an average speed of 100 knots, depending on weather conditions. In locations where a large number of activities were occurring, speed was decreased, or a circuit was performed, so that data could be recorded by the observers. Digital cameras were also used to photograph high use areas. The outward and return 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) considered the start time of the return flight.

The departure time for all flights was set at 8 am which allowed 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 seabreezes in the afternoon (BOM, 2009). These morning conditions are more suitable for boating 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 positioned at an angle which reduced glare off the water to further improve 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 general categories for analysis, based on research by Horneman *et al.* (2002) (Appendix 2). The observer in the front seat was responsible for identifying boat-based activity due 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 when visible. Another long-recognised problem with aerial surveys is low sighting frequency of objects close to the aircraft which can be attributed to the obstruction of downward visibility (Leatherwood *et al.*, 1982; Quang and Becker, 1997). This issue was addressed by instructing the observer to look 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 any counts of coastal

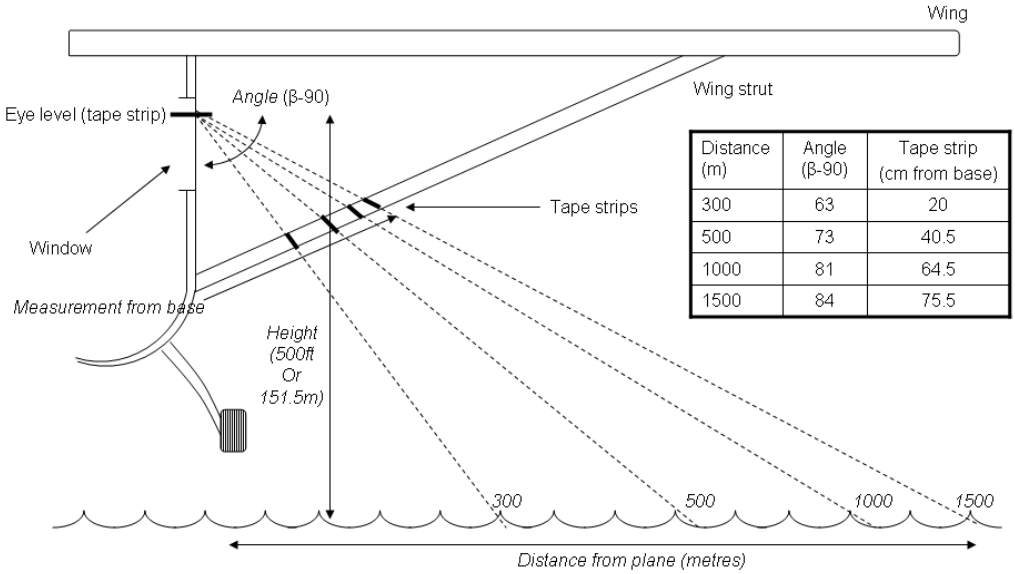
camps, boat trailers at boat ramps, vehicles in carparks or at access points, boats on the beach not currently being used for recreation and boats on moorings or in pens. These sites had been geo-referenced, and their facilities documented, prior to the aerial flights so that counts were standardised across the survey period (Appendix 3). 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 area in an identifiable clearing.

Real-time data were collected during aerial flights using a GPS (Garmin 72) 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 PalmPilot 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 travel.

Time and positional information identified the location of plane when the observation was made. A bearing and offset distance (i.e. distance the object is 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 as manually measuring the bearing can be difficult with objects being passed quickly. It is also often impractical to use electronic equipment such as compasses, inclinometers or rangefinders due to the high speed of travel.

Offset distance was obtained by applying calibration markers to the wing struts of the plane (Figure 3-1). 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. Limitations of this technique were that the plane was assumed to be flying in a horizontal position (i.e. not pitching) and in a straight line.



Distance (m)	Angle (β-90)	Tape strip (cm from base)
300	63	20
500	73	40.5
1000	81	64.5
1500	84	75.5

Figure 3-1 Diagrammatic representation of distance calibration markers used during aerial surveys [adapted from Ottichilio and Khaemba (2001)]. Note: not to scale.

Once the time and offset distance had been obtained by the observers, they recorded (in order of priority) the (1) platform (i.e. shore or boat), (2) type of activity and (3) number

of people in the group. Activity type was identified as specifically as possible, while a group was defined as a distinguishable unit of people who were undertaking activities together; analogous to the definition applied in Moore *et al.* (in review). The front observer also had to obtain additional information on boats, which included (in order of priority) the (1) vessel type (Table 3-2), (2) vessel status (anchored, motoring, drifting, moored, unknown), (3) substrate type (reef, sand, unknown) and (4) whether the boat was inside or outside the lagoon environment. If the vessel was motoring, the direction of travel was also recorded. A digital photograph was also taken by the observer during this time for later validation or if there was too much activity occurring for all details to be recorded during the flight. This was particularly useful at known, high-use beaches such as Bundegi Beach, Surf Beach, Coral Bay, Oyster Bridge, Turquoise Bay Beach and Turquoise Drift Loop (Figure 3-2). Total counts of individuals were completed at these sites, as it was impossible to distinguish separate groups due to the high density of users. These photographs were downloaded from the digital cameras (Canon Powershot A710 IS) at the completion of each flight and all people participating in recreational activity on the beach were counted from these images.

Weather conditions (i.e. wind speed and direction) were recorded at the start, finish and turning point of each flight using visual cues such as wave crests. At the completion of the flight, hourly weather data were downloaded from the Bureau of Meteorology and Australian Institute of Marine Science websites which included wind speed, wind direction and temperature. NMEA data strings were also downloaded from the PalmPilot to be imported into a MS Access database and linked with the information recorded by the observers.

Table 3-2 Categories of vessel types recorded during aerial and on-site observation surveys [adapted *from Adams* et al. (1992), Widmer and Underwood (2004) and Warnken and Leon (2006)].

Vessel type	*Description*
Motorised vessels	
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.
Non-motorised vessels	
Yacht	Vessel >7 m in length with the ability to be powered by sail. If motoring, then still identified as a sailing vessel.
Dinghy	Vessel <7 m in length, no fixed keel and can be 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.

3.1.2.2 Land-based coastal surveys

The land-based coastal surveys were an on-site technique designed to complement data collected during the aerial flights by using the same geo-referenced sites and counting techniques. This facilitated the comparison and possible integration of data between these methods. 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 overseas (Bissett *et al.*, 2000; Courbis, 2007; Dwight *et al.*, 2007; Lloret *et al.*, 2008). However, these studies collected data that were aggregated to a broad field of view while the current study used GPS and laser rangefinder technology to pinpoint the location of recreational activity, thereby providing fine-scale data for analysis.

Vantage points were identified along the survey route and were selected for their accessibility and their overlapping field of views along the entire coastline and lagoon area. These enabled geo-referenced observations of recreational activity and standard counts of coastal use to be made from these points (Appendix 3). The use of vantage points in surveys of boating or marine animals has 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. Randomisation of starting location could not be incorporated along the route due to long travel times. However, survey starting times were randomised (between 7.30 – 11 am) 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 were instantaneous counts (as all activities could be viewed simultaneously). However, as the coastal survey was conducted over a period of several hours, this was a progressive count (Pollock *et al.*, 1994). Issues with multiple sightings of groups throughout the day may result from this technique, and this was avoided by the researchers deliberately excluding a group if they had been counted

previously. However, if vessels were first observed motoring (transiting) the Marine Park, but were later sighed 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).

The coastal surveys were split into three routes of 140 – 160 km in length which could be completed in a single day by 4WD (Figure 3-2). Thus, it was possible to survey the entire NMP in three days. Surveys between Exmouth Marina and Yardie Creek 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 the NMP for day trips on weekends and anecdotal evidence suggested this may affect patterns of recreational use along this section of the coast. All other surveys were allocated on random days, covering both weekends/public holidays, weekdays and school holidays so that by the completion of the fieldwork programme, all day types had been sampled during each survey (Appendix 1).

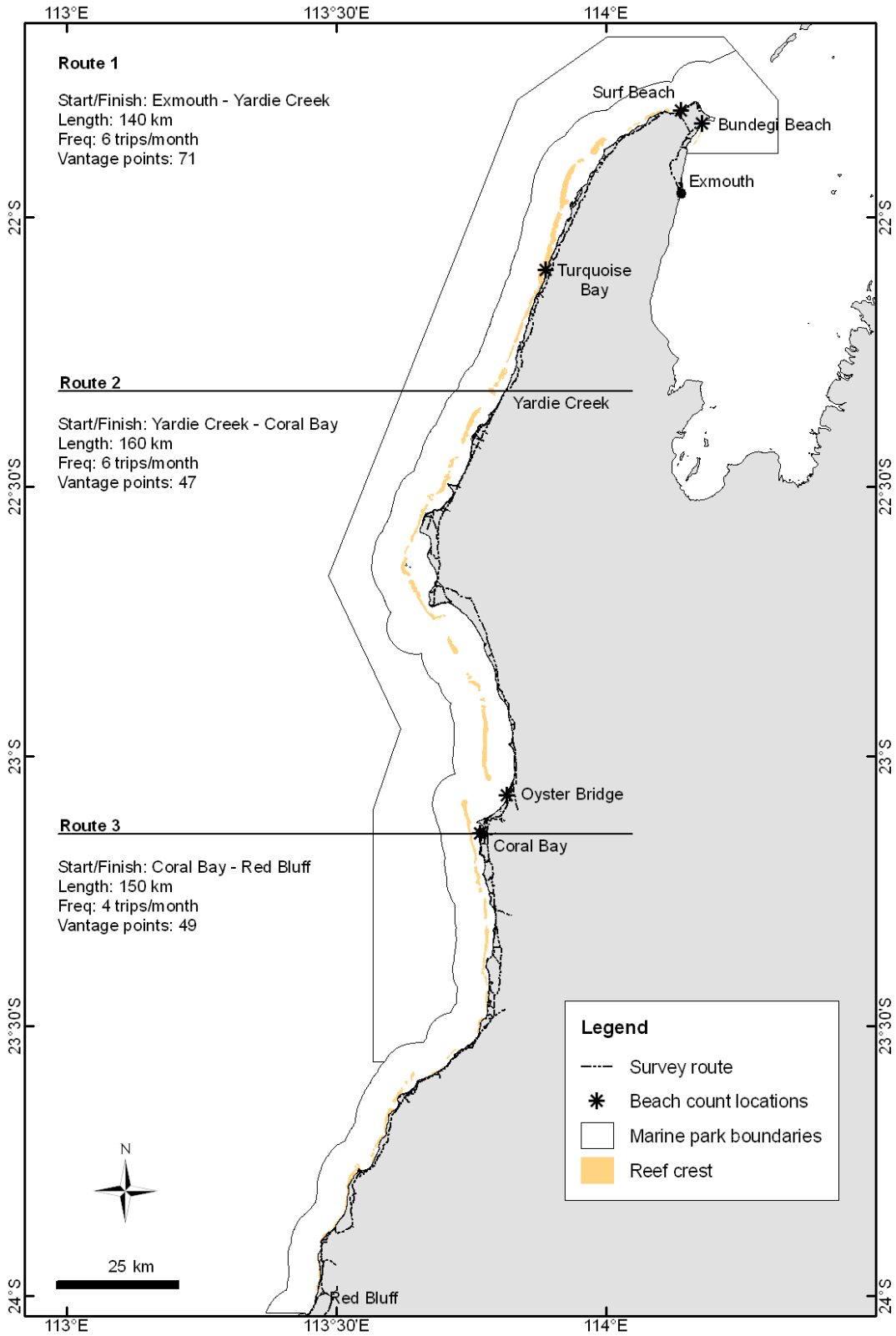


Figure 3-2 Location of instantaneous beach count sites and the three land-based coastal survey routes used for progressive counts including route length (km), sampling frequency and number of vantage points.

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 on the first day, continued on to Red Bluff 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.

Observations of shore or boat-based groups were made using a handheld Garmin GPS to record the 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), as with the aerial flights, and also in previous studies (Sidman *et al.*, 2000; Lynch *et al.*, 2004). 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. However, due to weather conditions such as haze, glare or cloud this distance was rarely achieved. The small size of some objects, such as small vessels (tinnies), which had a low reflectivity, also reduced this distance. During fieldwork, distance and bearings were consistently obtained >2 000 m and, if the object could not be detected using the rangefinder, a handheld compass was used to determine bearing, and the distance from the shore was estimated. By determining the proportional distance of the object to the reef crest, nautical charts of the lagoon area were then used to calculate the distance.

Once time and position (as a latitude and longitude) were obtained, the observers recorded (in order of priority), (1) platform (i.e. shore or boat), (2) type of activity and (3) number of people in the group. For boating activity, additional data was collected which included (in order of priority) the (1) vessel type (Table 3-2), (2) vessel status (anchored, motoring, drifting, moored, unknown), (3) substrate type (reef, sand, unknown) and (4) whether the boat was inside or outside the lagoon environment. Moreover, beach counts were conducted on the same high use locations that were photographed during the aerial flights (Figure 3-2). However, during coastal surveys the observer walked the length of the beach, counting beach users and their activities as they walked, similar to the approach used by Keirle (2002) to cover an *a priori* area.

As with the aerial flights, weather conditions (i.e. wind speed and direction) were recorded at the start and finish of each coastal survey using visual cues, such as wave crests, or a compass to determine wind direction. Hourly weather data, which included wind speed, wind direction and temperature, were downloaded from the Bureau of Meteorology and Australian Institute of Marine Science websites.

3.1.3 Mapping and spatial analysis

All maps were based on the geographic WGS84 datum, which is commonly used for marine applications as well as by Western Australian government agencies. The Universal Transverse Mercator (UTM) system of projection would be the other logical choice, as this would allow easier calculation of metrics, but Ningaloo is located on the boundary of two zones and these areas are exposed to distortions (Longley, 2005). However, there are also errors which may occur by calculating grids using geographic coordinates which were identified to be ~100 m along each axis of a 6 x 6 km grid.

A number of nested grids were created and used in this thesis 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) (Figure 3-3a).

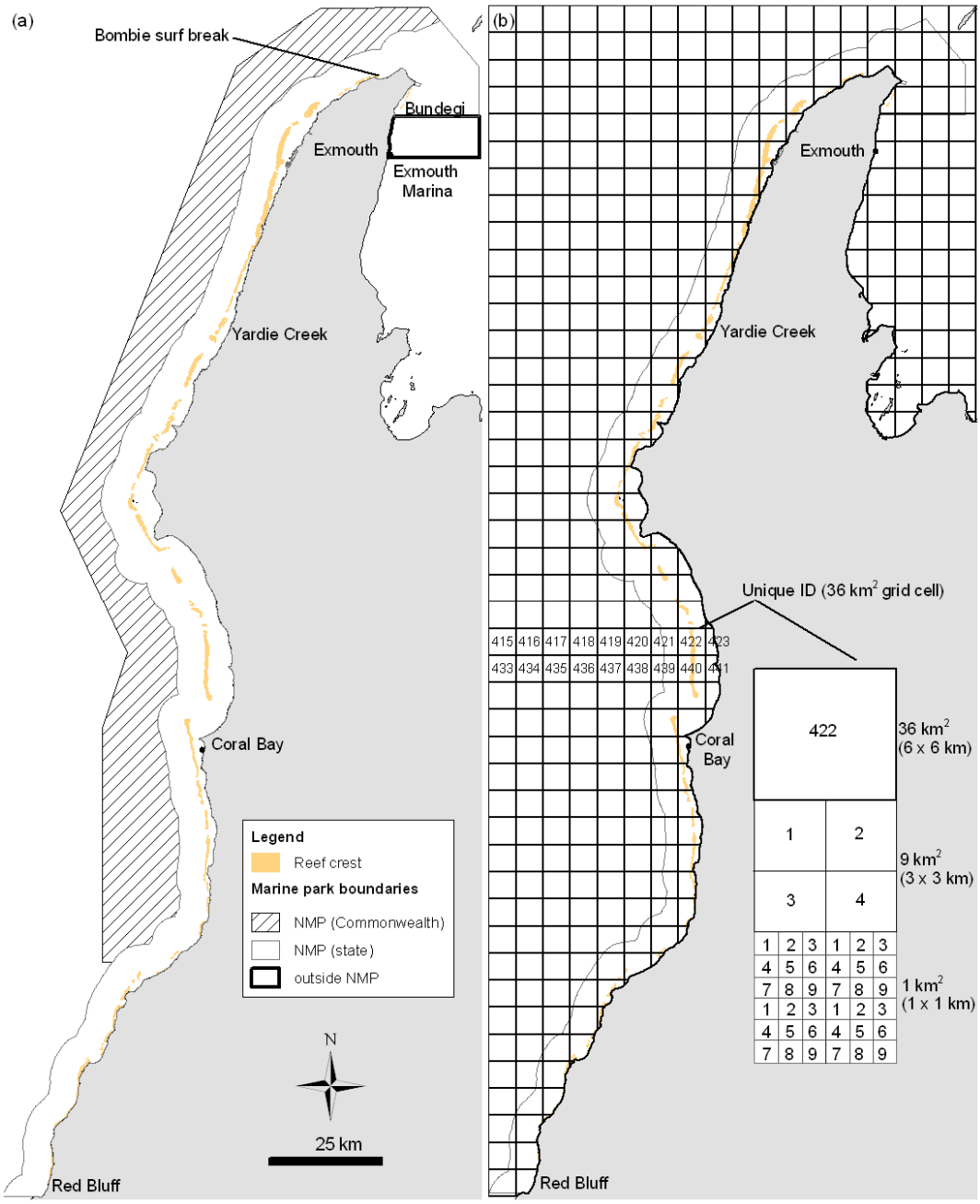


Figure 3-3 (a) Study area with NMP boundaries and (b) 36 km^2 grid cells (with unique ID numbers) and examples of 1 km^2 (1 x 1 km) and 9 km^2 (3 x 3 km) grid cells nested within the 36 km^2 (6 x 6 km) grid.

Although the focus of the study was to collect data within the lagoon, data points were obtained along the western boundary of the NMP (state waters) and, also between Bundegi and the Exmouth Marina. The western side of the NMP (state waters) was the effective boundary of the study area, and is displayed on all maps as a reference point. However, the grid cells were created from the top left corner of the rectangular grid extent with each cell assigned a unique identifying number linking the largest cells (36 km^2) to the smaller nested grids (1 km^2) (Figure 3-3b).

The linear nature of the coast (at MHWM) makes it a suitable feature from which to create a buffer (of standard distance both inland and seaward) that was the foundation for the analysis of shore activities. A number of buffer widths were trialled during analysis of observational survey data and 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 (Bombie) surf break located near North-West Cape (Figure 3-3). The buffer was edited at this location so that 100% of shore observations were included.

The overlapping of shore and boat-based activities was addressed by developing comparative scales of analysis for all observations. To this end, the locations of the coastal segments were demarcated by horizontal lines created by intersecting the buffer with the row lines from the 1, 9 and 36 km^2 grids (Figure 3-4). As with the grids for boat observations, each successively smaller set of segments was nested by assigning a unique identifying field. Although this resulted in uneven lengths (and areas), with the 6, 3 and 1 km segments having an average length of 8.0, 3.9 and 1.3 km, respectively, it was outweighed by the benefits of being able to compare between shore and boat observations in areas of overlap if necessary. When smaller segments were nested

within larger ones, some breakaway pieces were created, especially in areas of convoluted coast. These pieces were merged with adjacent neighbour polygons to prevent the construction of coastal segments which did not adjoin the coast. To facilitate viewing of these narrow coastal segments on maps depicting the entire study area, they were widened (to ~2 km) for display purposes on all maps.

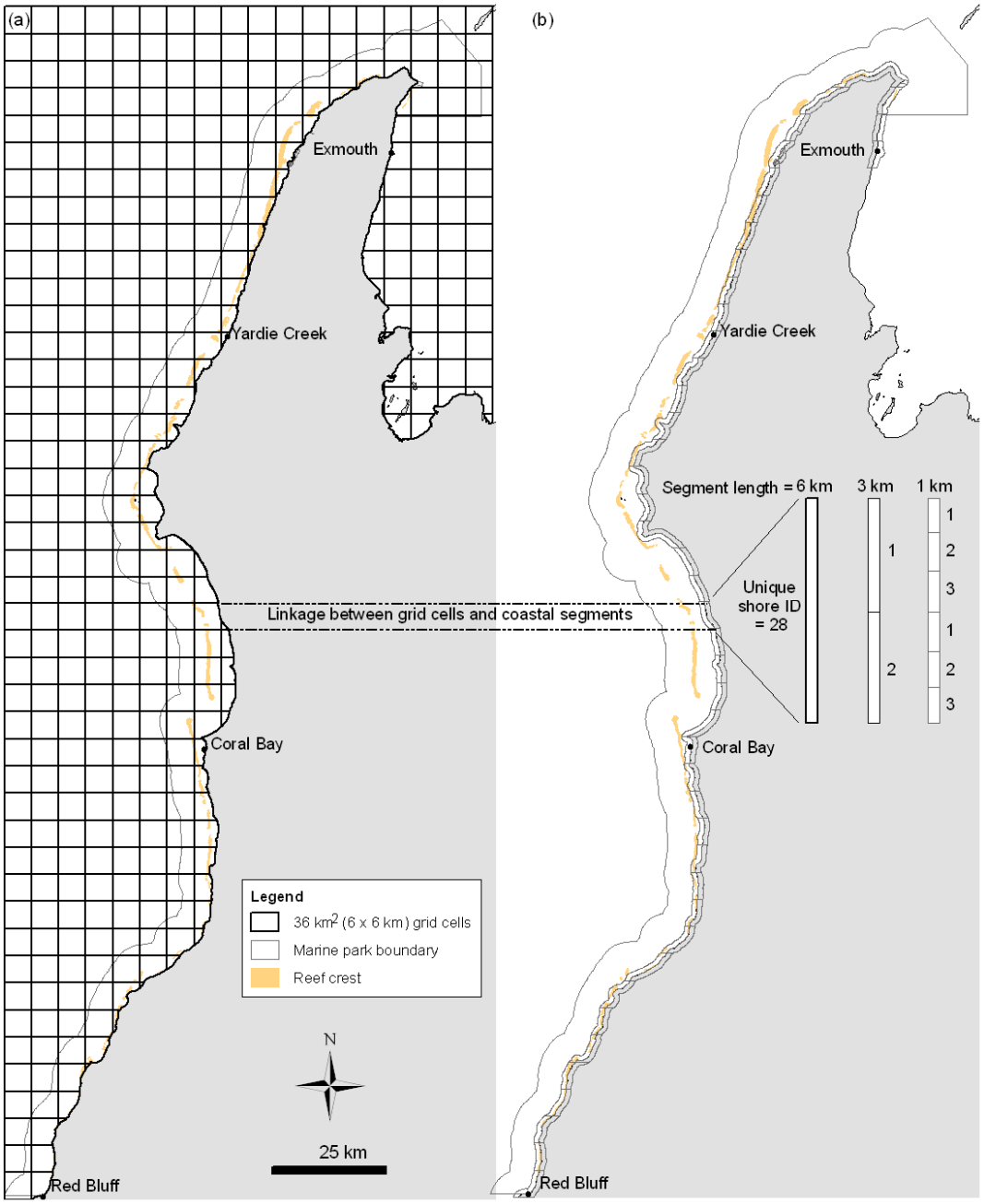


Figure 3-4 (a) 36 km^2 grid cells showing direct link with 6 km coastal segments and (b) the 6 km coastal segments with insert of nested 6, 3 and 1 km coastal segments buffered to 500 m inland and seaward from the mean high water mark.

To ensure continuity of analyses, consideration was given to standardising the unit of measurement and colour palettes. The unit of measurement was the mean number of people/survey (Figure 3-5a). Different colour scales were developed for analysis of all activities (combined) as well as for a single activity. Summaries of coastal use (i.e. camps, vehicles) which are represented as point data are also provided throughout the thesis and are represented by graduated symbols (Figure 3-5b), along with a measure of activity intensity, i.e. the number of different activities being undertaken in a specific cell or coastal segment (Figure 3-5c). The numerical scales are based on natural breaks in the data and are represented using standardised colour palettes.

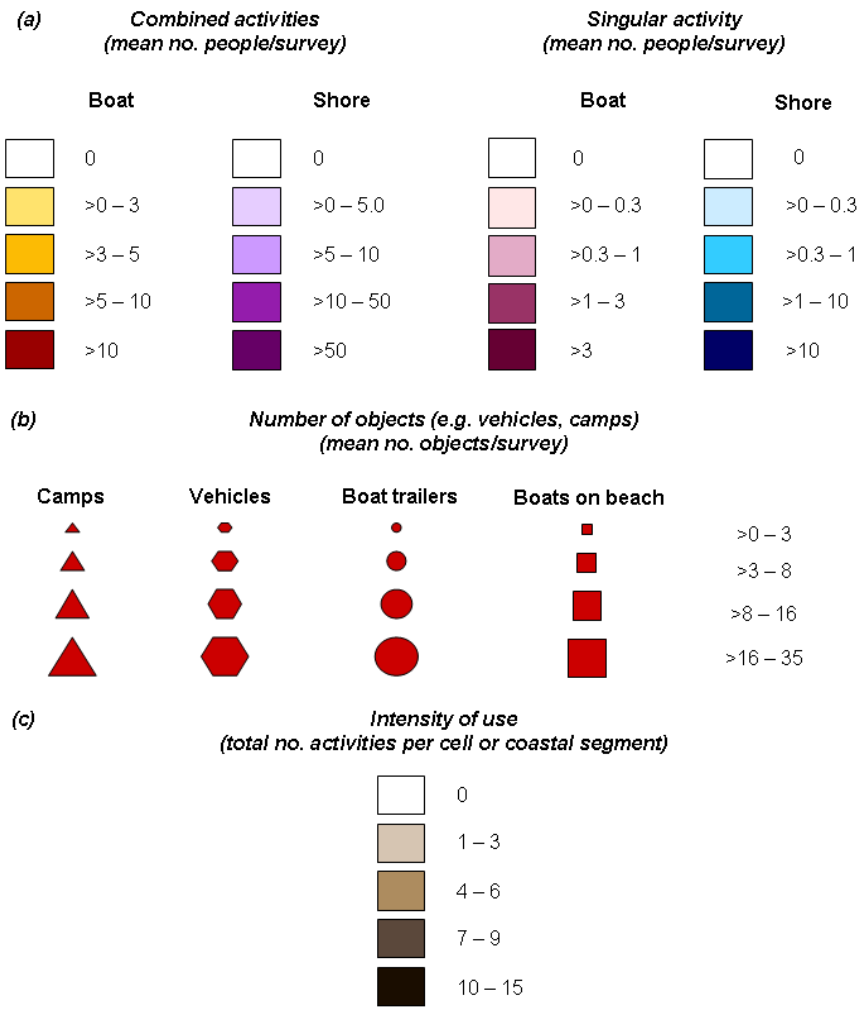


Figure 3-5 Numerical scales and colour palettes used throughout the thesis for comparability and continuity of data presentation of (a) mean number of people/survey undertaking activities, (b) number of objects and (c) intensity of activities.

3.1.4 Minimising spatial error in observation surveys

Improvements in sampling design has benefits for increasing the efficiency of data collection and allowing better interpretation of results (Cessford and Muhar, 2003; Kemper *et al.*, 2003). The development of equipment such as handheld GPS units also allows researchers to increase the spatial precision of data collection. However, as well as sampling errors, there are also inherent GPS errors which should be considered as they can account for positional inaccuracy of up to 25 m (Hulbert and French, 2001; Kowoma, 2005) (Table 3-3).

A PalmPilot was linked to a GPS unit during aerial and coastal observation surveys to extract NMEA data strings containing information on the extent of these GPS errors, such as Horizontal Dilution of Precision (HDOP) from which satellite geometry errors can be calculated. Horizontal Position Error (EPE), along with vertical and spherical equivalents, is another measurement of error based upon a variety of factors including HDOP and satellite signal quality. Errors may also vary between survey approaches, with inherent errors such as multipath effects changing between stationary and moving platforms (Weill, 1997). Other useful information documented by the data logger included number of satellites and fix quality as well as altitude (aerial surveys only).

Spatial errors caused by sampling include compass variation resulting from magnetic interference, wind effects causing the plane to yaw and distance estimation. Distance estimation is one of the largest sources of error in aerial surveys (Pollock and Kendall, 1987) and this issue was addressed using markers placed on wing struts. Other options include the use of a sighting gun (Southwell *et al.*, 2002) or altering the flight path to pass directly overhead of each sighted object so that an exact waypoint could be obtained (Chen, 1996; McClelland, 1996; Rugh *et al.*, 2005). This latter technique

would be difficult at Ningaloo because frequent departures from the linear flight path would make it challenging for both observers to maintain sight of shore and boat activity which was occurring in their area of responsibility. Interference from magnetic effects (such as cars) was mitigated by standing clear of any such objects when taking compass readings. Electronic equipment, such as cameras and watches, were synchronised prior to each flight to reduce the effect of clock and numerical errors.

Table 3-3 Description of possible GPS positional accuracy and error sources (Parkinson and Spilker, 1996; Olynik, 2002; Kowoma, 2005; Zandbergen, 2008)

Error Type	***Description***
GPS configuration	Quality and accuracy of the GPS signal affected by the type of receiver and antenna.
Location effects	Geographic latitude influences positional accuracy.
Interference	Occurs from both natural and artificial sources such as metallic features in cars that degrade GPS reception.
Atmospheric effects	Inconsistencies in atmospheric conditions of the ionosphere and troposphere affect GPS signals as they pass through the atmosphere.
Multipath distortion	Distortion caused by radio signals reflecting off the surrounding terrain, e.g. mountains.
Ephemeris (orbital) errors	Satellite dependent errors which occur when the GPS does not transmit the correct satellite location.
Satellite clock (time offset) errors	Atomic clocks in satellites experience clock drift and the quality of clocks in the satellites and handheld unit result in slightly different times.
Numerical errors	Rounding of data, handheld GPS can only determine points to fixed number of decimal points.
Selective availability	Deliberate degradation of the GPS signal quality for military purposes. Now deactivated.
Satellite geometry	Satellite positioning in relation to each other and the GPS receiver affect the quality of the signal.
Number of satellites	Increased number of satellites improves GPS performance.

3.2 Intercept questionnaire survey

3.2.1 Sampling design

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. This technique has been used extensively to collect information across broad tourism and recreation topics such as destination modelling (McKercher, 1998), visitor profiling (Prideaux and McClymont, 2006) and recreation use (Hadwen and Arthington, 2003). Advantages of interviews are they can be effectively integrated with other methods (such as observation surveys) as a complementary interpretive aid (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), such as in the current study which achieved a response rate of 99.5%. Other options, such as mail and telephone surveys, were impractical at Ningaloo due to the isolated areas where the majority of respondents were likely to be camping.

After documenting land-based observations, groups of recreational participants were interviewed by the researchers either during, or at the completion of, their recreational activity. Groups in this study were selected based on both quota and purposive sampling techniques. Quota sampling, a type of non-probability random sampling, used stratification combined with a non-random selection of sub-units within this area (Cochran, 1977; Frankfort-Nachmias and Nachmias, 1992; Neuman, 2006). The sub-unit in this study was the level of shore activity, with areas of high use (i.e. greater number of people) selected for more interviews than those with low use. Similar methods have been applied to selecting participants for studies on recreational boating (Sidman *et al.*, 2000) and tourism (Nyaupane *et al.*, 2004). High use locations for recreation were identified based on anecdotal evidence and reconnaissance trips in July

and September 2006. These sites corresponded to beach count locations and interviews at locations with lower use were conducted less frequently.

Purposive sampling was also applied to obtain a wide spectrum of activity types. This is another non-probability sampling method by which the researcher selects groups based on a particular characteristic or specialisation (Neuman, 2006). This is a popular technique used for studies targeting groups or individuals with particular knowledge and has been used extensively in tourism research (Mercer *et al.*, 1995; Li, 2000; Sirakaya *et al.*, 2003). In this study, purposive sampling was used to select for maximum variation (Patton, 1990) by obtaining data from people who were participating in recreational activities that were not frequently observed, or who were in isolated locations.

Within each group selected for an interview, one person was selected to respond to the questions based on who in the group had the next birthday. This is a widely accepted approach to interviewee selection and has been used in many questionnaire surveys (Oldendick *et al.*, 1988; Bryden, 2002; Battaglia *et al.*, 2008; Coombes *et al.*, 2009). Due to time restrictions created by the large distances travelled each day, the number of interviews was restricted to 5-10 per survey day (across the entire 12-months of fieldwork).

3.2.2 Questionnaire rationale

The questionnaire was designed to take approximately 5 – 10 minutes, with the researcher documenting responses to increase the reliability of answers. The questionnaire aim was to obtain information on the demographics, visit attributes and activity patterns of visitors to the NMP, which also included residents of the adjacent townsites of Exmouth and Coral Bay (Appendix 4). Section 1 pertained to observations

of the group made by the interviewer prior to, or at completion of, the interview. This included date and time of interview, interview location (geo-referenced using a GPS) and current recreational activity. The ages of all group members and group type (e.g. family, couple or commercial tour) were recorded. Group types were based on standard groupings used in prior studies (Horneman *et al.*, 2002; Hadwen *et al.*, 2003) while age categories were those applied by the Australian Bureau of Statistics (ABS, 1999).

Section 2 of the questionnaire dealt with current activity and trip information. These closed-response questions focused on length of time the interviewee was spending at the interview location (i.e. a recreation site), the main recreational activity that brought them to the location (which was not necessarily the activity they were undertaking at the time of interview) and, the number of people in the group who participated in the main activity for which they came to the beach.

The point from which a respondent accessed the beach was recorded as well as the location of their accommodation the previous night. Both the beach access point and accommodation location were geo-referenced at the completion of the interview or from locations previously recorded by the researchers. Travel networks, including distance and time, could then be calculated from this information. The length of stay at their current accommodation, and any other location within the NMP where they had stayed (or were planning to stay), was obtained. The respondents were asked to identify the major road used to access their current accommodation location.

The postcode (zipcode) of the interviewee's place of residence was also recorded, which is a standard practice question (Horneman *et al.*, 2002) that has been used previously in the region (Dowling, 1991; Remote Research, 2002; Sumner *et al.*, 2002). If the

response was 6707 or 6701, then the respondent was determined to be a resident and length of time they had resided in the region was documented.

It is important to clarify the definitions of residents, tourists and visitors that have been applied in this thesis as, given the complexity of Ningaloo, they have been adapted to more accurately represent the region (Table 3-4). These groups were expected to have different attitudes and behaviours (Confer *et al.*, 2005) and an understanding of these variations are useful for management purposes (Hornback and Eagles, 1999). For this study, visitors were classified as any respondent travelling to, or within, the NMP and using the marine environment or adjacent coastline for recreation. Although visitors are normally classified as not living permanently in a protected area (UN and WTO, 2008), this situation is complicated by the town of Coral Bay being located directly adjacent to the NMP, along with the employees associated with several pastoral leases situated on the coast. Tenants or employees residing in such locations are commonly excluded from analyses (ANZECC, 1996). However, these individuals are known to undertake recreational activities in the NMP (Ingram, 2008) and were included in this study.

Table 3-4 Definitions of visitors, tourists and residents used as a basis for classifying respondents, and as a basis for analysis, in this study [adapted from McIntrye (1993), ANZECC (1996), Hornback and Eagles (1999), Ormsby *et al.* (2004), UN and WTO (2008)].

Term	***Definition***
Visitor	A person who visits the lands and waters of a park or protected area for purposes mandated for the area, typically outdoor recreation, tourism or cultural appreciation, and who does not live permanently in the park.
Tourist	A person travelling to, and staying in a place, outside their usual environment for not more than one consecutive year for leisure, business or other purposes.
Resident	A person who resides permanently in the region adjacent to a park or protected area. In this case, represented by local government postcode boundaries of 6701 and 6707.

The visitor grouping was sub-divided into tourists and residents. As described earlier, residents were defined, for the purposes of this study, as people who provided the postcode 6707 or 6701 for their place of residence. Tourists were therefore defined as respondents whose permanent place of residence was outside these postcode regions. These groups could also be defined based on their distance travelled from home, as used by Murphy and Keller (1990) who defined a tourist as anyone travelling more than 42 km from their place of residence. However, this approach was not suited to Ningaloo, as it is isolated from large population centres, and only those residing within the immediate postcode areas are able to reach the Marine Park for day trips.

The final question in section 2 of the questionnaire asked the interviewee if they had been approached previously to complete this survey. This is a standard survey question (Horneman *et al.*, 2002) and allows interviewees to be excluded from some analysis (e.g. relating to demographic attributes) which would skew the results. If they responded affirmatively then they were required only to complete further questions if they were engaged in recreational fishing (Section 5) or were a resident who was on an extended trip into the NMP.

Section 3 of the questionnaire focused on recreational activity patterns for their entire trip (to date); identifying what recreational activities interviewees had participated in, and on how many days. Recall bias was taken into account when asking respondents to quantify the number of days they had undertaken each activity. This is a well documented survey bias which may cause inaccuracies in data reporting (Chu *et al.*, 1992; Tarrant and Manfredo, 1993; Pollock *et al.*, 1994; Beaman *et al.*, 2004). Effects were minimised by asking residents to only list activities they had completed on that

day, unless they were camping on a short-term trip to the NMP, when they were asked to provide information for their entire stay. Tourists who stayed for extended periods were asked the frequency at which they undertook each particular activity (e.g. daily, 3 times per week) and the number of days was calculated based on their length of stay to standardise the data with those staying for shorter periods (for which recall bias was not as likely to occur).

Interviewees were also questioned on whether they had a 4WD vehicle or boat with them on their trip, and the furthest location they had travelled from their accommodation or boat launching site for a shore and/or boat-based recreational activity, respectively. This information was provided either as a specific landmark, or as a direction and distance of travel. Both the accommodation, boating launching site and furthest travelled location were geo-referenced using handheld GPS units by the researchers or, for offshore locations, nautical charts and GIS processing (to determine location based on direction and distance of travel from a given launch site). This enabled calculation of a maximum distance travelled by respondents, and their spatial distribution throughout the Marine Park, during their trip until time of interview. Boat characteristics such as length, engine horsepower, fuel carrying capacity and launch locations were also obtained in this section of the questionnaire.

Section 4 collected data about patterns of previous visitation to the NMP. If the visitor was not undertaking their first trip to the region, they were asked the year of their first visit, the number of visits in the previous 12 months and date of the most recent trip. These are standard survey questions (Horneman *et al.*, 2002) and have been used previously in Exmouth (Dowling, 1991; Polley, 2002) and elsewhere (Hadwen *et al.*, 2003). To gather insight into visitor preferences for their accommodation, the

respondent was asked if he/she always stayed in the same place when visiting the NMP and, what the main reason was for choosing this location. The questionnaire had tick-boxes for several responses which were selected based on previous research (Remote Research, 2002) and *a priori* knowledge of visitors. However, this was designed as an open-ended question and many respondents chose to provide different answers to those provided in the questionnaire. These were re-coded into 13 general categories for analysis (Table 3-5). Finally, the occupation of the respondent was obtained and ascribed to general categories established by the Australian Bureau of Statistics (McLennan, 1997).

Table 3-5 General categories ascribed to the main reason respondents chose to stay at a particular place of accommodation at Ningaloo, in decreasing order of frequency.

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

The final section of the interview questionnaire related to groups that were fishing from the shore or returning from a boat fishing trip. These questions aimed to determine catch-per-unit effort of groups of recreational fishers and included time spent fishing, number of people fishing and numbers of retained and/or released fish. Species were identified and categorised according to the standard codes for aquatic biota (Yearsley *et al.*, 1997). In addition to this, questions were asked pertaining to night fishing, which is a traditionally difficult activity to determine due to difficulties associated with sampling at night, and the effect of sanctuary zones on fishing activity. This information has not been included as part of this thesis but has been analysed separately (Smallwood *et al.*, 2009).

Chapter 4 Synoptic patterns of recreational use: an aerial approach

4.1 Introduction

Recreational activities operate over various spatial and temporal scales and, to understand how they may influence an ecosystem, the intensity of an activity as well as its spatial extent must be known (Ban and Alder, 2008; Halpern *et al.*, 2008). However, an infinite number of spatial scales exist and these must be selected carefully as, if undertaken at too broad a scale, the resolution of the data will be lost which will inhibit the understanding of these activities (Eastwood *et al.*, 2007; Hadwen *et al.*, 2007). Factors that should be considered during this process are the scale of previous research, associated spatial errors and management needs. The size of analysis units should also reflect current management and administrative boundaries (Lewis *et al.*, 2003) as well as the practical limitations of data analysis and implementation of results (Pressey and Logan, 1998; Shriner *et al.*, 2006). The practicalities and financial costs to support data collection at different resolutions should also be considered as they may vary substantially.

Human activities have been mapped on land for many years, particularly in protected areas, which use roads, trails or population centres as proxies to define a sphere of influence. It is more difficult to identify these areas in marine environments due to the dynamic and ephemeral nature of many activities (Ban and Alder, 2008) as well as dispersed and non-linear travel networks. Early studies used non-systematic approaches to sub-dividing a study area to map activity distributions (Deuell and Lillesand, 1982; Adams *et al.*, 1992; Jennings, 1998) and, more recently, these units were defined by natural features such as coastal headlands (Lynch *et al.*, 2004) or larger watershed and socio-political sized blocks (Bassett and Edwards, 2003). The advancement of

Geographic Information Systems (GIS) also facilitated the development of standardised grids to systematically summarise data. Studies encompassing large tracts of the marine environment are generally collected and analysed at broader scales, i.e. 10 x 10 nautical miles (nm), (Leeworthy *et al.*, 2005), 6 x 6 nm (Deng *et al.*, 2005), 2 x 2 nm (Eastwood *et al.*, 2007) or 1 x 1 nm blocks (Leeworthy *et al.*, 2005). This enables easy visualisation of results over broad areas without sacrificing computer processing time (which will increase with a larger number of grid cells). Smaller study areas, such as confined bays, can be aggregated at finer scales, i.e. 15 x 15 m (Sidman *et al.*, 2000) without these constraints.

The same limitations apply to marine parks. Zone boundaries have been used for comparing abundance and biomass of recreationally targeted fish species (Westera *et al.*, 2003; Babcock *et al.*, 2008) and frequency of recreational activity (Shivlani and Suman, 2000) between take and no-take areas. However, using existing zone boundaries may limit the ability for the data to assist with assessing the effects of future changes. Optionally, a nested grid design may be applied, with consecutively smaller layers created and linked to larger cells (Chapter 3; Figure 3-3). This facilitates a multi-level approach to data analysis which was exemplified in the Great Barrier Reef Marine Park where different size grid cells were used for offshore (30 km^2) and nearshore (10 km^2) environments (Lewis *et al.*, 2003). A nested design has advantages as analyses can be undertaken at a broad-scale to identify areas for further investigation at finer scales or, inversely, at the finest scale to provide a base for lower resolution outputs, similar to Bruce and Eliot (2006) in the Shark Bay Marine Park.

The scales of analysis applied to previous research in a particular study area should also be considered to facilitate comparative studies between datasets, although this can be

complicated as they are frequently reported at different spatial resolutions, depending on reporting or monitoring requirements (Eastwood *et al.*, 2007; Pederson *et al.*, 2009). This is also true at Ningaloo, where research on recreational use has been based on 5 x 5 nm blocks (~80 km^2) to describe boat-based recreational fishing (Sumner *et al.*, 2002), management zones (between 8 – 49 000 hectares in size) for monitoring fisheries compliance (Fletcher and Santoro, 2008), coastal camping and land tenure boundaries, e.g. national parks, pastoral leases (Remote Research, 2002; Wood and Dowling, 2002; Wood, 2003b; Hughes and Mau, 2006). These factors, and future monitoring requirements, were considered in the nested design of grids and coastal segments developed in Chapter 3 (Section 3.1.3) for aggregating data from the current study.

The spatial accuracy and bias associated with data collection should also be considered when selecting a grid size which will provide an accurate representation of patterns or trends in the dataset (Hengl, 2006). Sampling errors have been investigated for aerial surveys, particularly the difficulties in accurately recording data from a moving platform, due to duplicate sightings and correctly ascertaining perpendicular distance from the flight path (Pollock and Kendall, 1987). The challenges of capturing and processing data quickly, and accurately, at high speed are mitigated by ongoing improvements in equipment and survey methods. This includes an increasing tendency to move towards automated data systems that eliminate the need for manual data entry or transcription (Butler *et al.*, 1995; Logan and Smith, 1997); thereby contributing towards an increased level of spatial accuracy for data points.

Analysis of recreational use in the marine environment is also confounded by the different platforms used by recreationalists (e.g. shore or boat), especially when located adjacent to the coast. Grids for the marine environment can be systematically created.

However, for activities that take place along the coastal strip and in nearshore environments, deciding the width, length and shape of the polygons can be complex as the coastline may be convoluted (Bartlett, 2000; Vafeidis *et al.*, 2004). Along with considerations relating to the particular characteristics of the study area (Hinch, 2008) and distribution of data points, there are additional challenges caused by the dynamic nature of the coastline which is constantly shifting due to tidal effects (Vafeidis *et al.*, 2004; Tolvanen and Kalliola, 2008). Previous studies have used several approaches to create coastal segments based on arbitrary distances (Fricker and Forbes, 1988), systematically using fixed lengths (Ralph and Miller, 1995; Coombes *et al.*, 2009) or attributes, such as beach type (Sherin and Edwardson, 1996).

Selecting scales of analysis at which the patterns of recreational activity can be explored using measures of density and spatial extent has other benefits. This includes the ability to identify potential sites for recreational conflict based on the number different activity types occurring in each grid cell or segment. Recreational conflict can be defined as interference with an activity that can be attributed to the behaviour of another group or individual (Jacob and Schreyer, 1980; Ivy *et al.*, 1992). This can be categorized into potential, actual, imagined and philosophical (Orams, 1999) and occurs when a diverse mix of users (with different attitudes, values and preferences) access, what they perceive to be, their fair share of a public resource (Dustin *et al.*, 2002). Conflicts over marine resources are diverse and can occur between many groups, such as anglers and divers (Lynch *et al.*, 2004) or jetskiiers and powerboaters (Wang and Dawson, 2000). The identification of sites where conflict is likely to occur is beneficial as it provides information to managers on periods at which management intervention may be required. It also determines sites for further monitoring and research into acceptable limits and perceptions of conflict or crowding.

4.2 Research objectives

The overarching aim of this chapter was to explore the synoptic patterns of recreational use in the Ningaloo Marine Park (NMP) using data collected during aerial surveys conducted throughout 2007. This pertains not only to quantifying recreational activities undertaken from shore and boat platforms, but the numbers of camps, vehicles and boat trailers as well as boats not currently in use (i.e. in marina pens or on the beach). This was achieved by addressing several research objectives including:

- determining the most suitable spatial and temporal scales of analysis for these data points,
- describing patterns of all shore and boat-based recreational activities using these selected scales of analysis,
- identifying sites which have potential for conflict between recreational activities: and
- quantifying the spatial accuracy of the collected data points.

4.3 Analysis techniques

The overall research design and aerial survey method was described in Chapter 3 (Methods), along with the measures of spatial error such as Horizontal Position Error (HPE) that were extracted as National Marine Electronic Association 0183 (NMEA) data strings. The geo-referenced data obtained on people participating in recreational activities from boats and the shore were imported and stored in a MS Access database at the completion of each flight. This database was then linked with the R and PRIMER statistical packages as well as ArcGIS 9.3 for analysis.

Clustering of observations was tested using second-order nearest neighbour Euclidean distance between points. This is the smallest possible unit from which clustering can be determined and was used to identify which grid size (36, 9 or 1 km^2) is able to

accurately highlight these patterns and should be used for further analysis. This technique has been used by Hengl (2006) for image-based processing and by Sidman et al. (2006) for studies of recreational boating in North America. Similar to these methods, summary statistics were used to determine the upper confidence interval which would account for 95% of distances to two nearest points from another point. Circular area ($A = \pi r^2$), which could then be converted to a grid of equal length sides, was calculated using this value as the radius. These grids will be representative of the spatial resolution at which clustering can be identified within the study area.

The effects of temporal factors on recreational use were also investigated using multivariate analysis to determine which grouping would provide the most distinction in these patterns. These temporal factors included;

- four seasonal quarters appropriate for Ningaloo, which experiences its hottest temperatures between October - March (BOM, 2009). These seasons were defined by the following months:
    - Summer – January to March
    - Autumn – April to June
    - Winter – July to September
    - Spring – October to December
- peak periods of tourist activity defined using historical visitor data (i.e. DEC vehicle counters) and the current study. These were defined as:
    - Peak – April to October (including school holidays in April, July and October)
    - Off-peak – November to March; and
- school holiday periods, which occurred in two week blocks during April, July and October and for an extended six week block in December/January.

Specific statistical approaches used to determine the significance of spatial and temporal effects on recreation 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) were used. Multivariate analysis was undertaken using the PRIMER and R statistical packages. The 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 which falls between -1 and +1, with a value of zero representing no difference between samples, and an associated ρ which indicates significance at 0.05 level.

Initial exploration of the data to select the spatial and temporal scales that would be utilised throughout the remainder of this thesis was based on number of observations recorded during aerial flights. However, to obtain a more accurate representation of participation in activities, especially those undertaken from the shore, number of people were applied to mapping and multivariate analyses. This was due to beach counts of shore activities at high use locations (e.g. Turquoise Bay or Coral Bay) which could not be attributed to separate groups (rather the total number of individuals were counted), and therefore one observation could represent >50 people.

Standard decision rules were used to alleviate this problem and assign a group size each time it was not able to be recorded during a survey. The possible biases introduced by using this technique were tested by applying non-parametric regression (i.e. rank order) to each grid cell and coastal segment based on both number of observations and number of people to identify the nature of this relationship. For shore activities, the assigned value was based on the mean group size calculated across all other observations undertaking the same activity (excluding beach counts). For example, the mean size of groups in beach (sun) shelters during all aerial flights was three people. Therefore, all observations of beach shelters with no number of people documented were assigned this group size (three).

Assigning a group size to boat-based activities was more complicated as people on vessels, such as charter boats, were often obscured by the cabin and, consequently, there were few reference observations in the dataset from which a mean group size could be calculated. The number of people on smaller vessels (excluding charter boats, cabin cruiser and commercial vessels) was calculated similarly to shore activities (i.e. 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, (i.e. tenders for offshore oil platforms and commercial fishing vessels) and cabin cruisers were assigned a mean of 5 people per trip, which was based on minimum safety crewing levels (Srinivas, 2007).

Several metrics were used to examine patterns of recreational use at Ningaloo within the selected spatial and temporal scales of analysis. Density of use was determined by investigating the mean number of people per survey within each grid cell or coastal segment for a specified time period (i.e. off-peak and peak months). The spatial extent (or distribution) of recreational activities was calculated as the total number of grid cells or coastal segments in which a particular activity occurred. Greater spatial extent is reflected by a higher number of cells or coastal segments. Intensity was calculated by identifying the number of activities occurring in each cell which is useful for determining potential areas of conflicts, similar to Ban and Alder (2008).

4.4 Results

4.4.1 Spatial and temporal patterns of usage

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

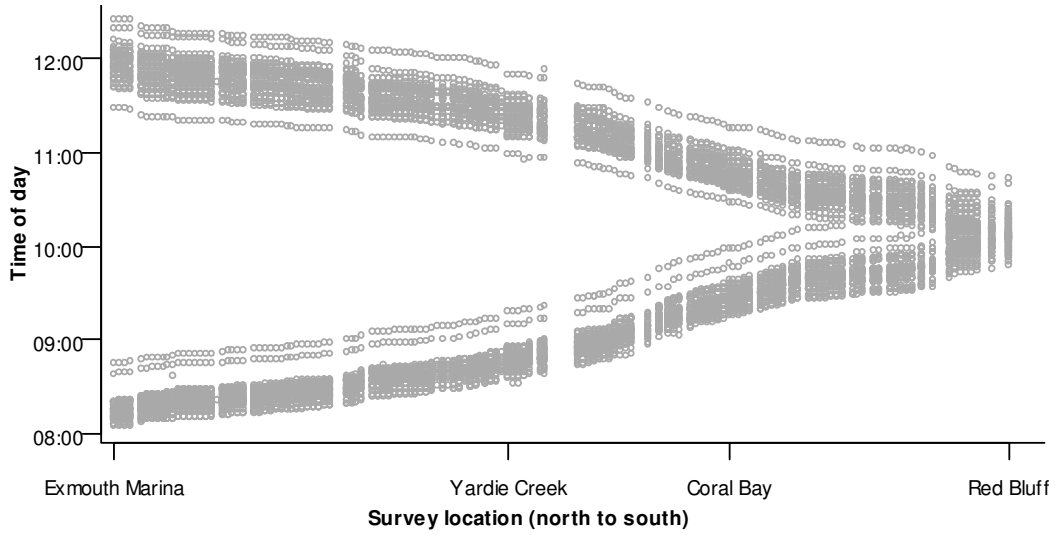


Figure 4-1 Time of observation at each location surveyed during every flight between Exmouth Marina and Red Bluff during 2007 (number of surveys = 34).

There was a total of 7 247 aerial observations of shore and boat activity made throughout the study. The total number of observations was significantly higher on the northbound flights when compared to southbound flights ($F_{(1, 66)} = 15.88$, $\rho<0.05$) (Figure 4-2). There was also significant temporal variation, with higher numbers 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 ($F_{(1, 64)} = 1.00$, $\rho>0.05$).

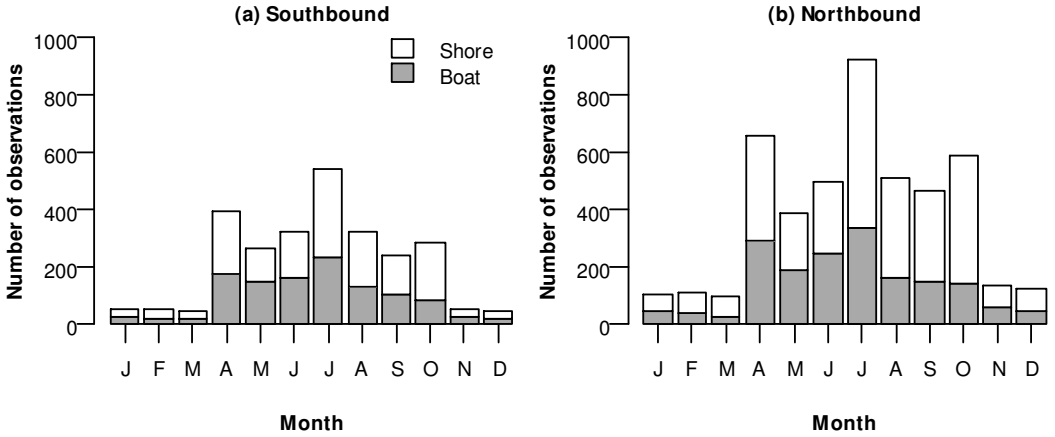


Figure 4-2 Total number of shore and boat observations for each month of (a) southbound and (b) northbound aerial surveys along Ningaloo (number of flights = 34).

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 (in the northern and southern-most extents). There were 13 different boat types, which were dominated by tinnies (small aluminium vessels) (26.8%), open boats >5 m in length (such as centre console vessels) (20.3%) and charter vessels (16.5%) (Figure 4-3). The largest boats (charter vessels and open boats >5 m in length) were recorded in highest numbers outside the lagoon whereas the smaller motorised vessels, comprising tinnies and tenders as well as non-motorised vessels such as kayaks, kitesurfers and windsurfers, were found almost exclusively inside the lagoon.

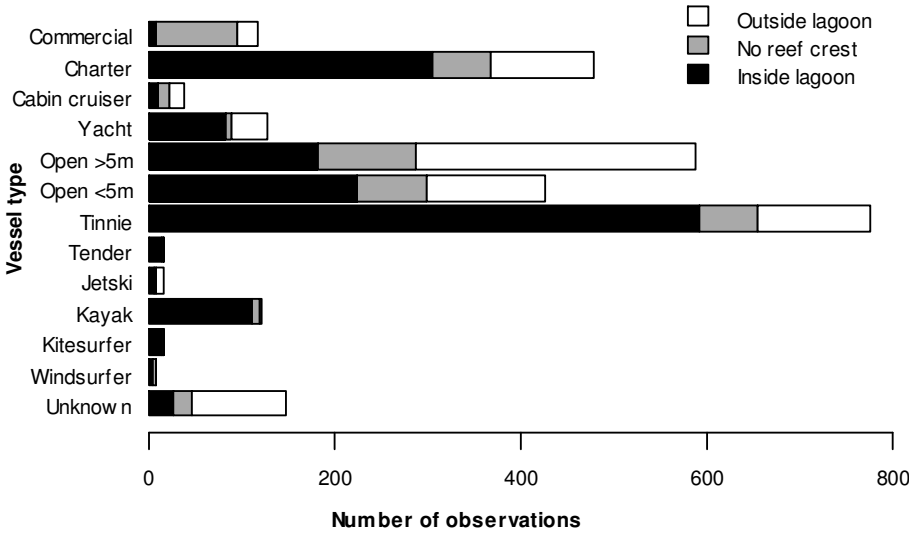


Figure 4-3 Total number of observations for each boat type recorded inside and outside the lagoon as well as adjacent to areas with no fringing reef crest during all aerial flights in 2007 (number of observations = 2 894).

Clustering of these boat observations was tested using second-order nearest neighbour Euclidean distance between points. These points were highly clustered (ρ<0.05) and summary statistics revealed the mean second-order distance between boats during aerial flights was 0.42 km (CI 95%: 0.40 – 0.44 km). This upper CI limit (0.44 km) accounts for 95% of distances to two nearest points from another point. Calculating the circular

area based on this distance yields a result of 1.32 km^2 which can be converted to a grid size of 1.1 x 1.1 km. Grid cells of this size would therefore identify clustering of boat observations within the study area. Subsequent analyses of boat observations will be based on number of people, and the implications of this also need to be considered prior to a spatial scale of analysis being selected.

There were 2 906 observations of boating activity obtained during the aerial surveys and the mean group size across all flights was 2.3 people. However, for 66.9% of observations, consisting mostly of larger boats such as charter and commercial vessels, the number of people was undetermined. When applying standard decision rules to assign a number of people to these observations, the total number of people was calculated to be 10 866, of which 63.2% were recorded during northbound flights. The maximum counts were obtained from flights during the April school holidays (417 people) and June Public Holiday (360 people). The possible biases introduced by assigning a group size were investigated using regression to identify the nature of the relationship (if any). This illustrated a strong positive relationship at 9 and 36 km^2 with R^2 values >0.789 during southbound and northbound flights, which deteriorated at 1 km^2 to R^2 values <0.471 (Table 4-1). The weak relationship at 1 km^2 suggests this would not be suitable for analysis based on number of people.

Table 4-1 Regression co-efficient (R^2) calculated using rank order of grid cells based on total number of people versus rank order of total number of boat-based observations for each flight direction for each grid size.

Grid size	***Regression co-efficient (R^2)***	
	Southbound	***Northbound***
36 km^2	0.891	0.897
9 km^2	0.816	0.789
1 km^2	0.471	0.356

The findings of these analyses revealed that 1 km^2 grid cells would identify fine scale clustering of boating activity although it would not be an accurate representation based on number of people. The 1 km^2 grid is also difficult to interpret visually (with >1 000 grid cells within the state NMP). Therefore, the larger 9 km^2 grid, which offers better visual interpretation and strong relationship between number of observations and number of people, will be used herein to aggregate data of boating activity.

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 teaching periods (Table 4-2). To determine which activities were responsible for these differences, a SIMPER analysis was performed; highlighting low levels of dissimilarity (29.6 – 43.1%) based on activity type and level of participation. It was therefore difficult to differentiate between temporal factors based on activity type, with wildlife viewing, diving, motoring and wildlife interactions occurring year round. However, analysis showed that off-peak/peak periods provided the strongest differentiation of activities and number of people (i.e. highest Global R). This temporal scale will therefore be used in conjunction with the 9 km^2 grid cells to describe patterns of boating activity.

The remaining factor to consider was the collection of boating data during both southbound and northbound trips, as the likelihood of double counting vessels during both directions is high. Analysis should therefore be conducted using only one flight direction to remove this bias. The mean number of people obtained per survey was mapped using 9 km^2 grid cells to investigate these differences.

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

Factor	***Global R***	***ρ***		
Off-peak/peak	0.348	<0.05*		
Season	0.259	<0.05*		
	Pairwise comparisons		*R*	*ρ*
	Winter, Spring		0.341	<0.05*
	Winter, Summer		0.350	<0.05*
	Winter, Autumn		0.058	>0.05
	Spring, Summer		0.070	>0.05
	Spring, Autumn		0.457	<0.05*
	Summer, Autumn		0.324	<0.05*
School holidays	0.014	>0.05		

Activity in both flight directions was concentrated adjacent to the coast (and inside the lagoon environment) (Figure 4-4). The highest densities of people were located in blocks adjacent to Coral Bay with a mean >5 people/survey. However, northbound flights had activity occurring in 4.2% more grid cells as well as a greater number of cells with higher densities of people, especially at Lighthouse Bay, Tantabiddi and Neds Camp. An ANOSIM test showed significant differences in the number of people and composition of recreational activities undertaken on different flight directions (R = 0.431, ρ<0.05*).* Although the R value is larger than found for temporal effects, a SIMPER analysis to determine the activities responsible for these differences in northbound and southbound flights still had a low level of dissimilarity (47.2%), 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 people and greater spatial extent of activities obtained on the northbound flight (conducted at the later flight time of 10 am – 12 noon), these data were select for further analysis of boating activity.

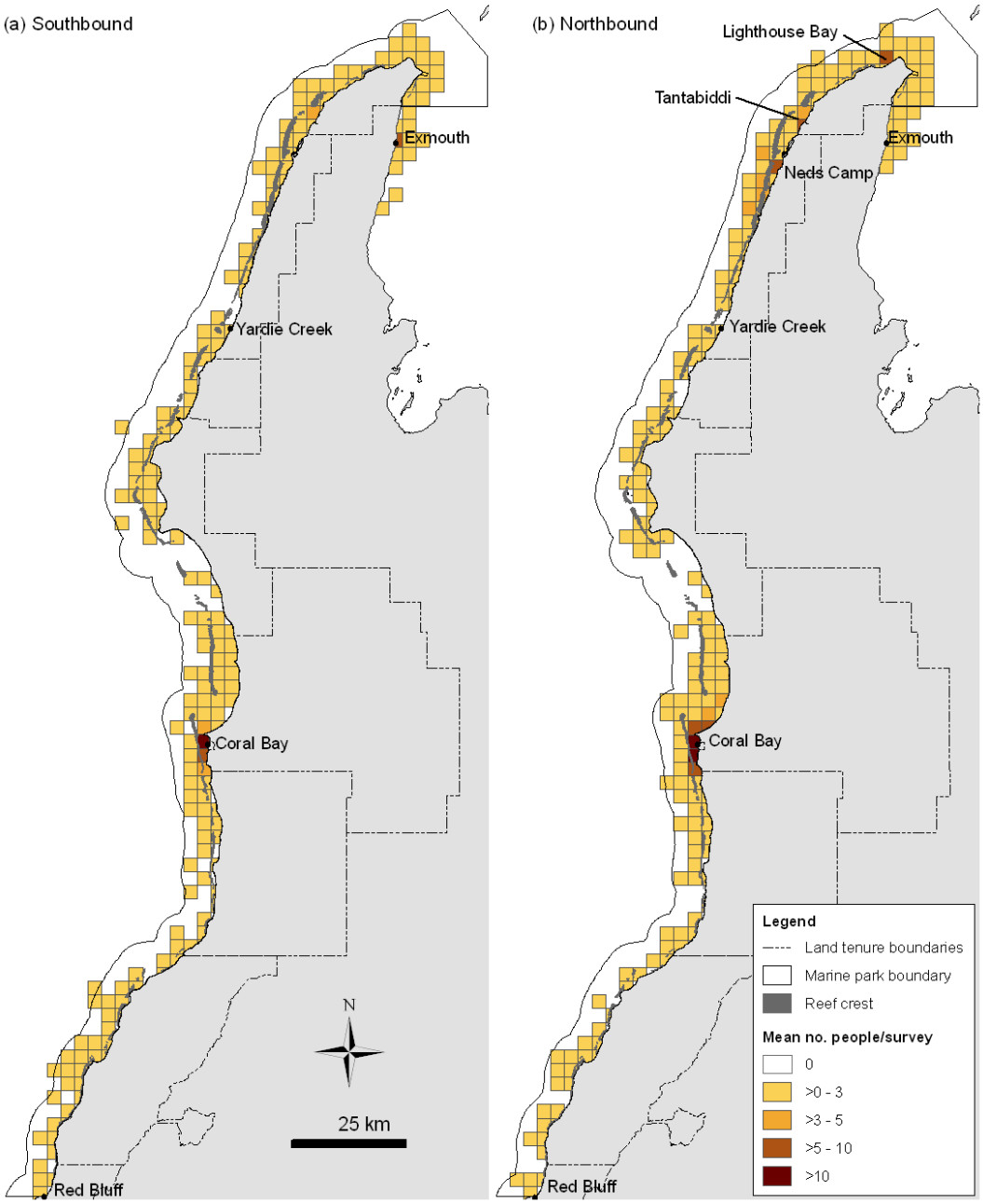


Figure 4-4 Mean number of people per survey participating in boat-based recreation within each 9 km^2 grid cell on all (a) southbound and (b) northbound aerial flights (number of flights = 34).

The effect of off-peak and peak periods on the density and spatial extent of people participating in boat-based activities can be clearly identified (Figure 4-5). People were distributed in 45.2% more grid cells in peak months, with expansion along the coast and outside the fringing reef crest. Only grid cells adjacent to Coral Bay and Lighthouse Bay had a mean >3 people/survey in off-peak months, expanding to Tantabiddi and

Neds Camp in peak months. There was no boating activity observed immediately to the south of Jane Bay, adjacent to Stevens Camp, Cape Farquhar or Gnaraloo Homestead.

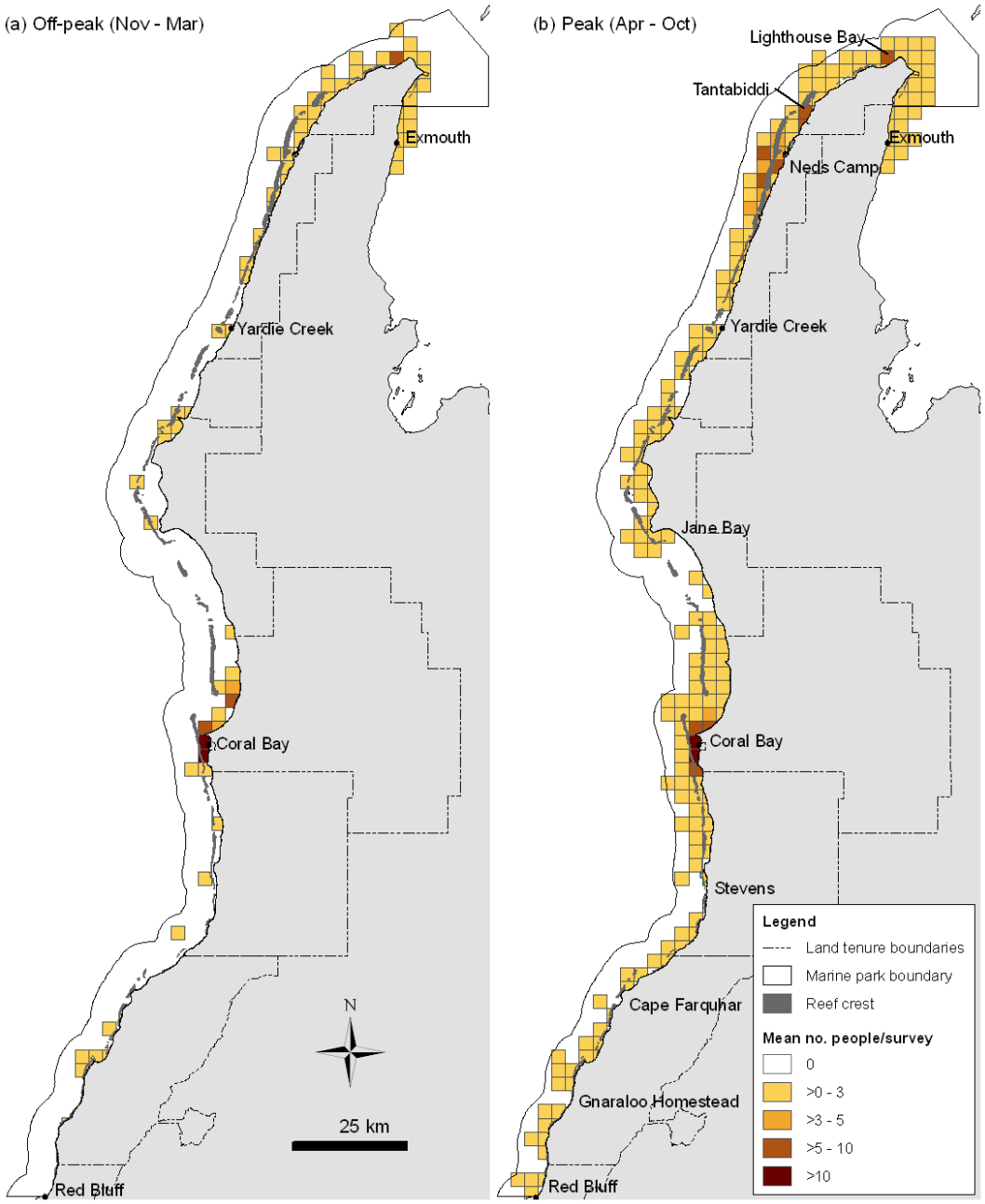


Figure 4-5 Mean number of people per survey recorded during northbound aerial flights participating in boat-based recreation within each 9 km^2 grid cell during (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24).

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 (Figure 4-6). Activities included fishing, spearfishing, diving, kayaking, motoring, snorkelling, sailing sports, wildlife viewing and wildlife interactions.

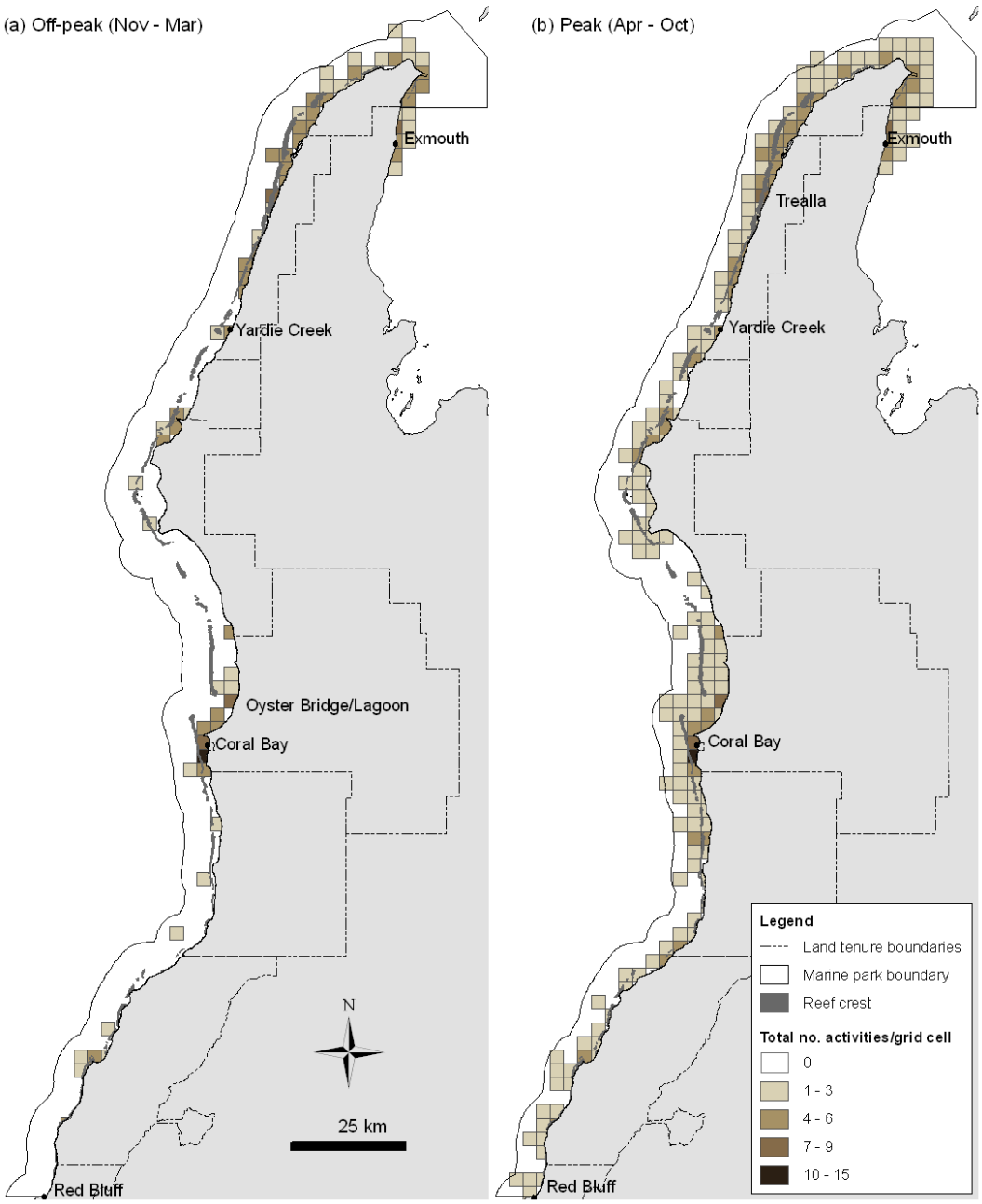


Figure 4-6 Intensity of boat-based activities within each 9 km^2 grid cell during northbound flights in (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24).

4.4.3 Shore-based activities

There were 4 341 observations of groups undertaking recreational activities from the shore during aerial surveys. The mean group size across all aerial flights was 3.5 people, excluding 0.6% of groups whose size was undetermined. When applying the standard decision rules (described in Section 4.3) 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 count was 896 people which occurred during the October school holidays. As with boat-based activities, the relationship between the number of people and number of observations within each coastal segment was investigated. Each coastal segment was ranked using number of people and number of observations which showed a strong positive relationship at the broadest scales (3 and 6 km segments) with R^2 value >0.863 for both flight directions (Table 4-3). Unlike the grid cells used for boat-based activities, the strength of this relationship did not dissipate at finer scales, with R^2 values >0.831 for 1 km coastal segments. These strong relationships and the beach count technique applied at known high use locations supported the use of number of people for the analysis of shore activity at all spatial scales.

Table 4-3 Regression co-efficient (R^2) calculated using rank order of coastal segments based on total number of people versus rank order of total number of shore-based observations for each flight direction for each grid size.

Coastal segment	***Regression co-efficient (R^2)***	
	Southbound	***Northbound***
6 km	0.858	0.963
3 km	0.859	0.963
1 km	0.901	0.831

Clustering of shore observations was also tested using second-order nearest neighbour Euclidean distance between points and was found to be highly clustered ($\rho<0.05$).

Summary statistics revealed the mean second-order distance between shore observations was 0.06 km (CI 95%: 0.06 – 0.07 km). Calculating the circular area based on this distance yielded a result of 0.23 km^2, or a grid of 0.5 x 0.5 km. This result is confounded by the minimum width of coastal segments, which was fixed at 1 km in Chapter 3 (Methods) to encompass all shore activity. However, this analysis supports the use of fine scale 1 x 1 km coastal segments although, as with boating activity, it is difficult to visually interpret patterns from coastal segments of this length. Therefore, larger 3 km coastal segments (which correspond to the 9 km^2, or 3 km x 3 km, grid cells used for boating) will be used to aggregate the number of people participating in shore activities.

The effects of temporal factors on shore activities were investigated and showed significant differences between season and off-peak/peak months in terms of participation; however, there was no significant difference for school holiday versus teaching periods (Table 4-4). Pairwise comparisons between seasons showed strongest differences were between winter and summer periods ($R = 0.596$; $\rho<0.05$). A SIMPER analysis determined which activities were responsible for these differences and highlighted low levels of dissimilarity (25.0 – 34.2%) between each pairwise comparison. Dominant activities were present across all temporal periods, particularly fishing, surfing, walking, wildlife interactions, swimming and relaxing.

Analysis of temporal factors supported the use of seasons for analysis as they provide the strongest differentiation of activities and number of people, although this was not as marked as for boating activity. To ensure continuity between platforms, off-peak/peak periods were selected as the temporal scale of analysis in conjunction with the 3 km coastal segments to describe patterns of shore activity. However, a remaining factor to

consider is the collection of shore data during both southbound and northbound trips, as the likelihood of double counting is high, as with boating activity. Analysis was therefore conducted using only one flight direction to remove this bias.

Table 4-4 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.

Factor	***Global R***	***ρ***		
Off-peak/peak	0.269	<0.05*		
Season	0.325	<0.05*		
	Pairwise comparisons		*R*	*ρ*
	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 there was a similar spatial extent of activities for both flight directions (Figure 4-7). Shore use was concentrated around Lighthouse Bay (extending south), Turquoise Bay, Coral Bay and Gnaraloo Bay. 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, ρ<0.05). Although the R value is 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.

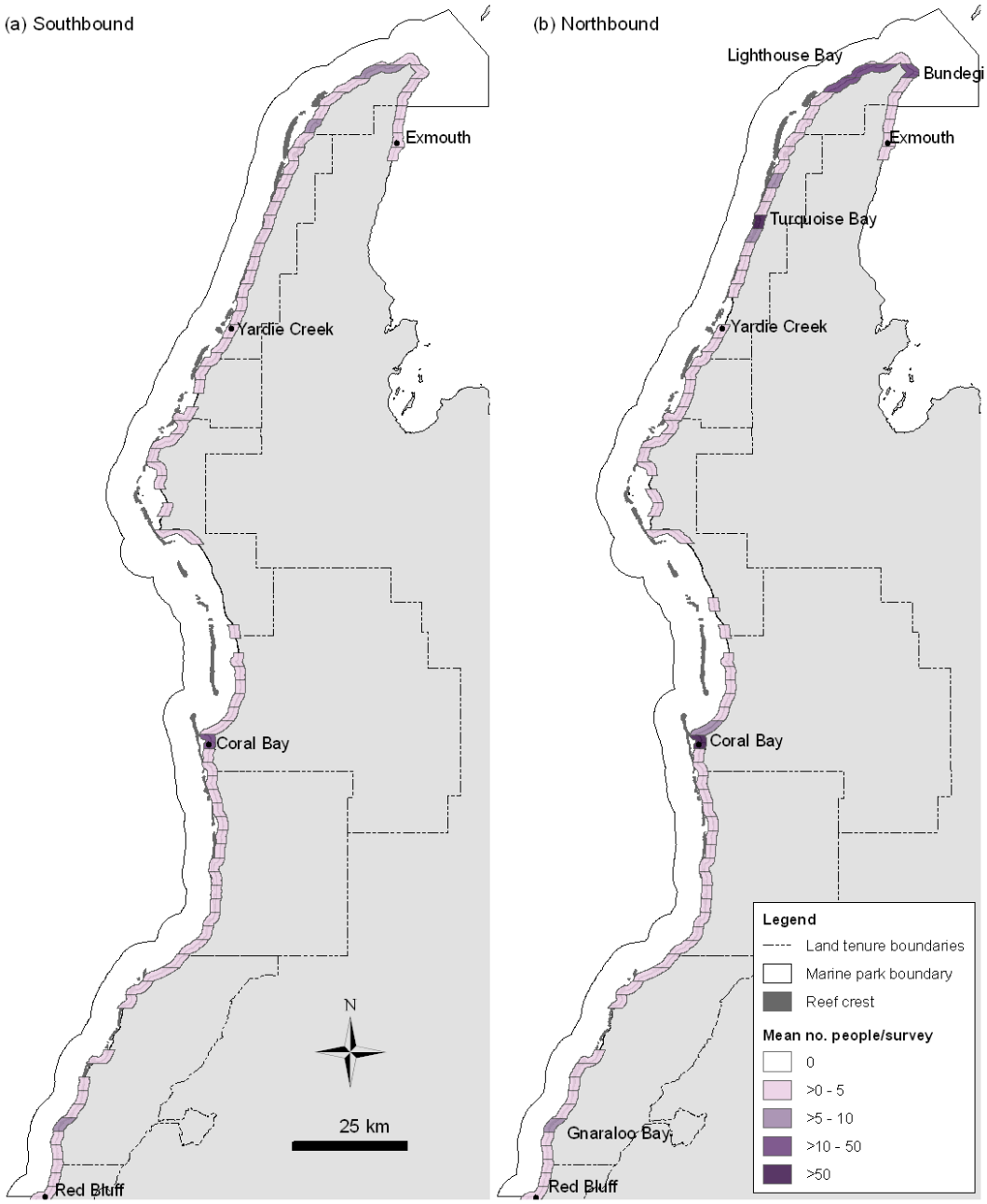


Figure 4-7 Mean number of people per survey recorded participating in shore-based recreation within each 3 km coastal segment for all (a) southbound and (b) northbound aerial flights (number of flights = 34).

The effect of off-peak and peak periods on density and spatial extent of people participating in shore-based activities was clearly identified (Figure 4-8). In peak months, people were found in greater densities (mean > 50 people/survey), especially adjacent to Turquoise Bay and Coral Bay, and distributed in 25.4% more coastal segments. Other locations with >5 people/survey in these months were around Bundegi

Beach, Lighthouse Bay, Lakeside and Gnaraloo Bay. Areas to the north of Yardie Creek, south of Jane Bay and around Cape Farquhar had no shore activity recorded.

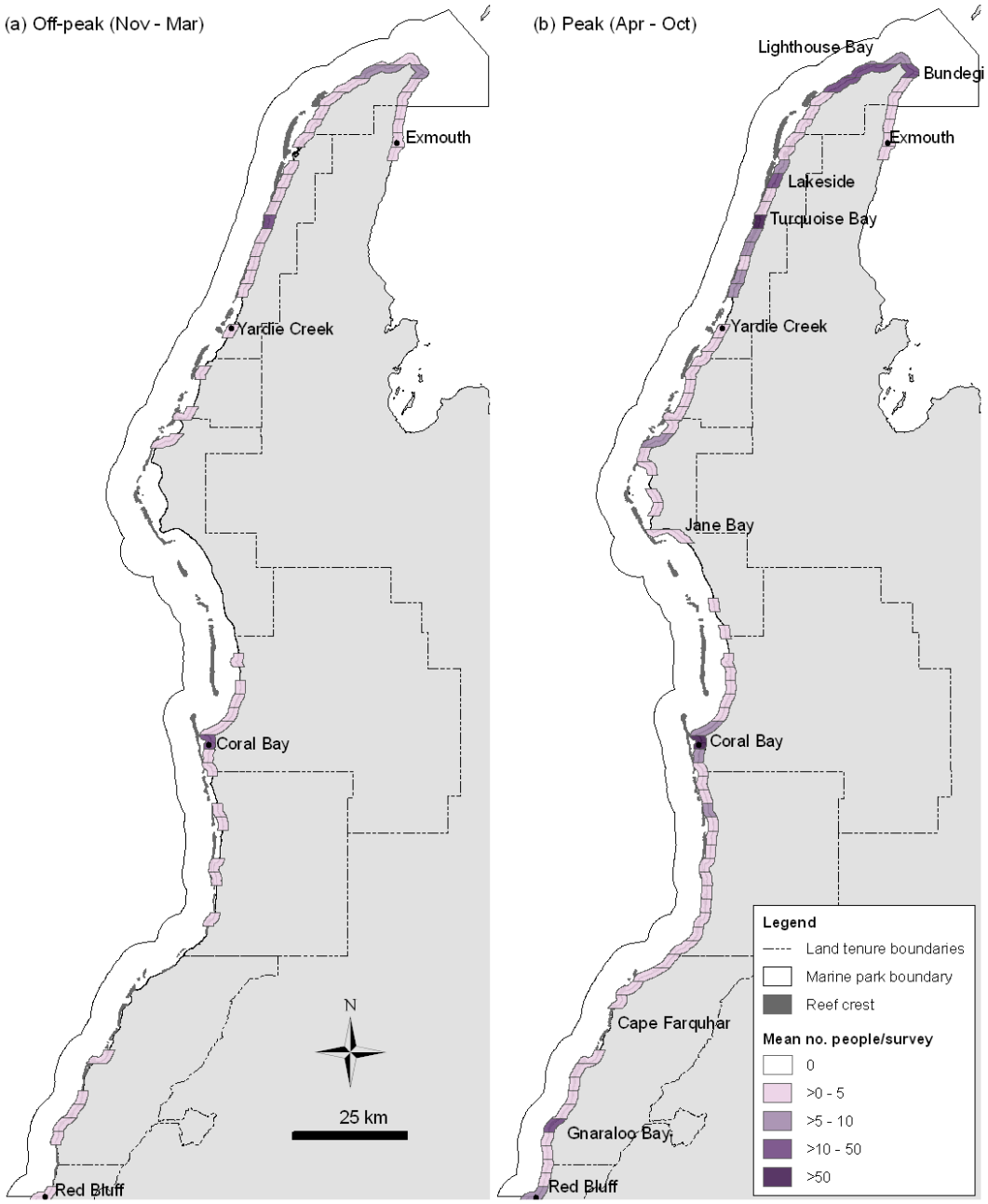


Figure 4-8 Mean number of people per survey recorded during northbound aerial flights participating in shore-based recreation within each 3 km coastal segment during (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24).

Intensity of shore use was determined by the number of different activities which occurred in each coastal segment. There were up to 13 activities/grid cell recorded in

off-peak and peak months at Lighthouse Bay, Lefroy Bay, Coral Bay, 14 Mile and Gnaraloo Bay (Figure 4-9). Activities such as fishing, swimming, snorkelling, relaxing, surfing, walking, sailing sports, beach games, wildlife viewing and wildlife interactions were undertaken at these locations.

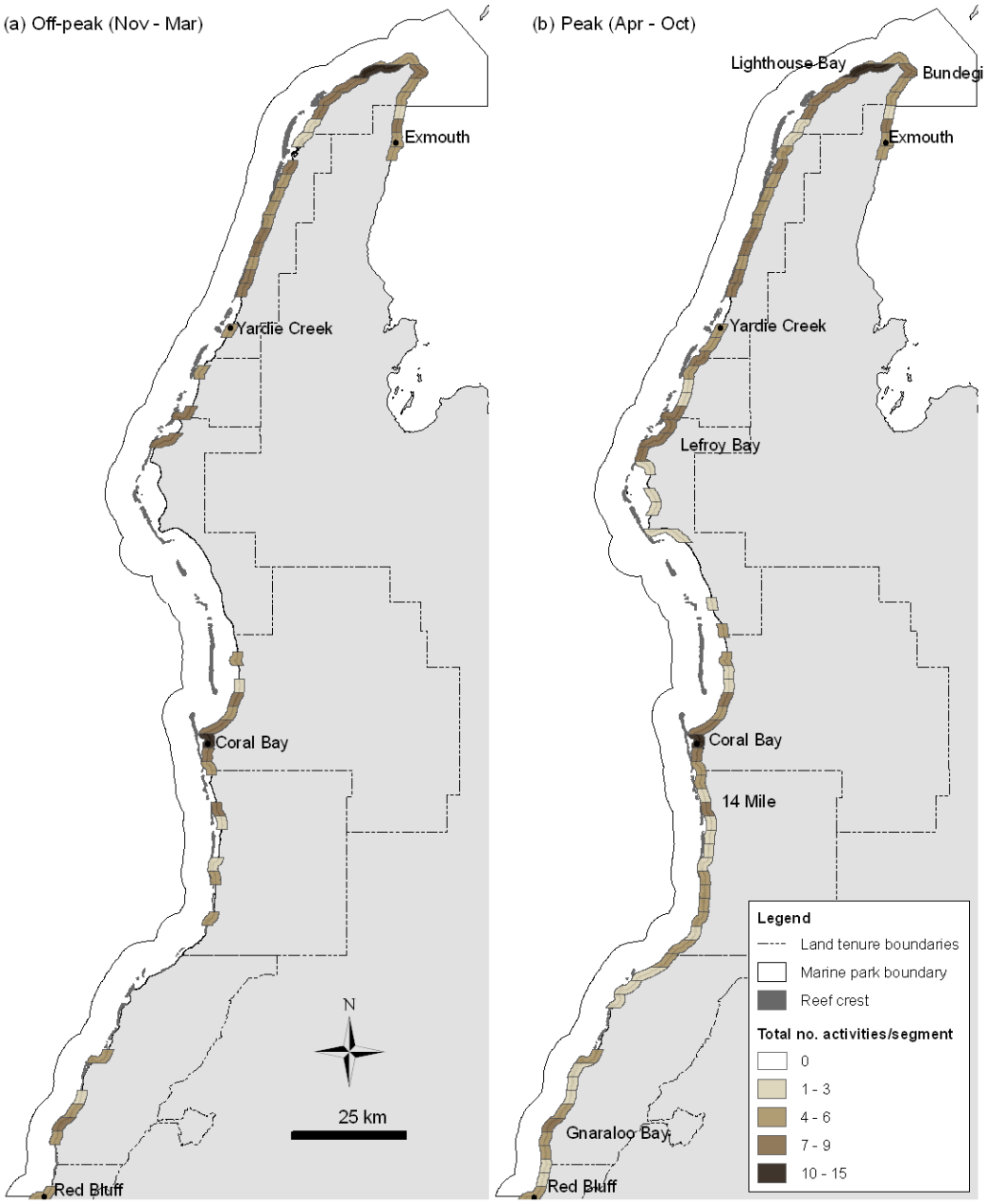


Figure 4-9 Intensity of shore-based activities within each 3 km coastal segment during northbound flights in (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24).

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 utilised 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 from vehicles and boat trailers, which had higher mean counts on northbound flights than southbound ones (Table 4-5; Figure 4-10).

Table 4-5 Mean, standard error and significance of dependent variables (one-way ANOVA) when comparing fixed counts obtained on southbound and northbound aerial flights. Note: * indicates significant value.

Dependent variable	***Southbound***		***Northbound***		***ρ value***
	Mean	***± SE***	***Mean***	***± SE***	
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 4-10). 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.

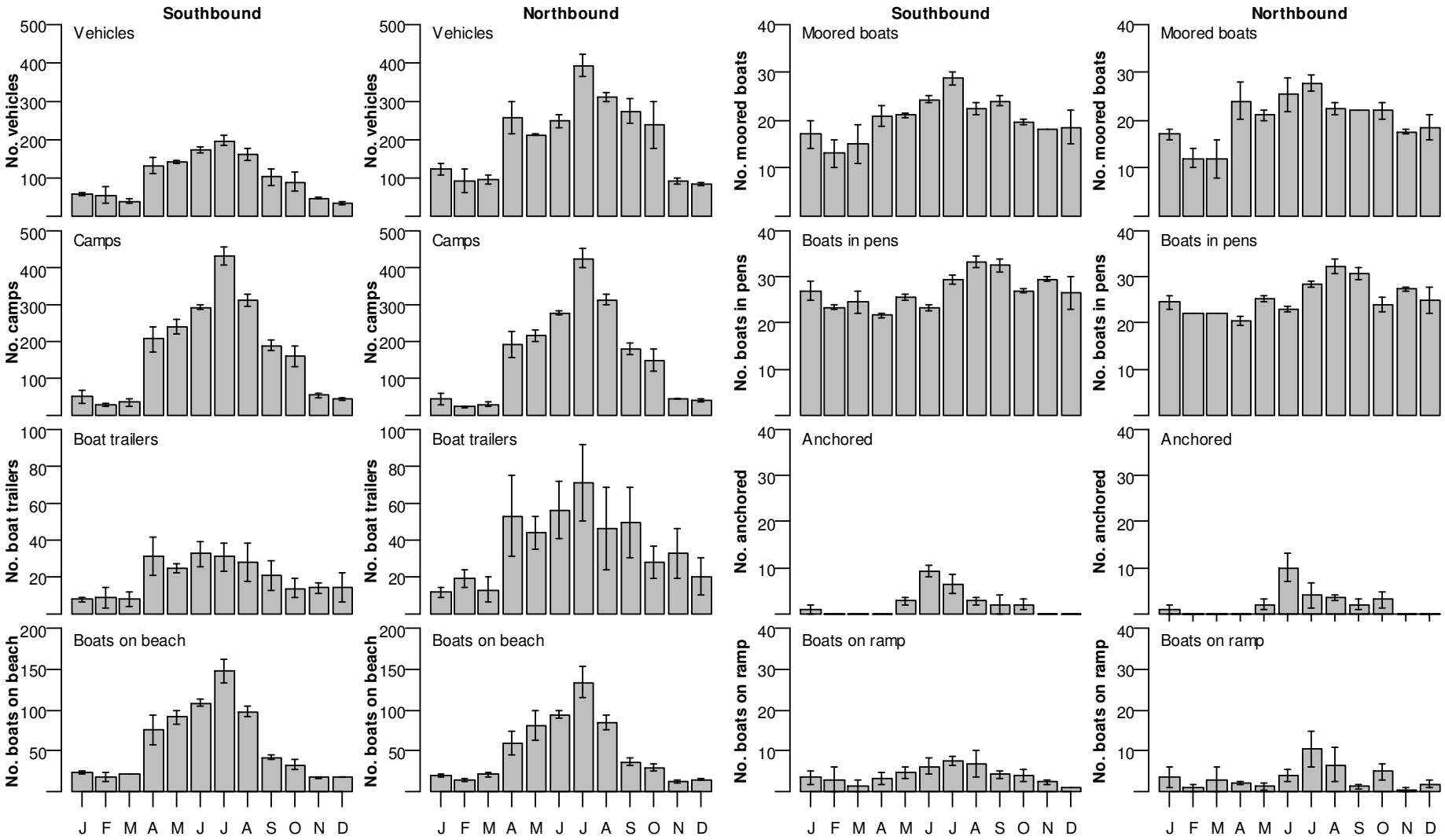


Figure 4-10 Mean number of vehicles (cars, buses and quadbikes), camps, boat trailers, boats launching on ramp, boats on the beach, boats on moorings, boats in marina pens and anchored vessels per month for southbound and northbound aerial flights conducted during 2007 (±95% CI) (number of flights = 34).

Data from the fixed counts of camps, vehicles, boat trailers and boats on the beach which occurred during northbound flights were also displayed on maps. However, unlike recreational use from boats and the shore, which were aggregated to grids or coastal segments, the mean was calculated across all surveys and assigned to the geo-referenced centroid location of each site (e.g. camping area, boat ramp or carpark).

Camps were distributed over a greater number of sites in peak months and highest densities were obtained at 3 Mile, 14 Mile, Red Bluff and Lefroy Bay which had means >16 camps/survey (Figure 4-11). However, 3 Mile and Red Bluff also recorded high densities of camps in off-peak months. Many sites in Cape Range National Park (CRNP) also had low densities of campers in off-peak months. Camps in Coral Bay and Exmouth were not documented 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 a calculation of capacity to be performed, 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.

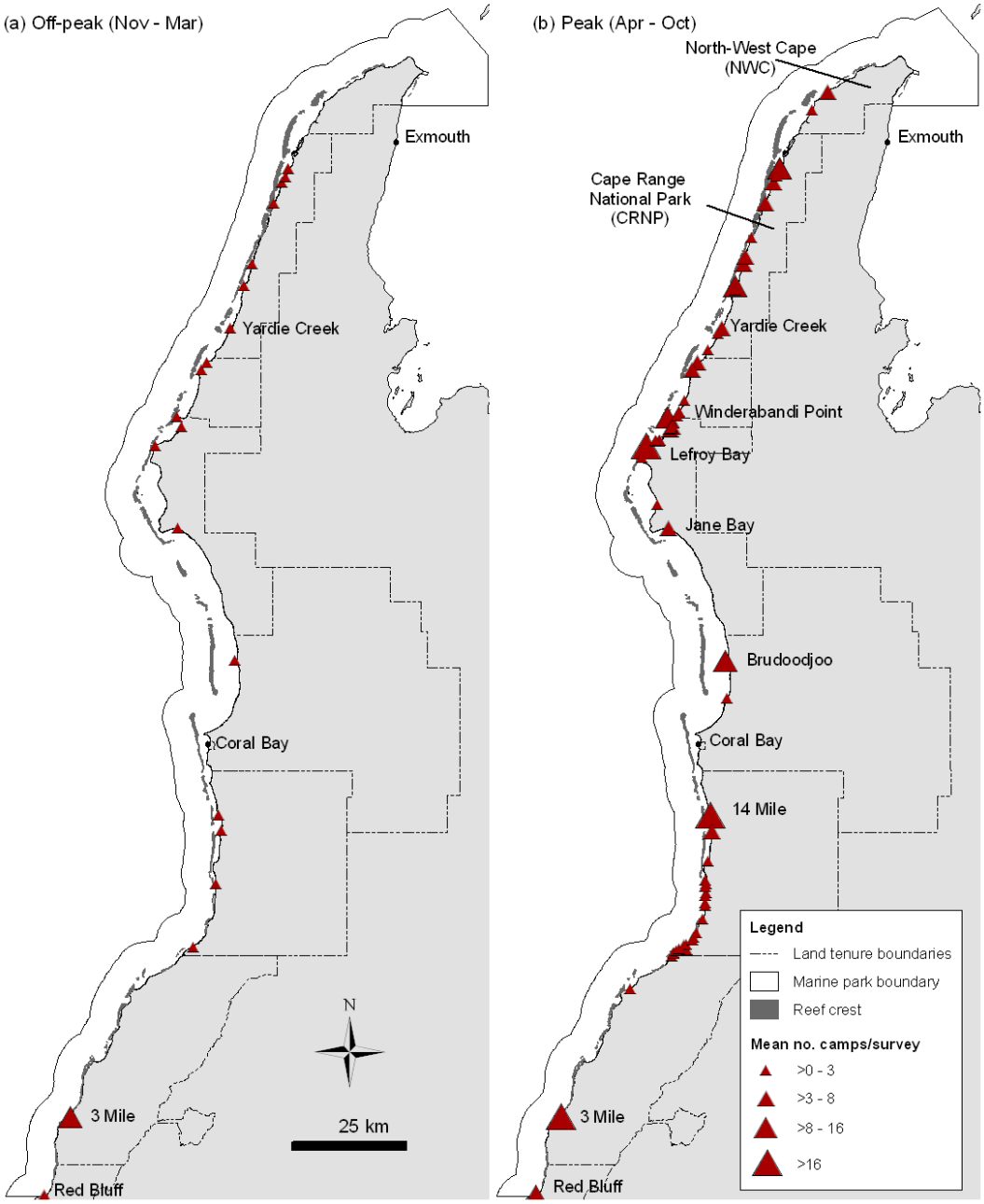


Figure 4-11 Mean number of camps recorded in (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24) during northbound aerial flights throughout 2007.

Regular aerial flights by DEC have resulted in counts of coastal camps along the entire coastal strip during April (since 1995) and July (since 1998). The single April flight undertaken by DEC in 2007 fell within the confidence limits obtained from the mean number of camps recorded this month during the four flights completed from the current

study (Figure 4-12). However, the single July count by DEC was substantially higher than the confidence limits obtained from the mean of four flights undertaken during this same month for the current study.

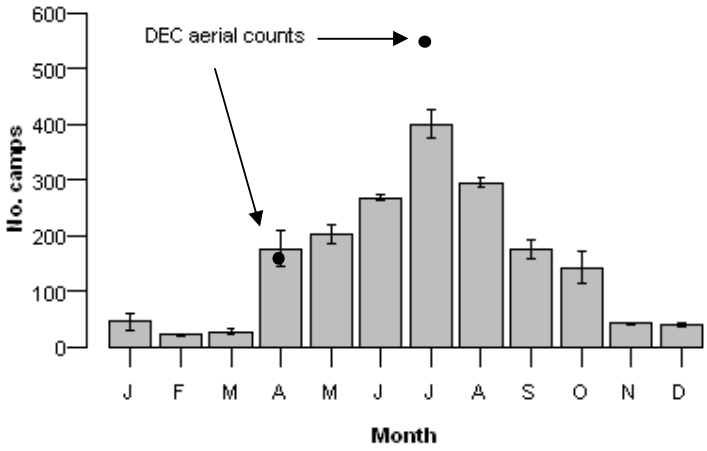


Figure 4-12 Comparison of mean number of camps obtained for each months of aerial flights along the Ningaloo coast in 2007 (±95% CI), with those from DEC flights in April and July of the same year.

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 4-13). This spread of vehicles was especially evident in CRNP and along North-West Cape which have numerous carparks. The highest densities of vehicles were obtained along this stretch of coast at Exmouth Marina, Turquoise Bay, Coral Bay and Yardie Creek as well as Gnaraloo Bay in the southern extent of the Marine Park.

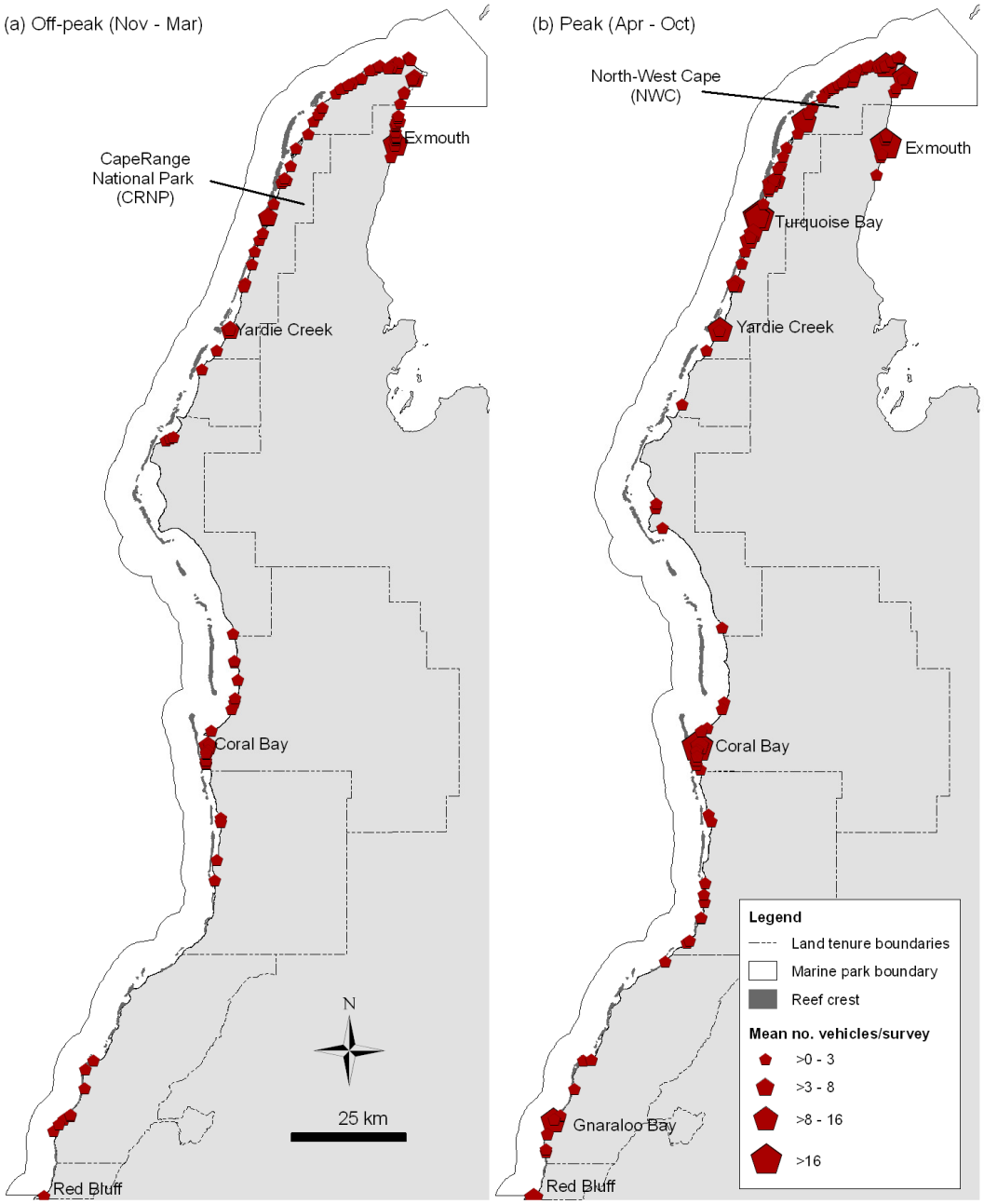


Figure 4-13 Mean number of vehicles recorded in (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24) during northbound aerial flights throughout 2007.

Boat trailers were observed at fewer sites along the Ningaloo coast when compared to camps or vehicles although their distribution was similar in both peak and off-peak periods (Figure 4-14). The highest densities, with a mean >16 boat trailers/survey, was obtained during peak months at sealed ramps at Tantabiddi, Exmouth and also Bundegi There were few boat trailers counted between Winderabandi Point and Coral Bay.

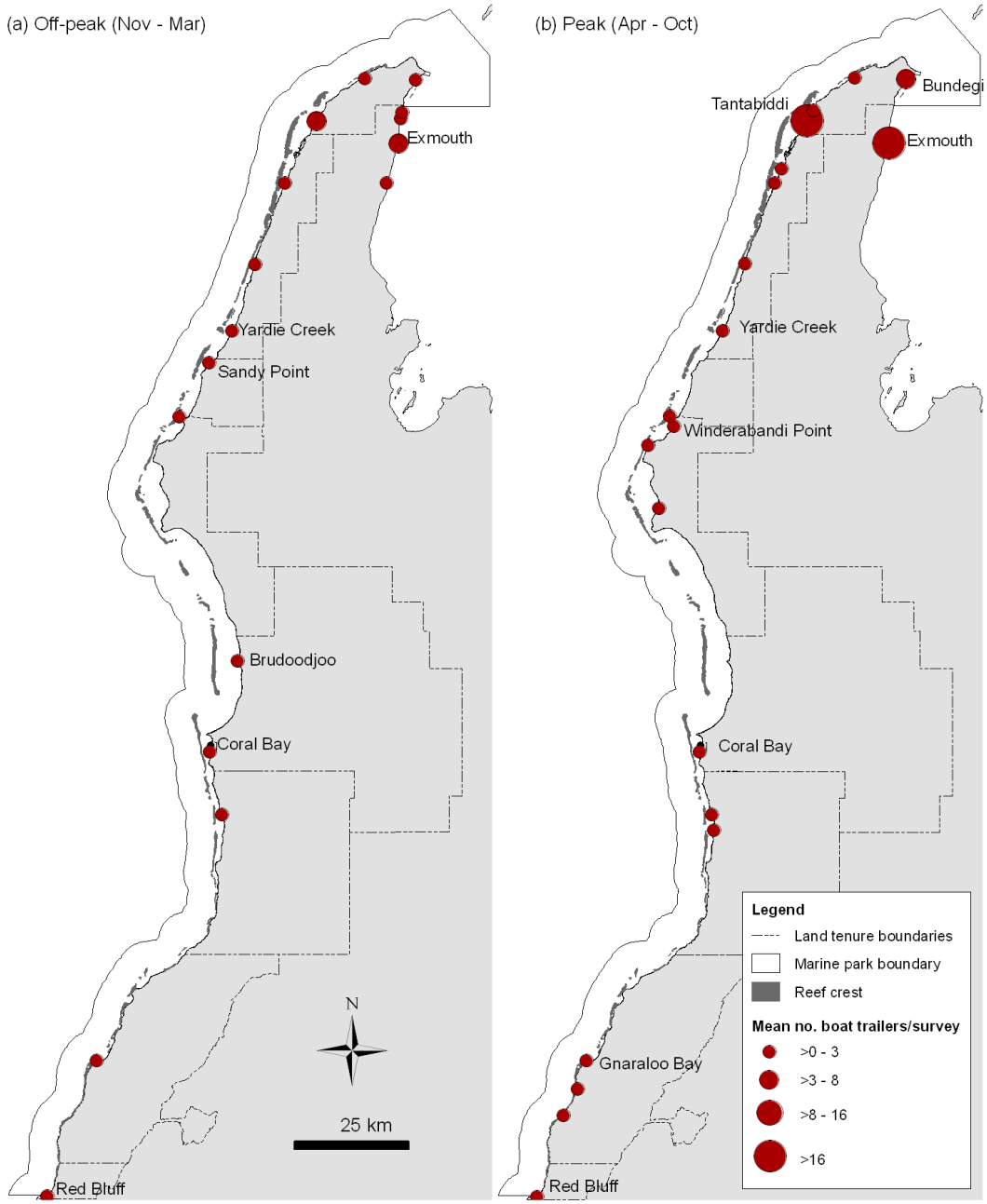


Figure 4-14 Mean number of boat trailers recorded in (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24) during northbound aerial flights throughout 2007.

Boats on the beach comprised those vessels that were not being used for recreation at the time of observation during northbound aerial flights. Vessels included recreational boat types (i.e. tinnies), that were generally located adjacent to coastal camping areas, and charter boats at Coral Bay. Boats on the beach were recorded at more sites in the

peak months, with the highest densities obtained at Bundegi, Brudoodjoo, Coral Bay and 14 Mile (Figure 4-15).

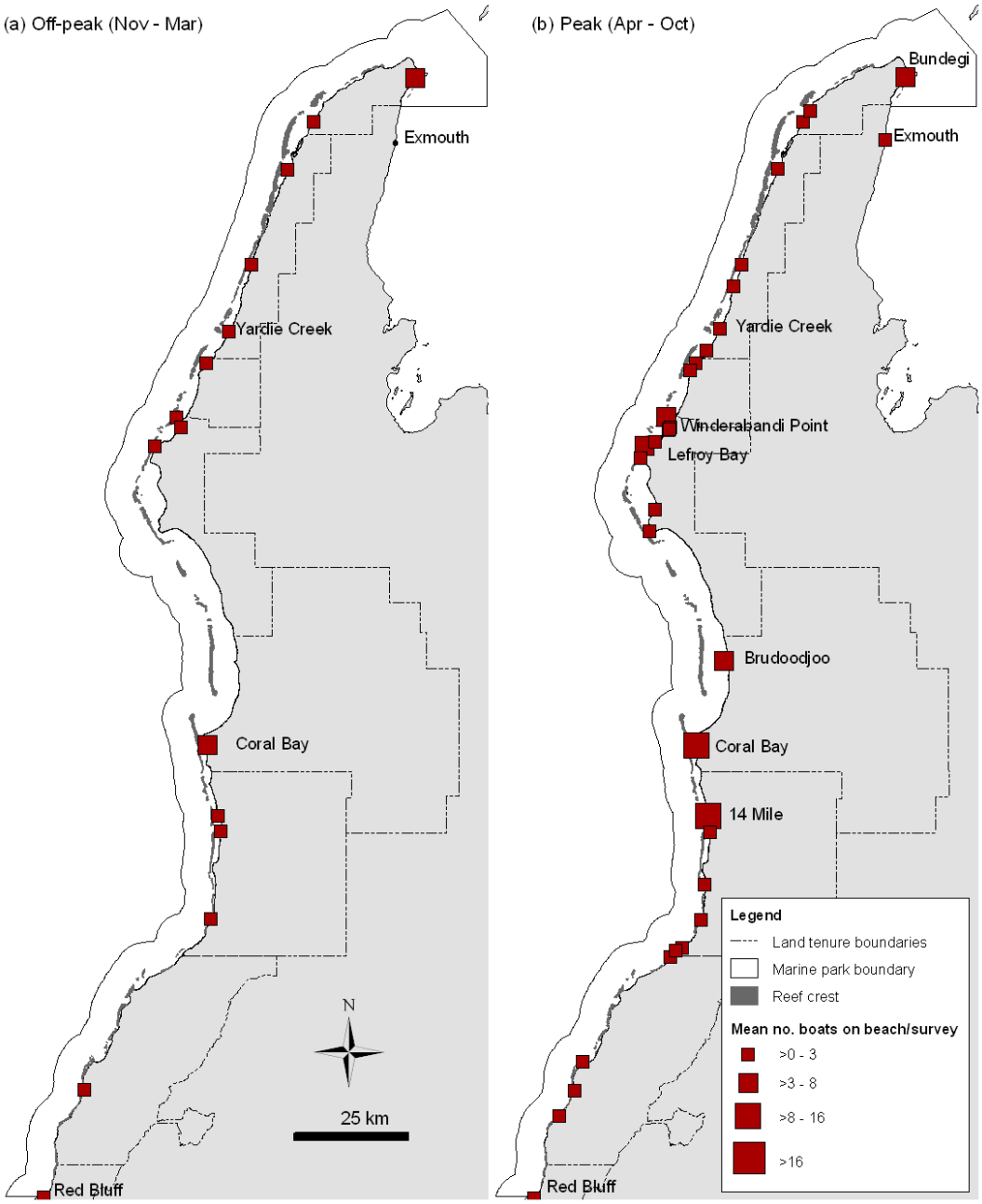


Figure 4-15 Mean number of boats on beach recorded in (a) off-peak (number of flights = 10) and (b) peak months (number of flights = 24) during northbound aerial flights throughout 2007.

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 (explained in Chapter 3). 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 (such as HPE) that could be used to determine spatial error. Of all data points, 22.0% were determined using known landmarks, which had previously been geo-referenced via land-based surveys and therefore had no sampling error. The NMEA output for the remaining points is summarised in Table 4-6. The mean number of satellites obtained during the flights was 10 and HPE was small, with a mean value of 4.5 m.

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). The mean altitude was 164.0 m and, for every 1 m of variation from 151.5 m, an associated distance error of 0.1 m could be expected. Due to infrequent occasions where the pilot had to change altitude to avoid other aircraft, the maximum height obtained was 494.7 m. However, this error only applied to boating, as the co-ordinates of shore activities were calculated relative to the mean high water mark. Based on the mean height, the error in estimating distance for boat activities due to variations in altitude was 2.1 m (*SD* = 4.0 m).

Table 4-6 Summary of NMEA string data obtained from GPS units while observing shore and boat-based activities during 34 aerial flights along the Ningaloo coast in 2007 (number of observations = 6 705). Note: * for observations of boat-based activities only (number of observations = 2 776)

NMEA Output	***Minimum***	***Mean***	***Maximum***
Fix quality	1	1	1
Number of satellites	3	10	12
HPE (metres)	3.3	4.5	116.6
Altitude (metres) *	86.9	164.0	494.7

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 exposed to the increased error, which is difficult to quantify. In terms of completeness, less then half of boat observations to a distance of 1 500 m from the flight path had both activity and number of people identified (Figure 4-16a). Beyond 1 500 m, there were almost no observations with both these details acquired by the observers. For shore activity the maximum distance for observations was 1 500 m, as the plane flew perpendicular 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 4-16b).

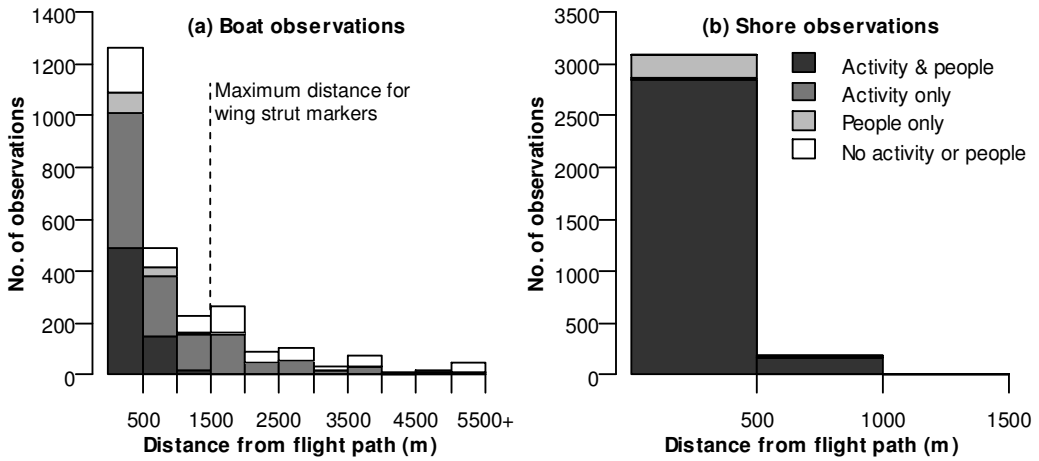


Figure 4-16 Distance from flight path, in metres, for all (a) boat and (b) shore observations and the completeness of the observation in terms of identifying number of people and activity type.

4.5 Discussion

4.5.1 Spatial and temporal variability of recreational use

Temporal factors 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). At the broadest scales, this refers to influential factors such as seasonality and school holidays. Higher levels of beach visitation generally occur during summer months, which coincide with lengthy school holiday breaks and warmer temperatures which are more attractive to recreation (Lim and McAleer, 2001). There are also finer-scale temporal factors that affect patterns of recreation, such as day of the week and daily weather patterns (i.e. temperature, precipitation), and these will be discussed in the following chapter using specific case studies. This discussion will focus on explaining the effect of broad temporal and spatial factors on recreational and coastal use (i.e. camps, vehicles) occurring along the Ningaloo coast.

Ningaloo, and northern Australia, exhibit a unique pattern of visitation due to the very high temperatures and extreme weather events (such as cyclones) which occur during the spring and summer months, particularly December – March (BOM, 2009), which coincides with lengthy school holiday breaks. Peak periods of visitation therefore occur outside of these months, during periods of lower wind speed and cooler temperatures (April – October), which is when the majority of previous research at Ningaloo has been focused (Wood, 2003a; 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 overlooked in previous research in the region.

In peak months, boating activity expanded along the coast outside the sheltered lagoon environment. There were some locations, such as to the south of Jane Bay (on Ningaloo Station) and Stevens (on Warroora Station) at which little boating activity occurred in either off-peak or peak periods. This is due to factors relating to access, lack of suitable boat launching facilities and, in the case of Stevens, 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, such as to the south of Jane Bay and around Cape Farquhar, had no activity observed during northbound aerial flights. As with boating, this is likely to be related to the lack of access to these coastal areas.

The expansion of activity from boats and the shore along the coast coincided with increased number of camps, vehicles, boat trailers and boats on the beach. These facilities provide points from which humans can access, and therefore impact, on coastal and marine resources. Although this is a complex relationship, it can be generalised that the highest human influences occur in areas closest to such facilities (Sanderson *et al.*, 2002). Research by Worley Parsons (2006) asked respondents to identify a general region 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. These distribution patterns will be further explored in an analysis of travel networks (Chapter 7).

The number of sites available for camping in CRNP is finite, and therefore the average number recorded as occupied in peak months cannot be increased. Mean occupancy in CRNP for the majority of peak months was >80% on northbound flights. This occupancy was slightly increased based on southbound flight data, as these counts were

undertaken earlier in the day prior to people departing the area. Although this was not a significant difference it may be useful for planning future aerial surveys in these earlier (southbound) time periods. 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 undesignated sites, have no maximum limit.

Aerial flights have been used to survey marine megafauna (Sleeman *et al.*, 2007; Wilson *et al.*, 2007) and turtles (Preen *et al.*, 1997) at Ningaloo but there has been little undertaken with respect to recreational use except for single counts of coastal camps by DEC each April and July (which has recently been expanded to October and December). There was variation in the total number of camps identified during the two surveys, especially for July, with the current study obtaining a substantially lower mean number of camps. Weather conditions were likely to have played a role in this result, with several days of rain and strong winds caused by winter cold fronts affecting both studies. Variations in counting techniques between observers could be another source of error although every effort was made by the researchers to standardize this technique prior to the commencement of aerial flights for consistency across 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 change between off-peak/peak months and >10 activities were recorded from boats and the shore during both these periods. Highest diversity of boat activities was concentrated north of Exmouth Marina adjacent to Oyster

Bridge/Lagoon, 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 are 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 launches further south was also aimed at separating boating away from popular snorkelling and swimming sites.

4.5.2 Sampling error

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 and survey design (some of which were discussed in Chapter 3) including 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 reduce the errors associated with these points. Aerial flights, which took 4 hours were cost-effective when balanced against the cost and time required to survey the same length of coast using land-based techniques (3 days).

Flights were scheduled with a standardised departure time of 8 am. South- and northbound surveys took ~2 hours each and were completed between 8 am – 10 am and 10 am – 12 noon, respectively. The morning sampling regime was aimed to reduce the effect of the strong onshore south and south-westerly breezes (>30 km/hour) on opportunities for viewing recreational use. These breezes predominately occur during the afternoon period along the Ningaloo coast and, although the morning periods may be dominated by easterly breezes (BOM, 2009), these blow offshore and are more suited for recreation from boats and the shore. It was also hoped the earlier southbound flights would provide an opportunity to capture information on camps prior to groups departing the area.

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, indicating there may be more groups in the Marine Park during this time. This was supported by more people recorded engaged in recreational activities from boats and the shore on later flights. Previous research by Neiman (2007) and Worley Parsons (2006) also found the highest number of boat launches occurred around 11 am. Therefore, the northbound flights provided a more complete understanding of recreational activity with greater densities and spatial extent.

Accuracy assessments are a common validation method for spatial classifications of habitats and other features (Lunetta and Lyon, 2004), but there are few studies worldwide that calculate errors associated with data points collected during studies of human use. The mean spatial error in the current study due to sampling errors was calculated to be 4.3 m and 6.1 m for shore and boat activity, respectively. A further 25 m error can be attributed to inherent GPS biases (Hulbert and French, 2001; Kowoma, 2005). Therefore, the total spatial error for each point is ~ 30 m, which is comparable to other studies. Aerial surveys in the United Kingdom digitised the location of people on the beach to a precision of 1 metre based on video footage (Coombes *et al.*, 2009). This is substantially less than the 300 m obtained for vessel positions during observational aerial surveys in Alaska (Soiseth *et al.*, 2007). The small error attributable to the sampling effects in the current study supports the use of fine-scale grids for analysis of shore and boat data, as did the clustering of data points, which was highly significant. However, it was difficult to visually interpret the data at finer-scales, therefore 9 km^2 grid cells and 3 km coastal segments were selected to explore the synoptic patterns of recreational activity.

There were additional errors due to tidal effects and observations >1 500 m distant that were difficult to quantify. Analysis of shore activity was based on mean high water mark and variations in tidal levels may have implications for the location of some data points. However, aggregating shore activity to a 1 km wide coastal segment for analysis incorporates the differences which would result from a maximum tidal range of 2 m (Commonwealth of Australia, 2002). Observations with an offset distance >1 500 m comprised 24.8% of data points and this was also difficult to quantify but would be expected to increase sampling error.

This study was designed to focus on recreational activities occurring along the shore and in the lagoon environment of Ningaloo. However, 29.6% of boats recorded during aerial flights were located outside the fringing reef crest (located an average of 2.5 km from the coast). This demonstrated that aerial surveys provide a good observing platform from which a sample of recreational use occurring outside the lagoon environment can be obtained; thereby confirming the decision to define the outer edge of the study area as the boundary of the NMP (state waters) at 3 nm. This has wider implications for surveying marine parks, with aerial flights providing rapid data collection and coverage of a large area with high spatial accuracy.

The limitation to data collected during aerial surveys was the high number of boats recorded with incomplete data, especially group size on larger vessels whose structures hindered observation. Missing data values were acquired by using external data sources and averaging across activity and boat types which was found to produce group sizes comparable to previous studies. The mean group size for the current study was 2.3 people per vessel while a boating study in Coral Bay found that although the majority of recreational vessels had a capacity of 5 - 6 people, the most common group size was 2 – 4 people per boat (Worley Parsons, 2006).

4.6 Conclusions

Geo-referenced data collected during 34 aerial flights provided a synoptic overview of recreational activities throughout the entire NMP. The scales of analysis were selected using statistical tests to identify those which would display maximum variation of use between temporal and spatial factors, while still considering visual interpretation of the data. 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 at Tantabiddi and Neds Camp. Shore 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 camps and boats on the beach to these locations. The intensity of activities was maintained year round, especially at locations such as Coral Bay and Turquoise Bay, identifying areas of potential conflict, which should be the focus of future research. Aerial flights are an effective technique for obtaining data on recreational use with high spatial accuracy, which has applications for surveying marine parks elsewhere. The geo-referenced data are also advantageous as the scale of analysis can be modified to meet management needs or for integration with other datasets.

Chapter 5 Characterizing fine scale patterns of recreational use: a land-based survey approach

5.1 Introduction

Coral reef systems are usually associated with clear, warm water and relatively shallow depths (Wood, 1999) and, are well known for their exceptional biodiversity of marine habitats and species 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), who are attracted to coral reefs to view and interact with, or extract from, these environments. Ningaloo Reef is no exception, with a diversity of species that is comparable to that of the Great Barrier Reef (Lough, 1998). However, as one of the largest fringing coral reefs in the world (Wilkinson, 2008), Ningaloo is more accessible to visitors than many barrier or offshore reef systems.

Within a coral reef system, the distribution of biological communities varies due to factors such exposure to wave action, substrate and reef morphology (Roberts *et al.*, 2003). Similar patterns are also found for visitors, with their spatial and temporal distribution affected by numerous environmental and anthropogenic influences. This includes infrastructure such as such as roads, campsites and boat ramps (Bruce and Eliot, 2006; Hadwen *et al.*, 2007), seasonality (Amelung *et al.*, 2007), coastal geomorphology (Valdemoro and Jimenez, 2006; Schlacher and Thompson, 2008), management (i.e. implementation of marine protected areas and zoning) (Bohnsack, 2000) as well as more ephemeral influences like 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 of recreationalists, 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) or 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 recreational activities other than fishing.

Marine protected areas have been widely implemented in coral reef systems in recent years for the purpose of biodiversity conservation (Spalding *et al.*, 2001). People are attracted to these sites as they expect to find high abundances and diversity of marine life (Hawkins *et al.*, 2005). The Ningaloo Marine Park (NMP) (state waters) is a multiple use marine park that contains five different zone types; general use (50%), 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 (Chapter 2; Table 2-2) thereby influencing the distribution of recreation. This is pertinent for extractive activities such as recreational line fishing, spearfishing and netting which are prohibited in sanctuary zones. Shell collecting is not permitted anywhere in the Marine Park, while netting and spearfishing are confined to general use and recreation zones located along the southern extent of Ningaloo Reef. This study is also the first to explore the effect of special

purpose (SBA) zones introduced in 2004 during the re-zoning of the NMP. These are areas where shore-based line fishing is permitted in narrow coastal areas excised from sanctuary zones (Chapter 2; Figure 2-5). A special purpose (benthic protection) zone was also introduced to restrict benthic fishing in the northern extent of the Marine Park adjacent to Mandu sanctuary zone.

Ningaloo also supports a number of different types of coastal geomorphology and habitats which have been broadly categorised into sandy beach, a mix of beach/rocky shore, rocky shore 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). At Ningaloo, these effects may also be exacerbated by exposure of these dune systems to grazing by feral animals and livestock on pastoral leases which extend to the coast (CALM and MPRA, 2005).

Reef geomorphology may also affect the distribution of boating activity. The fringing reef crest is likely to restrict the dispersal of boats into open waters, as there are few safe passages through which this can occur, i.e. North and South Passages, located in close proximity to Coral Bay. However, there are also benefits to this structure, with the fringing reef crest creating a lagoon environment sheltered from large swells.

The marine habitats of Ningaloo have also been broadly characterised from aerial photos and include coral reef, bare reef, macroalgae, seagrass and sand categories (Bancroft and Sheridan, 2000). Coral reefs are viewed as being attractive to divers, who are drawn to warmer waters, high levels of biodiversity and interesting topographies found within these environments (Rouphael and Inglis, 1997; Davenport and Davenport, 2006). Research has also identified that divers prefer to see larger and more abundant fish species during dive charter trips (Rudd and Tupper, 2002). Fish species also have habitat preferences which will attract anglers to a particular site, e.g. species of whiting are commonly found on shallow sandy habitats (Cusack and Roennfeldt, 2003) while large pelagic species such as mackerel are commonly associated with the outer reef environment (Babcock *et al.*, 2008).

Broad seasonal trends were identified as affecting the level and type of recreational use at Ningaloo (Chapter 4), which is a pattern also documented in other studies worldwide (Amelung *et al.*, 2007). However, there are also more ephemeral and localised daily weather conditions (i.e. wind speed) which may influence recreation patterns. These factors have been identified previously as having major influences on leisure and recreational behaviour (Brandenburg and Arnberger, 2001; Ploner and Brandenburg, 2003), particularly in terms of temperature and wind speed for water-based activities (Berkhout and Brouwer, 2005).

Synoptic patterns of recreational use throughout the NMP were identified in the previous chapter using data collected during aerial surveys. This facilitated an understanding of the density and spatial extent of all recreation types occurring from boats and the shore during off-peak and peak months. Similar measures were also used to identify the spatial and temporal distribution of vehicles, camps, boat trailers and

boats. This chapter moves on from this synoptic overview to characterise fine-scale patterns of recreational use via 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 period to observe and document groups than when flying, and are able to integrate additional techniques (i.e. interviews) which can facilitate a more in-depth understanding of user behaviour and characteristics (Chapters 6 and 7). Coastal surveys were also completed more frequently, with all sections of the coast visited either 72 or 48 times in a year, when compared to 34 aerial flights.

There were challenges to conducting coastal surveys over a large study area such as Ningaloo. The coast was separated into three routes of 140 – 160 km in length; each able to be covered in a single day. Even so, randomisation of starting location was not possible due to these distances, combined with the linear nature of the coast. However, this linear 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 fewer vantage points. Examples include monitoring the behaviour of groups interacting with turtles on selected beaches at Ningaloo (Waayers and Newsome, 2006) or 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 limited to a smaller number of survey days at each site, e.g. three (Keirle, 2002) or four surveys (Arnberger *et al.*, 2005).

5.2 Research objectives

The overarching aim of this chapter 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 addressing several research objectives including:

- selecting specific recreational activities to describe at fine spatial and temporal scales,
- investigating factors such as zoning, infrastructure, geomorphology and weather conditions and their effect on the distribution of these activities; and
- quantifying the spatial accuracy of the collected data points.

5.3 Analysis techniques

The research design for coastal surveys was described in Chapter 3 (Methods). 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 in the previous chapter (i.e. 9 km^2 grid cells and 3 km coastal segments). However, for specific recreational activities, the geo-referenced data points were used to emphasise the fine-scale resolution of these data for sites within the study area. Standardisation of techniques between these chapters also extended to HPE, number of satellites and fix quality used to calculate spatial accuracy of data points, metrics (density and spatial extent) of recreational use and decision rules used to assign a group size to those for which were undetermined.

As an extension to analysis conducted in the previous chapter, the effects of daily weather conditions, coastal geomorphology, marine habitats and zoning on patterns of recreational use were 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 were determined from broad classifications digitised from aerial photos 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 Summary of spatial and temporal patterns of use

Coastal surveys were split into three survey routes of ~100 km each which were travelled over 192 days in 2007. During this time, 8 957 observations of recreational activity from boats and the shore were documented. The survey start/end locations were at Exmouth Marina, Yardie Creek and Red Bluff. The start time of each survey was randomised between 7.30 am – 11 am and all three routes were travelled an equal number of times in each direction. This technique assisted with negating the effect of no randomisation of start times, discussed in Chapter 3. By the completion of fieldwork, all survey routes had been conducted an equal number of times in each direction and the points in Figure 5-1 represent the time of observation at each location.

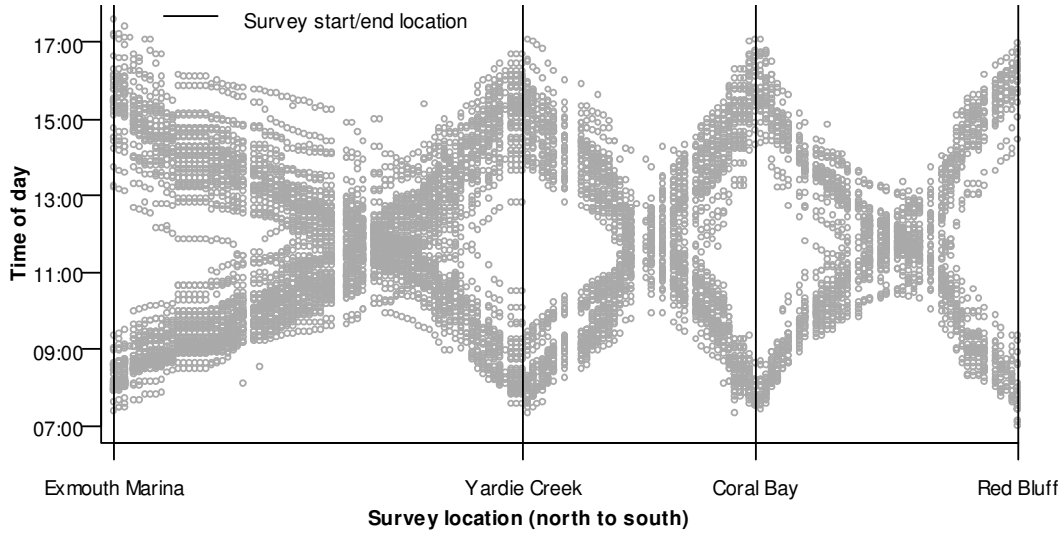


Figure 5-1 Time of observation at each survey location, for all coastal surveys (showing route start and end points) between Exmouth Marina and Red Bluff during 2007 (number of surveys = 192).

The two northernmost survey routes from Exmouth – Yardie Creek and Yardie Creek – Coral Bay were sampled 6 times per month and had a significantly higher number of observations (5 452 and 2 553 observations, respectively) than the southern route which was sampled 4 times per month ($F_{(1, 188)}$=52.03, ρ<0.05). Peak months between April – October had the highest number of observations for these routes, although there were >200 observations for each off-peak month recorded between Exmouth – Yardie Creek (Figure 5-2a,b). The southern route from Coral Bay – Red Bluff was sampled less frequently (4 surveys/month) and there were 932 observations recorded. Peak months also had the highest number of observations along this route (Figure 5-2c). The variation between off-peak and peak periods was significant (($F_{(1, 189)}$=38.84, ρ<0.05) however, there was no interactive effect between this factor and route type ($F_{(1, 2)}$=3.00, ρ>0.05).

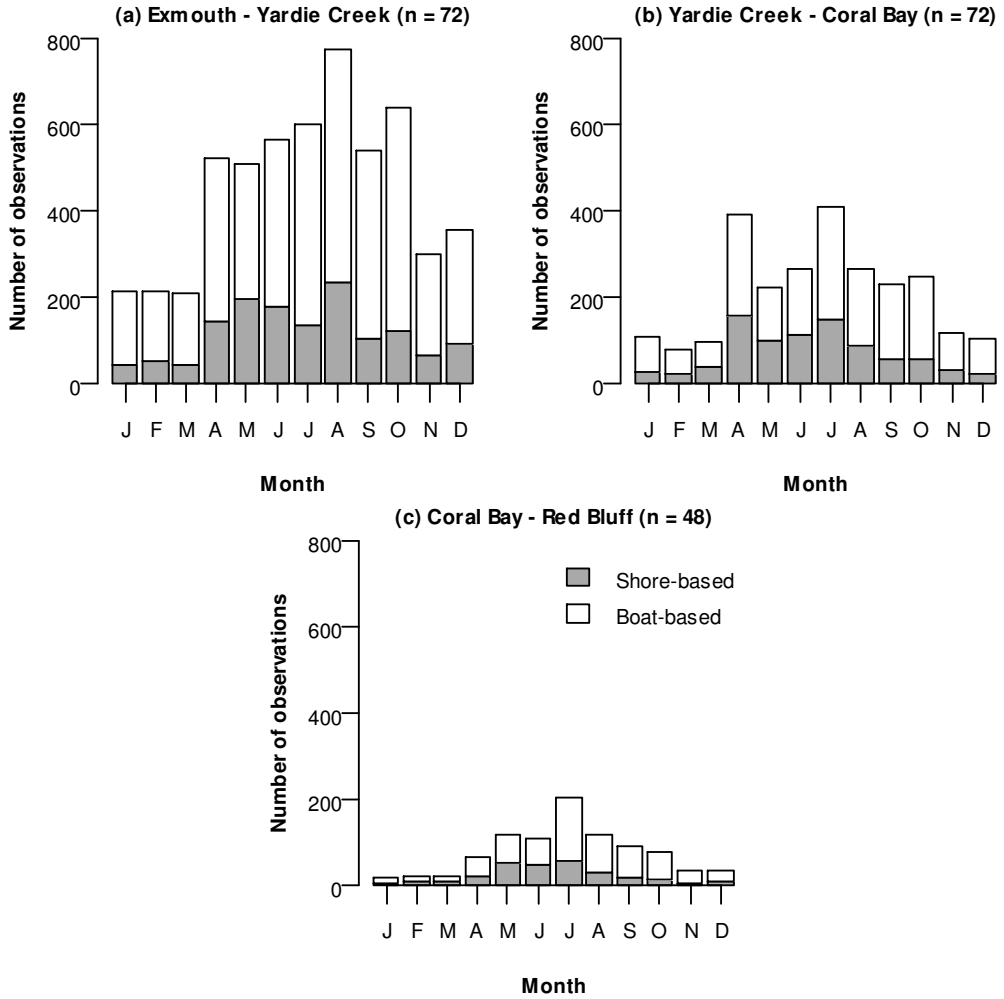


Figure 5-2 Total number of observations of shore- and boat-based recreational activity for each month of coastal surveys between a) Exmouth – Yardie Creek, (b) Yardie Creek – Coral Bay and, (c) Coral Bay – Red Bluff where n = number of surveys.

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, tinnies (small aluminium vessels) (28.4%), charter vessels (18.3%) and open boats >5 m in length (such as centre consoles) (17.6%) were the most abundant (Figure 5-3). The largest boats (charter vessels and open vessels >5 m in length) were recorded in the highest numbers outside the lagoon whereas the smallest motorised vessels, comprising tinnies, tenders and non-motorised vessels, such as kayaks and yachts, were found almost exclusively inside the lagoon.

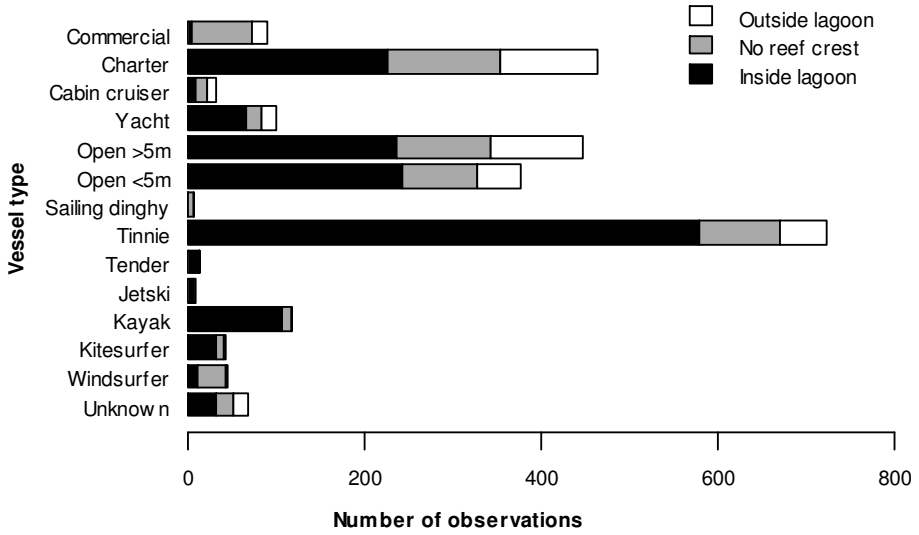


Figure 5-3 Total number of observations for each boat type recorded inside and outside the lagoon as well as adjacent to areas with no fringing reef crest (number of observations = 2 545).

There were 2 576 observations of groups undertaking recreational activities from boats during coastal surveys with mean group size was 2.3 people. For 52.5% of boats, which comprised mostly charter and commercial vessels, the number of people was undetermined. Applying 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). The possible biases introduced by assigning a group size were investigated using regression to determine the nature of this relationship (if any). This illustrated a strong positive relationship at 9 and 36 km^2 scales with R^2 values >0.822 which deteriorated at 1 km^2 to an R^2 value of 0.530 (Table 5-1). Based on these findings, and for standardisation with the previous chapter, 9 km^2 grid cells and number of people was used for analysis of boating activity during off-peak and peak months.

Table 5-1 Regression co-efficient (R^2) calculated using rank order of grid cells based on total number of people versus rank order of total number of boat-based observations for all coastal surveys.

Grid size	*Regression co-efficient (R^2)*
36 km^2	0.881
9 km^2	0.822
1 km^2	0.530

Boat activity did occur in off-peak months and was concentrated adjacent to the coast, with the highest density at Coral Bay (Figure 5-4). Expansion along the coast and beyond the reef crest occurred in peak months and the highest densities of people, with a mean >5 people/survey, were located adjacent to boat launching sites at Tantabiddi, Neds Camp and around Coral Bay as well as in Lighthouse Bay.

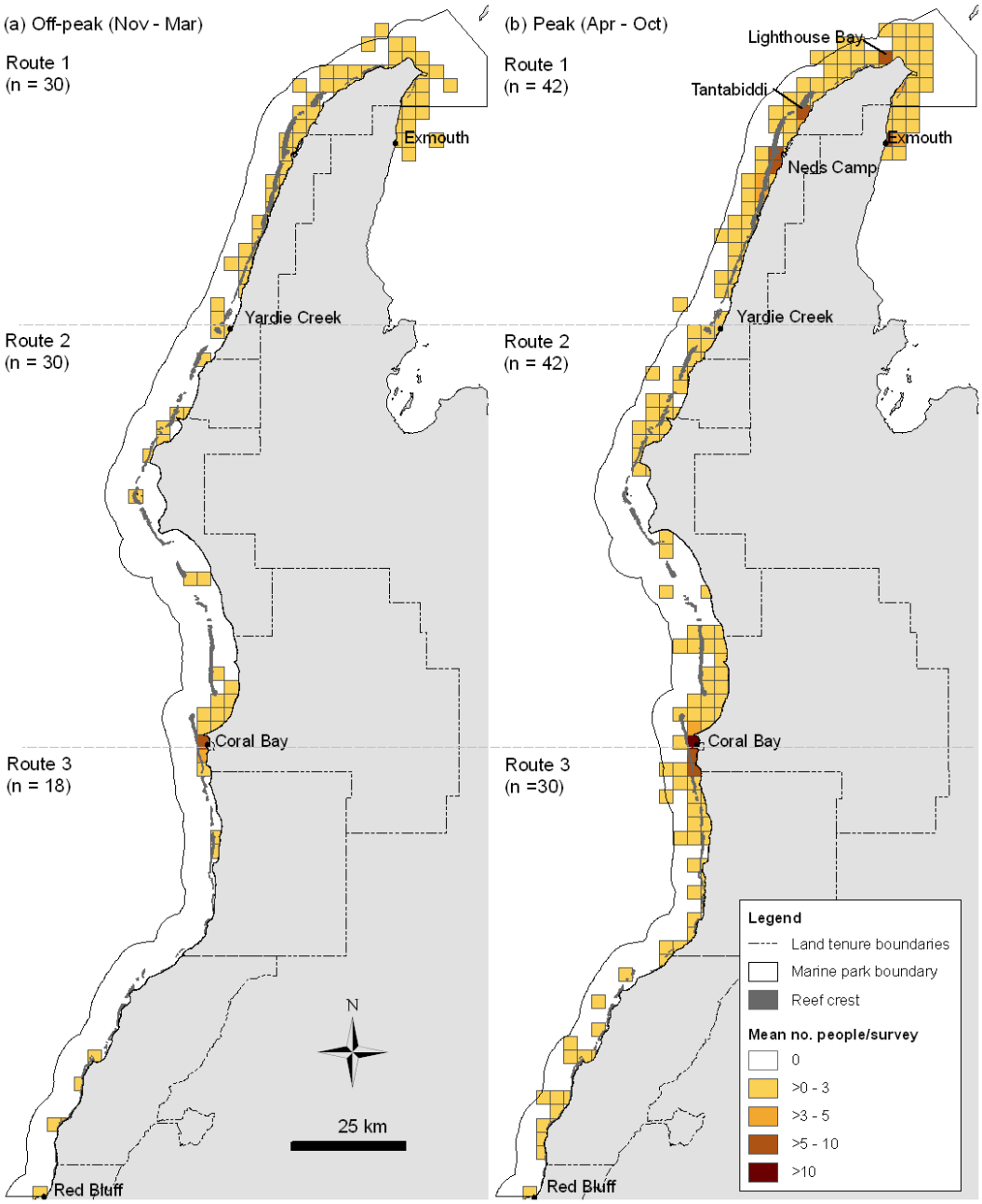


Figure 5-4 Mean number of people per survey recorded during coastal surveys participating in boat-based recreation within 9 km^2 grid cell during (a) off-peak and (b) peak months (n = number of surveys).

The most popular activities undertaken from boats was motoring (transiting), wildlife interactions and diving although in a considerable proportion (26.7%) the activity could not be ascertained (i.e. unknown) (Table 5-4). These activities had the highest number of participants and many also had large spatial extents (i.e. were present in a more grid cells). The differentiation between wildlife viewing and wildlife interaction is based on 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. Wildlife interaction and fishing had the largest disparity between number of people and spatial extent. The distribution of these boat activities is explored below with respect to zoning, coastal geomorphology and weather conditions.

Table 5-2 Most frequently undertaken boat-based activities based on percentage of people and spatial extent for each recreational activity within 9 km^2 grid cells recorded during coastal surveys. Note: there are a total of 385 grid cells in the study area to the edge of the NMP (state waters).

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 ($r^2 = 0.03$; $\rho>0.05$). However, there was a significant association between zone and activity type (χ^2 (38) = 2 468, $\rho<0.05$). 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 5-5). Fishing from boats was recorded in sanctuary zones by 12.7% of people undertaking this activity.

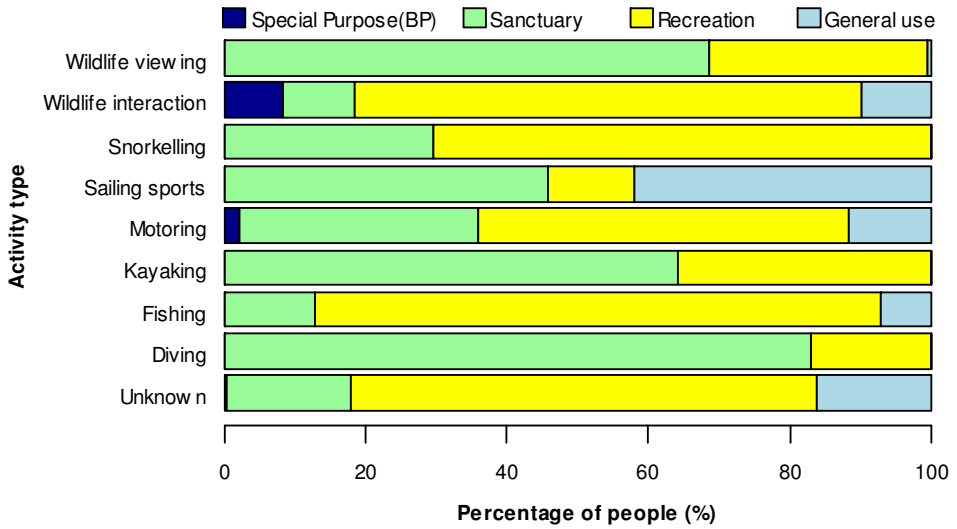


Figure 5-5 Percentage of people observed undertaking a specific activity type from boats within each NMP (state waters) zone type (number of people = 8 826).

The differences between recreational activity and the five broad marine habitat categories were investigated and found to be significant (χ^2 (32) = 1 416, $\rho<0.05$). 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 5-6). Sandy substrates were most associated with kayaking and sailing sports.

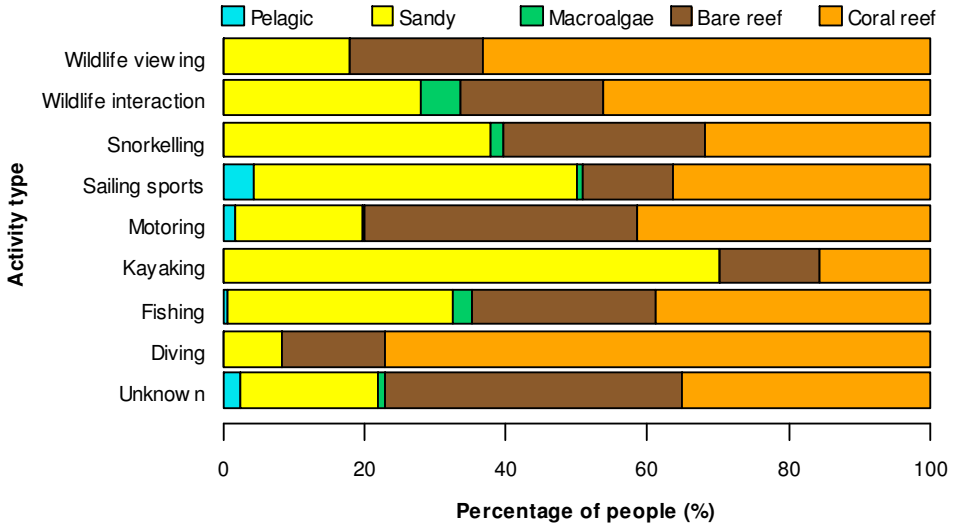


Figure 5-6 Percentage of people observed undertaking a specific activity type from boats within each broad type of marine habitat [adapted from Bancroft and Sheridan (2000)] (number of people = 8 729).

Weather conditions were influenced participation in specific recreational activities, with significant differences for air temperature ($F_{(1, 8)} = 26.08$, $\rho<0.05$), wind speed ($F_{(1, 8)} = 57.36$, $\rho<0.05$) and wind direction ($F_{(1, 8)} = 22.24$, $\rho<0.05$). Further investigation found the majority of people were participating in boat activities within the 25 ^{o}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. Except for sailing sports, all activities were undertaken during easterlies and south-westerlies (the dominant wind directions for Ningaloo). Sailing sports were observed more frequently during south and south-westerly onshore breezes.

5.4.3 Shore-based activities

There were 6 361 observations of groups 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 standardised decision rules to assign a number of people to these values, the total number of people was

determined to be 23 282, of which only 7.0% were documented along the southernmost survey route (Coral Bay and Red Bluff). As with boat-based activities, the relationship between the number of people and number of observations within each coastal segment was investigated. This showed a strong positive relationship at the broadest scales (3 and 6 km segments) with R^2 values >0.863 (Table 5-3). Unlike the grid cells used for boat-based activities, the strength of this relationship did not dissipate at finer scales. These strong relationships supported the use of number of people for analysis of shore activity while 3 km coastal segments and off-peak/peak periods were applied for standardisation between survey techniques.

Table 5-3 Regression co-efficient (R^2) calculated using rank order of grid cells based on total number of people versus rank order of total number of shore-based observations for all coastal surveys.

Coastal segment	***Regression co-efficient (R^2)***
6 km	0.963
3 km	0.978
1 km	0.944

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 5-7). The highest densities of shore activity that occurred during peak months were concentrated around Turquoise Bay and Coral Bay, with a mean >50 people/survey. Coral Bay also achieved this density of activity in off-peak periods. High densities of people were also evident in coastal segments at Bundegi Beach, to the south of Lighthouse Bay, and Lakeside during peak months.

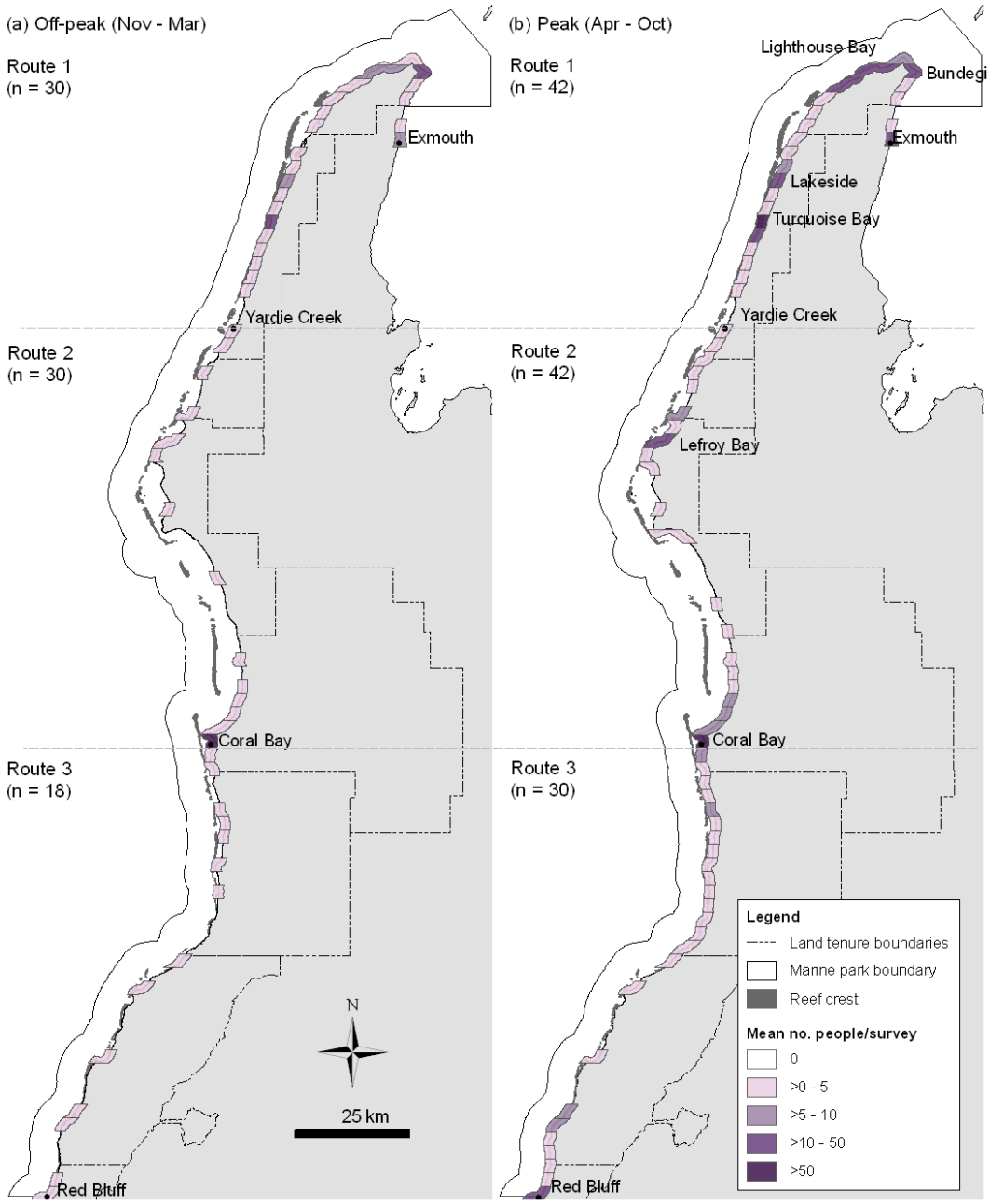


Figure 5-7 Mean number of people per survey recorded during all coastal surveys participating in shore-based recreation within each 3 km coastal segment during (a) off-peak and (b) peak months (n = number of surveys).

The most popular activities undertaken from the shore were relaxing, walking, snorkelling and fishing (Table 5-4). 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. The distribution of these shore activities is explored below with respect to zoning, coastal geomorphology and weather conditions.

Table 5-4 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. Note: there are a total of 92 coastal segments in the study area along the coast of the NMP (state waters).

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

People along the shore were recorded mainly in sanctuary (48.7%) and recreational (36.6%) zones within the NMP (state waters). 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 ($r^2 = 0.053$; $\rho>0.05$) but there was a significant association between zone and activity type (χ^2 (66) = 9 395, $\rho<0.05$). Snorkelling had the highest percentage of association with sanctuary zones (84.8%), along with wildlife interactions and relaxing (Figure 5-8). The majority of people were fishing in recreation zones while >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.

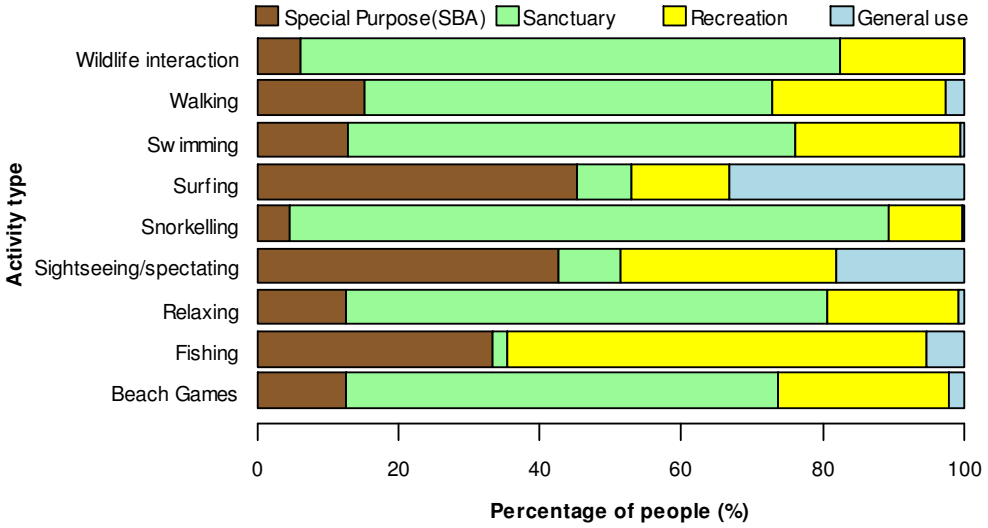


Figure 5-8 Percentage of people observed undertaking a specific activity type from the shore within each NMP (state waters) zone type (number of people = 22 726).

The differences between shore activity and coastal geomorphology categories was significant (χ^2 (24) = 3 387, ρ<0.05). The majority of activities were associated with sandy beaches, especially swimming and beach games (Figure 5-9). 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 mangrove environments (not shown in Figure 5-9).

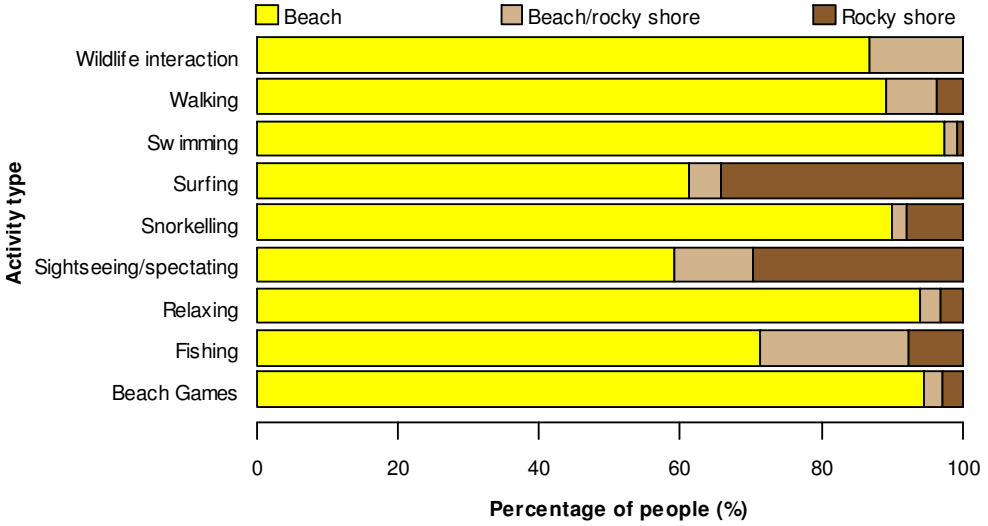


Figure 5-9 Percentage of people observed undertaking a specific activity type from the shore within each broad type of coastal geomorphology [adapted from Bancroft and Sheridan (2000)] (number of people = 22 726).

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

5.4.4 Case studies of specific recreational activities

Motoring (transiting), wildlife interaction, diving and fishing were chosen as case studies for boating activities. This was due to the high percentage of people involved and relevance to social values identified in the current NMP management plan (CALM and MPRA, 2005). Recreational fishing from boats is also one of the few activities where an existing dataset (Sumner *et al.*, 2002) enables comparison between findings with respect to spatial distribution. Relaxing, snorkelling, fishing and surfing were selected as case studies for shore activities. Similarly to boating, these shore activities were selected based on their proliferation, relevance to the social values in the current NMP management plan (CALM and MPRA, 2005) and ability for comparison with an existing dataset of recreational fishing (Sumner *et al.*, 2002).

5.4.4.1 Motoring (transiting)

Motoring was the most common boat-based activity, comprising 31.7% of people on boats during the coastal surveys and in 32.5% of grid cells within the NMP (state waters). This activity was dispersed around North-West Cape in off-peak months and also adjacent to Coral Bay, where activity was concentrated inside the lagoon (Figure 5-10). Higher densities were obtained during peak months, especially adjacent to Coral Bay, and activity expanded within the lagoon environment and outside the reef crest.

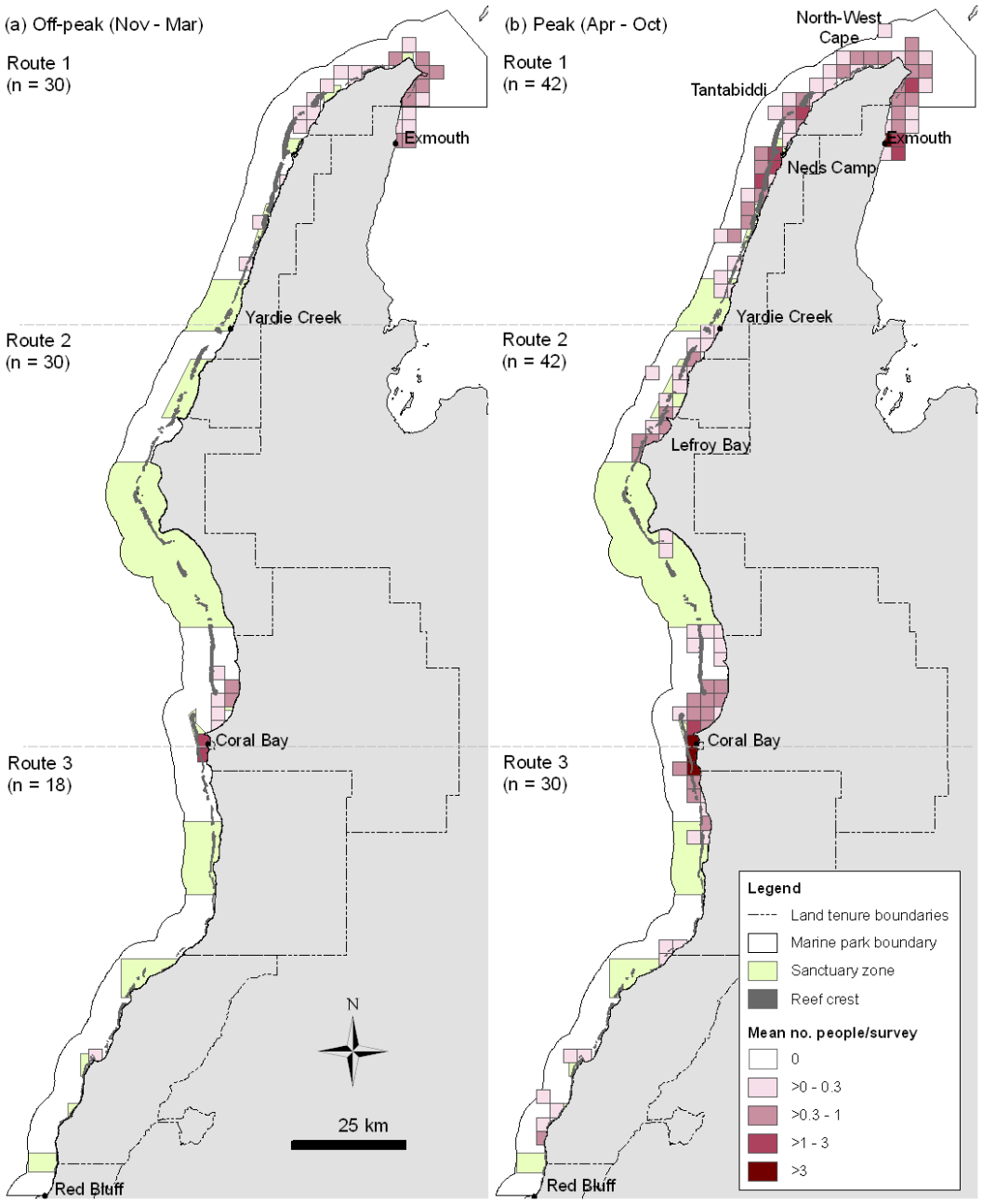


Figure 5-10 Mean number of people recorded on boats motoring during coastal surveys within each 9 km^2 grid cell for (a) off-peak and (b) peak months along with NMP sanctuary zones (n = number of surveys).

5.4.4.2 Wildlife interactions

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 5-11).

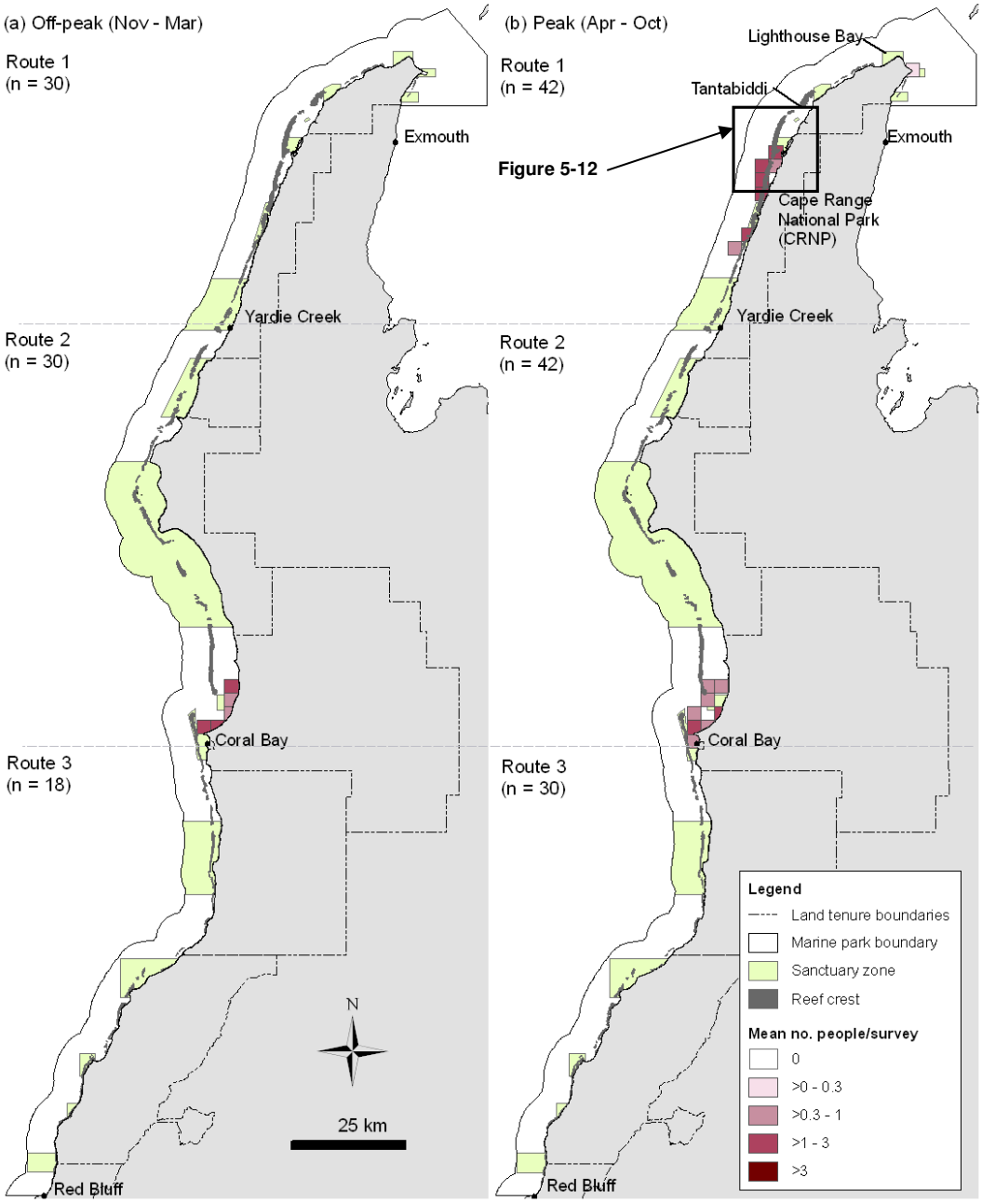


Figure 5-11 Mean number of people recorded interacting with wildlife from boats during coastal surveys within each 9 km^2 grid cell for (a) off-peak and (b) peak months along with NMP sanctuary zones (n = number of surveys).

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 5-12). 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.

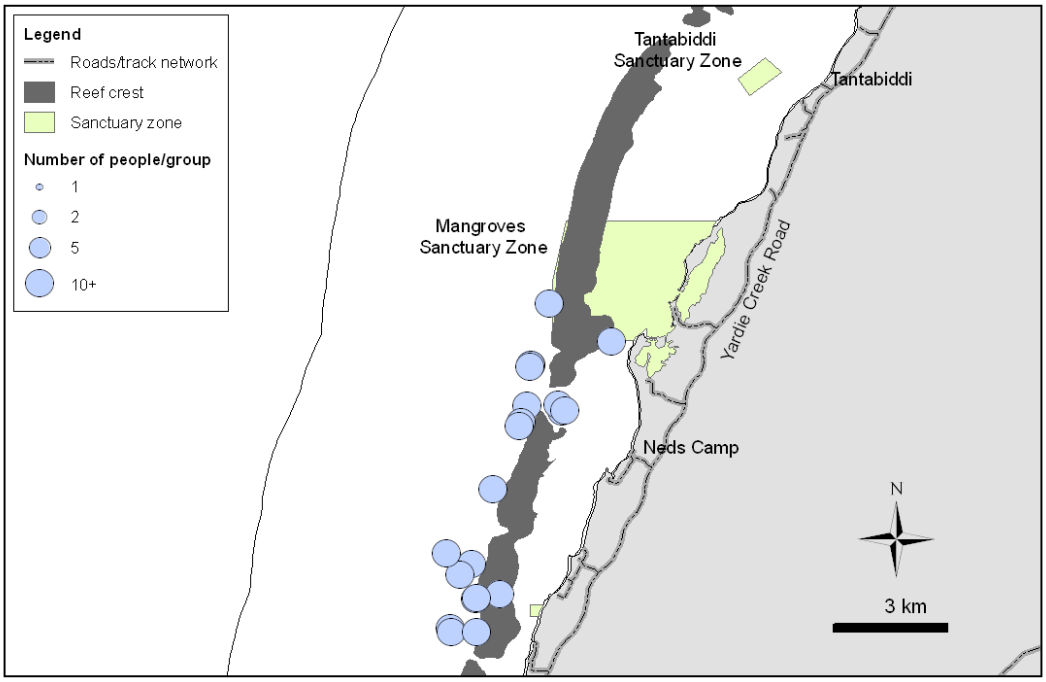


Figure 5-12 Geo-referenced location of each boat observed interacting with wildlife (such as whale sharks) offshore from Cape Range National Park, and the number of people, during coastal surveys in peak months along with location of sanctuary zones (number of surveys = 42).

5.4.4.3 Diving

Diving using compressed air was located at only a few specific sites throughout the NMP. Activity was recorded in both off-peak and peak months at these locations in Lighthouse Bay, Bundegi and Neds Camp as well as to the north and south of Coral Bay (Figure 5-13). There was no diving observed in the southern extent of the NMP beyond Coral Bay.

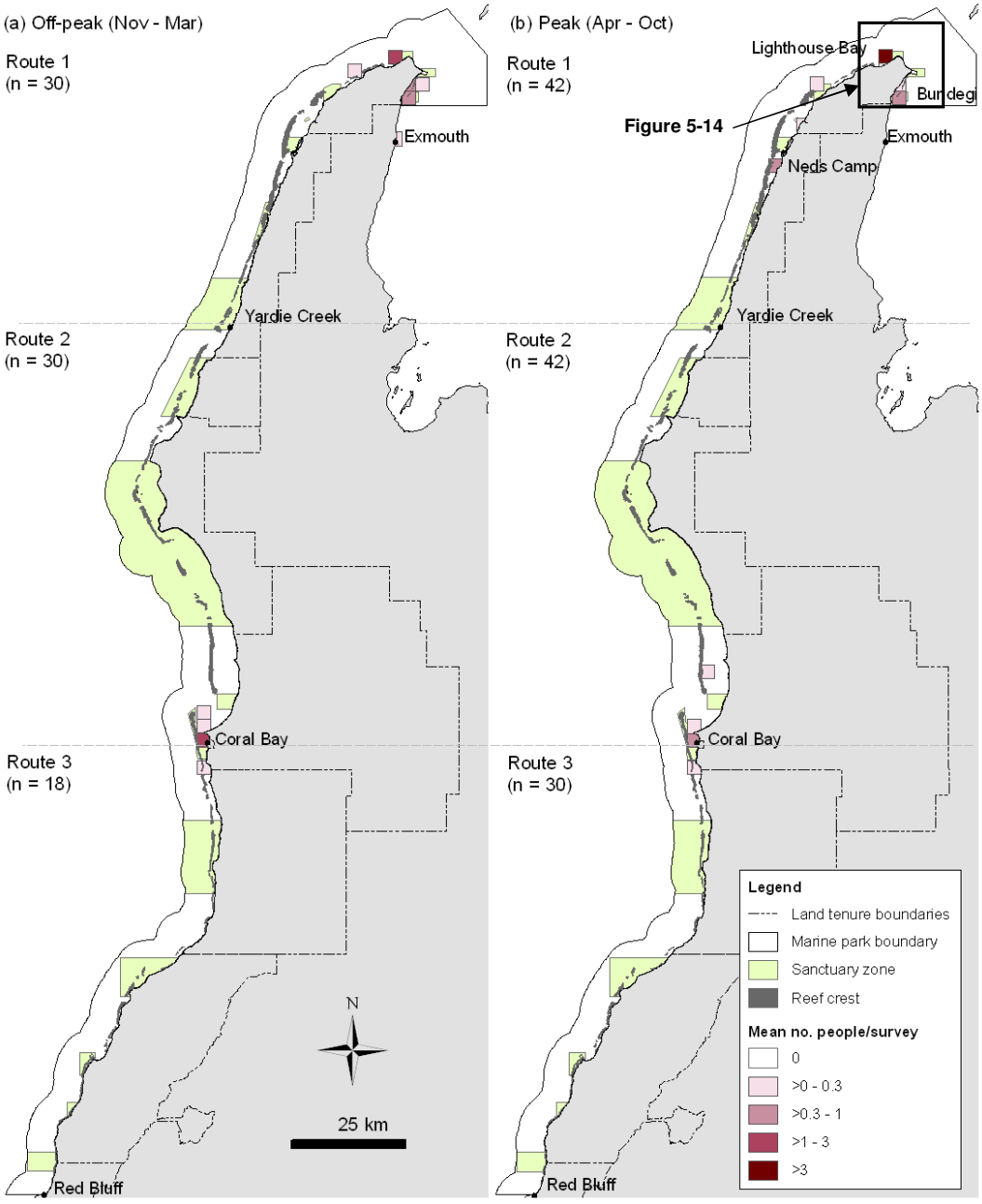


Figure 5-13 Mean number of people recorded diving from boats during coastal surveys in each 9 km^2 grid cell for (a) off-peak and (b) peak months along with NMP sanctuary zones (n = number of surveys).

Boats observed with people diving in peak months were concentrated within two locations around North-West Cape, namely, Lighthouse Bay Sanctuary Zone and Bundegi Sanctuary Zone (Figure 5-14). The large group size, which was generally >10+ people, indicates the majority of these vessels were charters, and the geo-referenced

locations of these vessels are clustered together at these locations due permanent moorings installed at these dive sites.

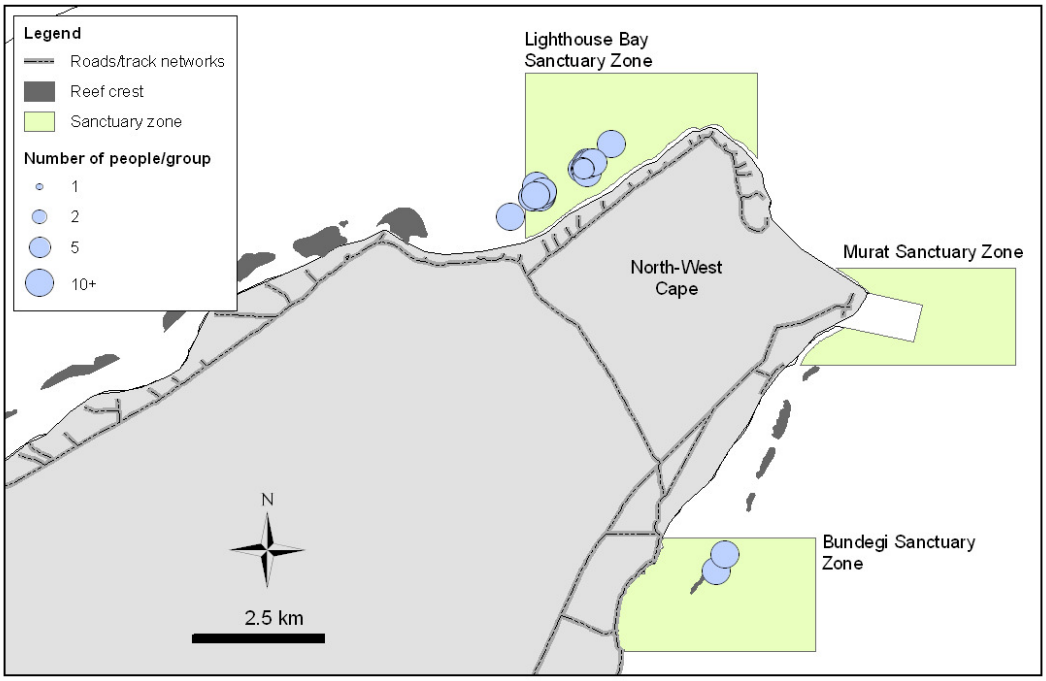


Figure 5-14 Geo-referenced locations of each boat observed diving around North-West Cape, and the number of people, during coastal surveys in peak months along with location of sanctuary zones (number of surveys = 42).

5.4.4.4 Recreational fishing from boats

Recreational fishing from boats comprised only 5.8% of people observed participating in activity during the coastal surveys, although this was distributed across 16.1% of grid cells. Little fishing from boats occurred in off-peak months, especially to the south of Lefroy Bay, except at Coral Bay and Gnaraloo Bay (Figure 5-15). However, there was greater distribution in peak months and the highest densities were recorded adjacent to Tantabiddi, Neds Camp and 14 Mile. Compliance with sanctuary zones was not as high for people fishing from boats (when compared to those from the shore) with 12.7% observed while fishing inside these areas at Coral Bay and north of Lefroy Bay.

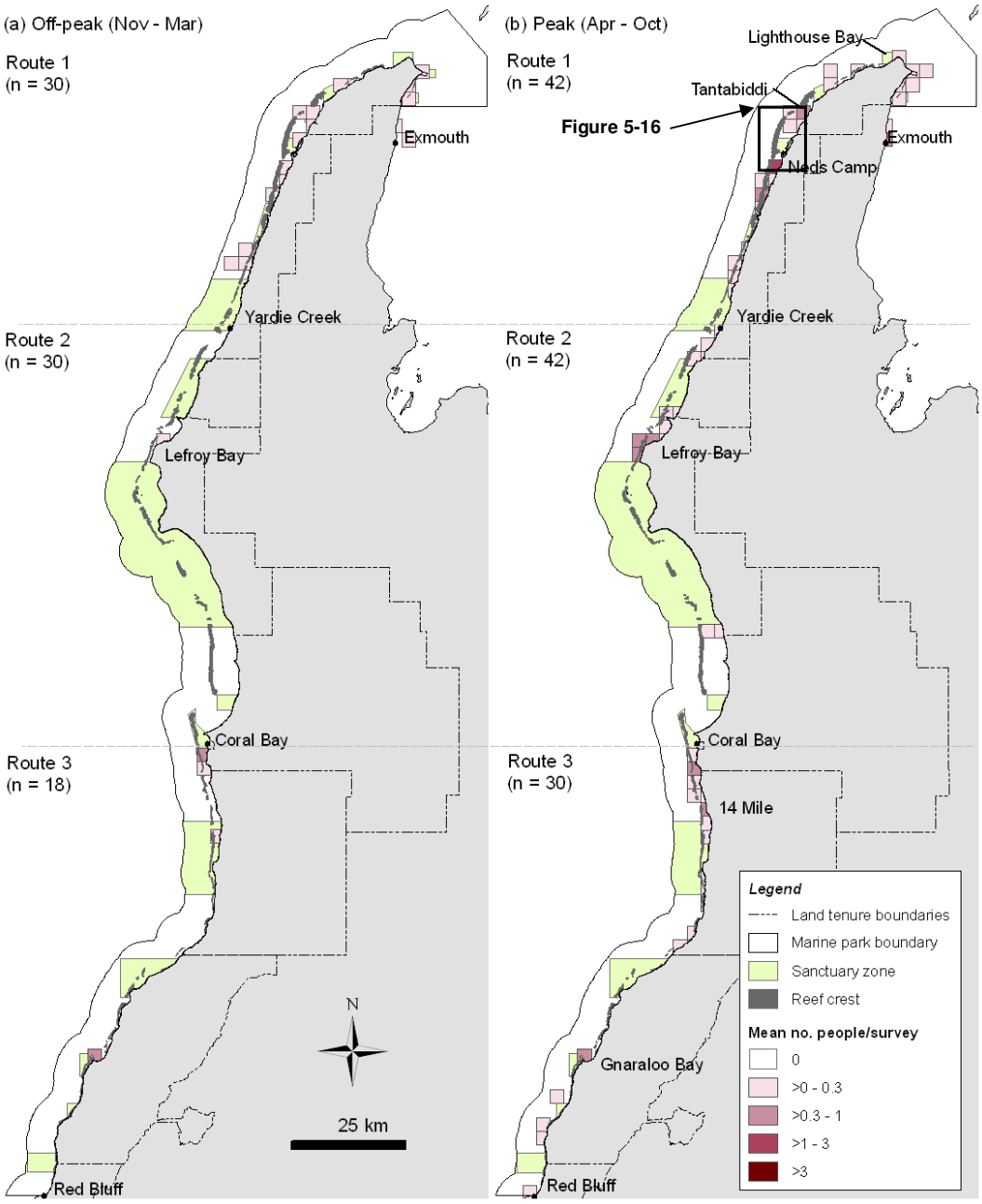


Figure 5-15 Mean number of people recorded fishing from boats during coastal surveys within each 9 km^2 grid cell for (a) off-peak and (b) peak months along with NMP sanctuary zones (n = number of surveys).

The area of highest fishing density in peak months was adjacent to Tantabiddi and extending south beyond Neds Camp, which was selected for further investigation. Boat fishing in this area was concentrated inside the fringing reef crest and outside of sanctuary areas (Figure 5-16). Sand Dune, Tantabiddi, Neds Camp and Mesa Camp

were also the only locations in this vicinity where boats could be easily launched, indicating that vessels are concentrating around these sites.

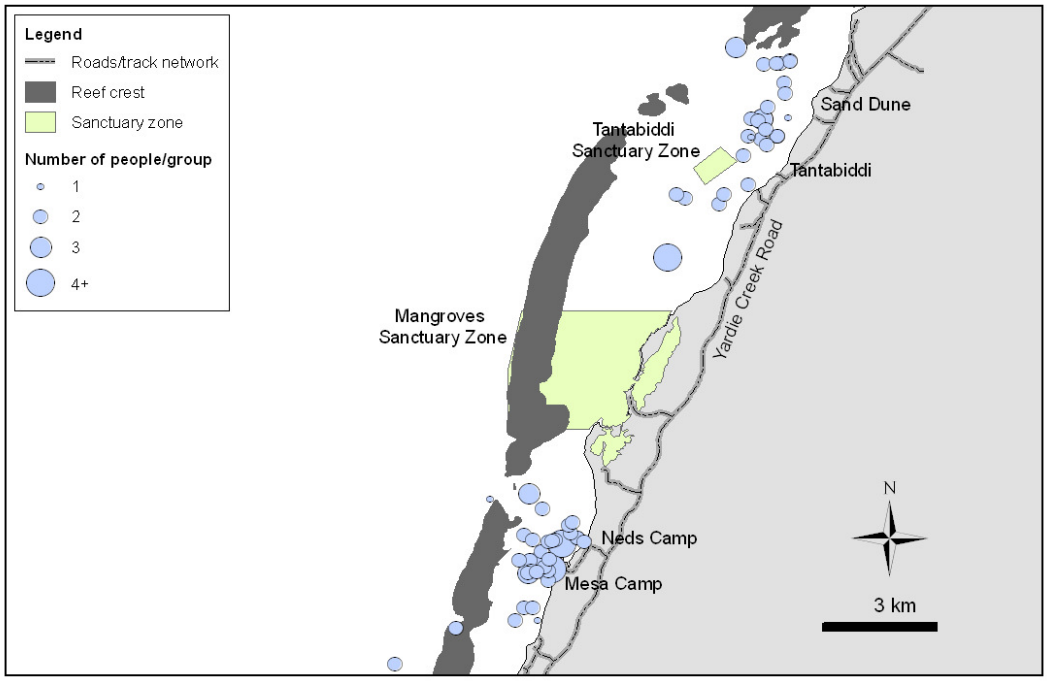


Figure 5-16 Tantabiddi and surrounds with geo-referenced location of each boat observed fishing, and the number of people, during coastal surveys in peak months along with location of sanctuary zones (number of surveys = 42).

5.4.4.5 Relaxing on the beach

Relaxing was the most common activity undertaken along the shore at Ningaloo, comprising 37.7% of people. It was also widely distributed in 65.2% of coastal segments (Figure 5-17). The highest densities of people relaxing (mean >10 people/survey) 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 mean densities of people relaxing were >1 and <10 people/survey.

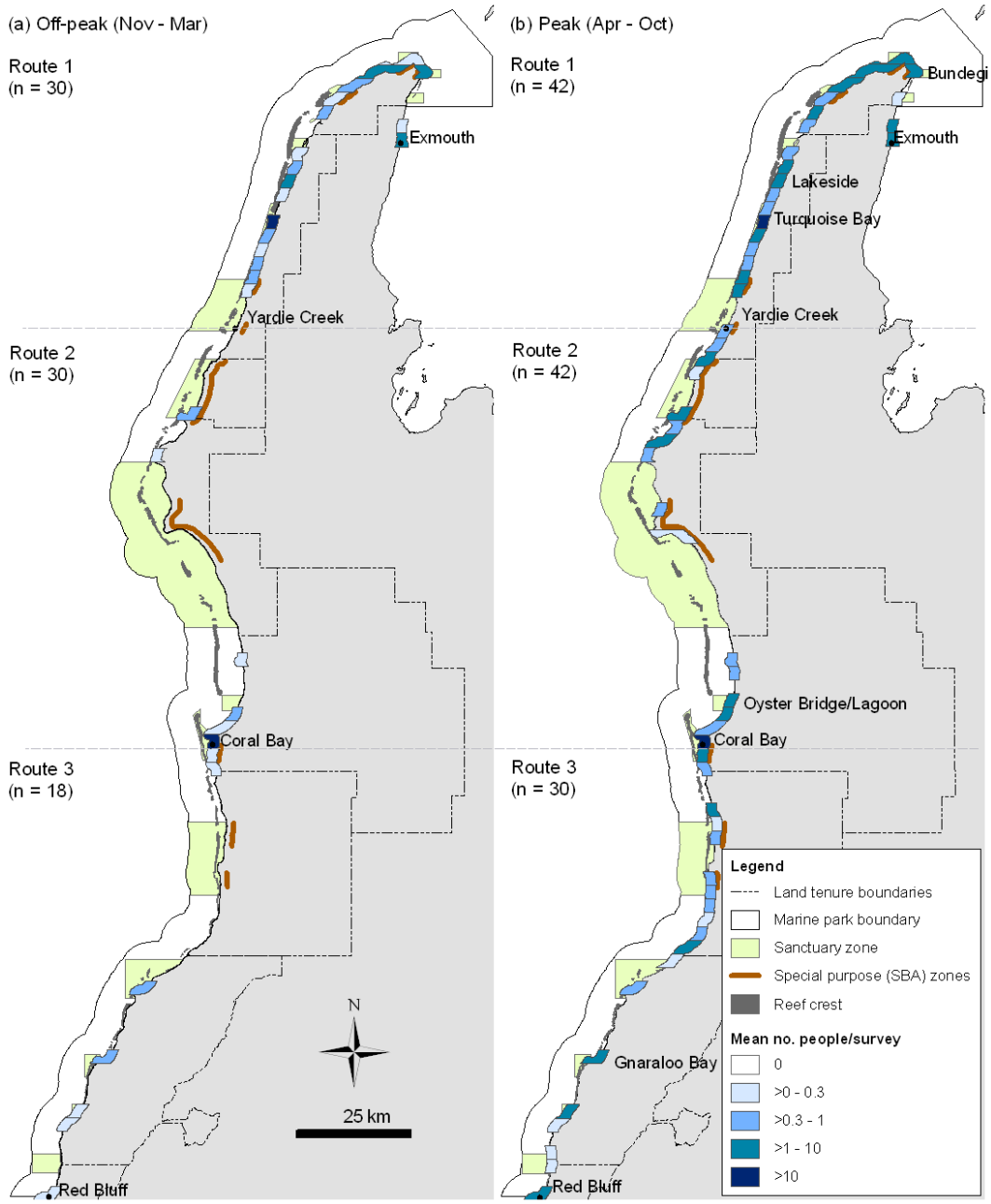


Figure 5-17 Mean number of people recorded relaxing on the beach during coastal surveys within each 3 km coastal segment for (a) off-peak and (b) peak months, with NMP sanctuary zones (n = number of surveys).

5.4.4.6 Snorkelling from the shore

Snorkelling from the shore comprised 11.7% of people and the highest densities were in coastal segments which included Turquoise Bay, Lakeside and Oyster Stacks in CRNP, Coral Bay and Oyster Bridge/Lagoon (Figure 5-18). However, there were large tracts of coast to the south of Yardie Creek where no snorkelling was recorded during the study.

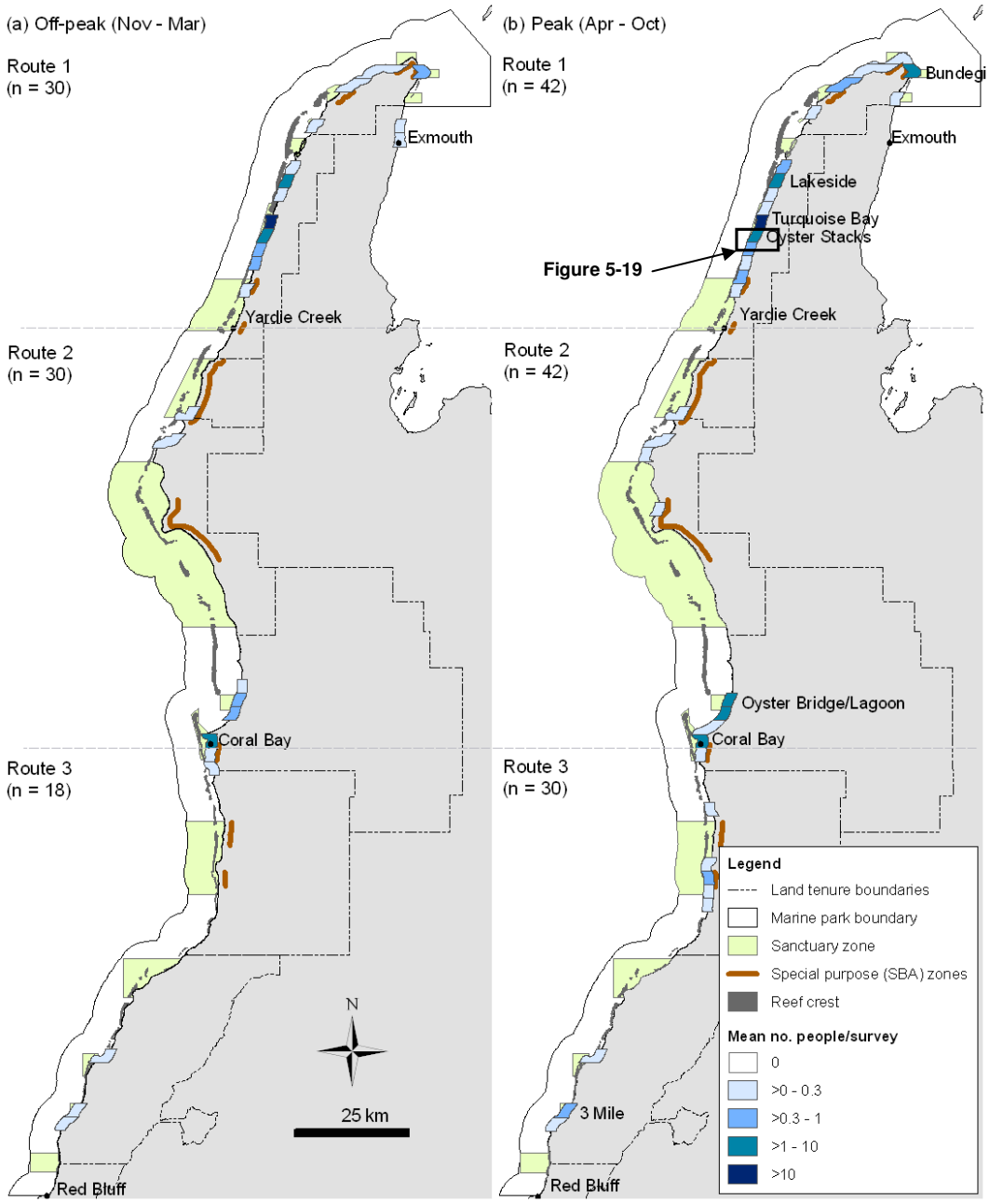


Figure 5-18 Mean number of people recorded snorkelling from the shore during coastal surveys within each 3 km coastal segment for (a) off-peak and (b) peak months along with NMP sanctuary zones (n = number of surveys).

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 (which obtained the highest densities of snorkelling activity) as data collected at this high use location were aggregated to beach level. At Oyster Stacks, snorkelling was concentrated

within the lagoon, which is very narrow at this point, adjacent to the carpark and access point but distributed >0.5 km to the south of South Mandu access point (Figure 5-19). The size of groups at South Mandu was also larger than at Oyster Stacks due to guided snorkelling tours at this site.

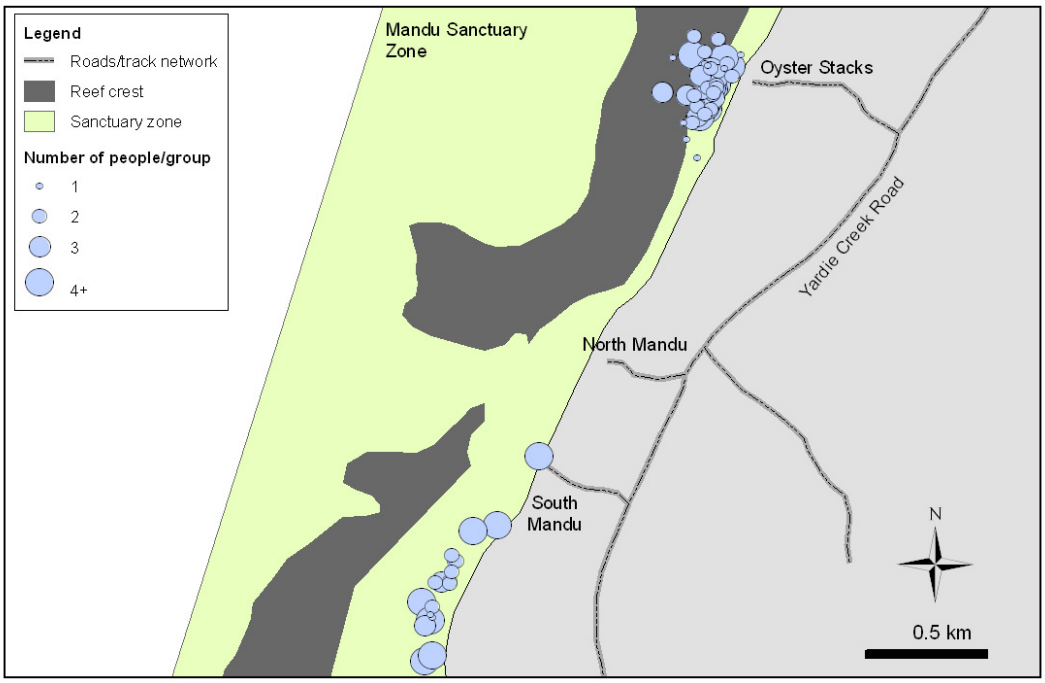


Figure 5-19 Oyster Stacks with geo-referenced location (and size) of each group observed snorkelling from the shore, during coastal surveys in peak months along with location of sanctuary zones (number of surveys = 42).

5.4.4.7 Recreational fishing from the shore

Recreational fishing comprised 8.9% of people counted along the shore and had a large spatial extent comprising 67.4% of coastal segments. The highest densities of people were attained in peak months, especially at Lighthouse Bay, Neds Camp, Lefroy Bay and surrounding Coral Bay (Figure 5-20). Shore-based recreational fishers took advantage of special purpose (SBA) zones which permit fishing along the coastal margins of sanctuary zones; especially around Lighthouse Bay and to the south of Coral Bay. Compliance amongst shore fishers was higher than from boats, with only 2% of people observed while fishing in sanctuary zones; namely, Coral Bay, Bundegi and

Mandu Sanctuary zones. Conversely, some areas where shore fishing is permitted, such as regions to the north and south of Gnaraloo Bay, no people were recorded undertaking this activity.

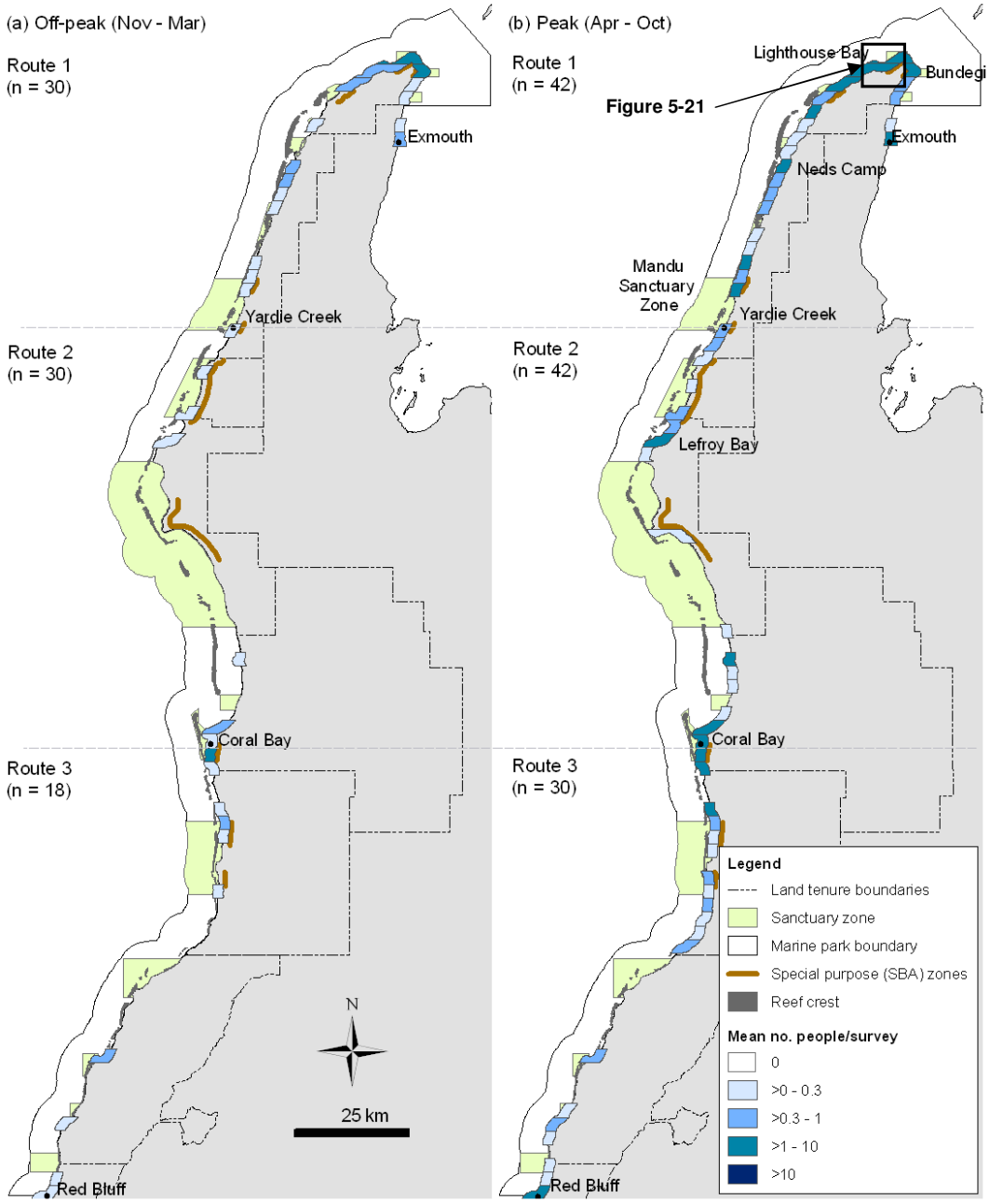


Figure 5-20 Mean number of people recorded fishing from the shore during coastal surveys within each 3 km coastal segment for (a) off-peak and (b) peak months along with NMP sanctuary and special purpose (SBA) zones (n = number of surveys).

Lighthouse Bay was selected as a case study using geo-referenced points because of high density of fishing activity combined with a range of zone types, i.e. sanctuary with a special purpose zone situated adjacent to a recreation zone (not shown). Groups fishing during peak months were concentrated along the shoreline of Lighthouse Bay Sanctuary Zone, which has a designed special purpose (SBA) zone (Figure 5-21). Numerous tracks along this section of the coast also enabled easy access to the beach.

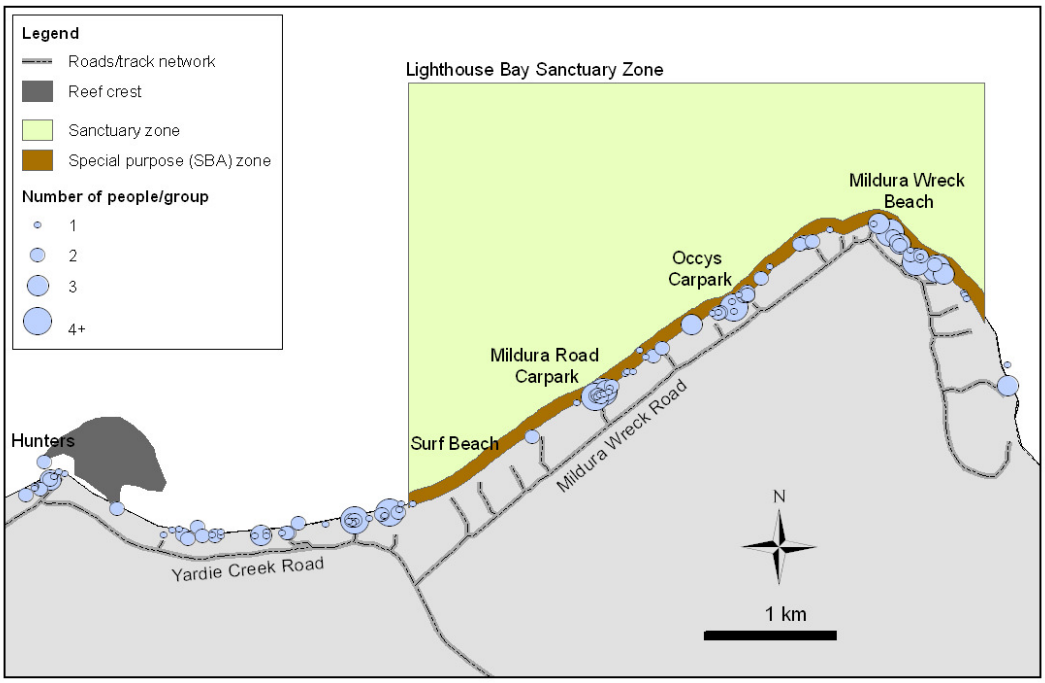


Figure 5-21 Lighthouse Bay with geo-referenced location (and size) of each group observed fishing from the shore during coastal surveys in peak months along with location of special purpose (shore-based activity) and sanctuary zones (number of surveys = 42).

5.4.4.8 Surfing

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 5-22). This activity was concentrated around Lighthouse Bay in the northern extent of the Marine Park and at 3 Mile and Red Bluff located on pastoral leases to the south.

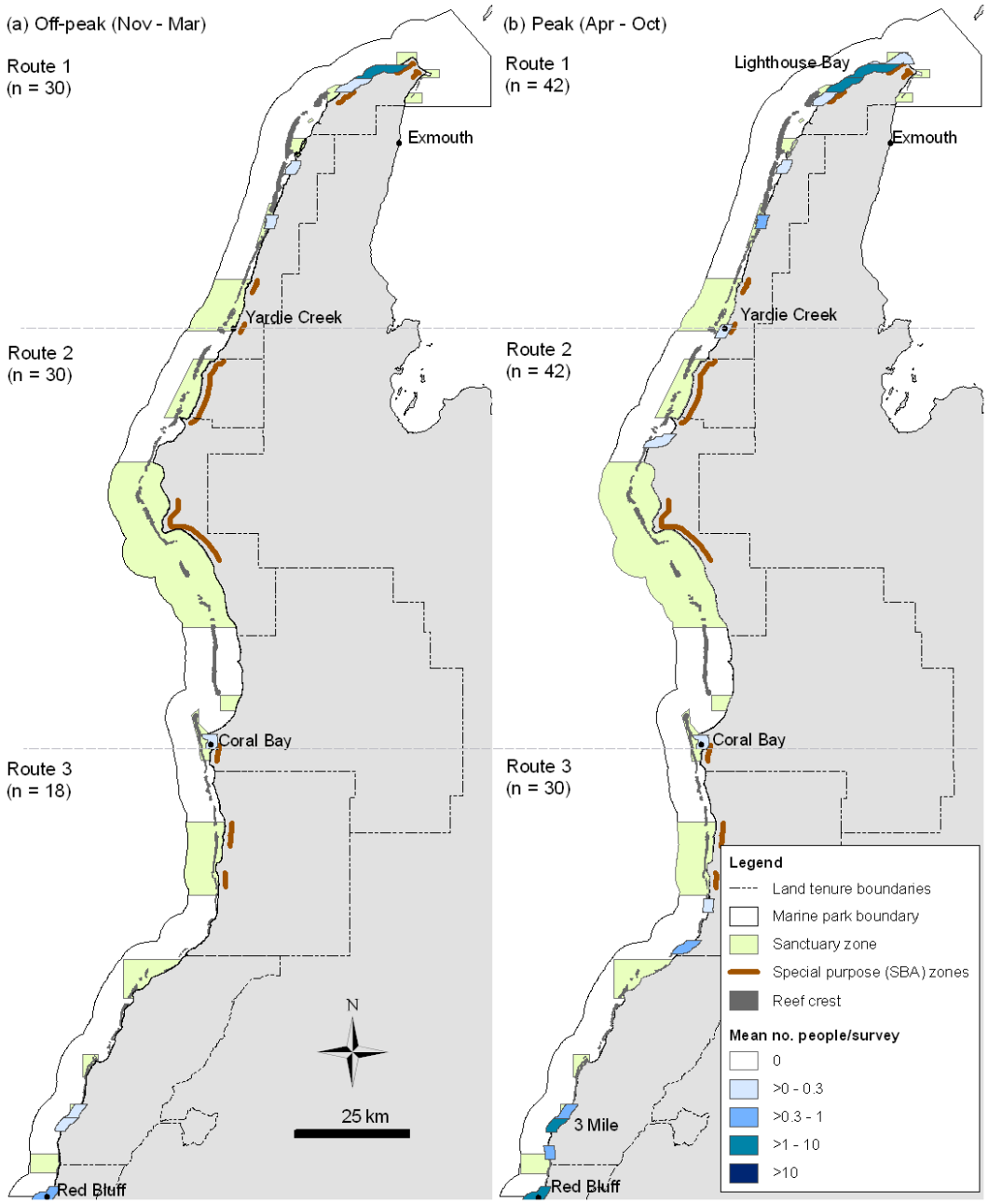


Figure 5-22 Mean number of people recorded surfing during coastal surveys within each 3 km coastal segment for (a) off-peak and (b) peak months along with NMP sanctuary zones (n = number of surveys).

5.4.5 Spatial accuracy

The spatial errors associated with pinpointing the location of shore and boat observations were the same, as the co-ordinates were computed using the same techniques (explained in Chapter 3). Fixed locations, such as a carpark 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 is summarised in Table 5-5. The mean number of satellites obtained during the coastal surveys was 10 (close to the highest possible number of 12) and HPE was small, with a mean value of 4.1 m.

Table 5-5 Summary of NMEA string data obtained from GPS units during 192 land-based coastal surveys along the Ningaloo coast in 2007 (number of observations = 3 880).

NMEA Output	*Minimum*	*Mean*	*Maximum*
Fix quality	1	1	1
Number of satellites	6	10	12
HPE (metres)	3.4	4.1	6.2

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 5-23).

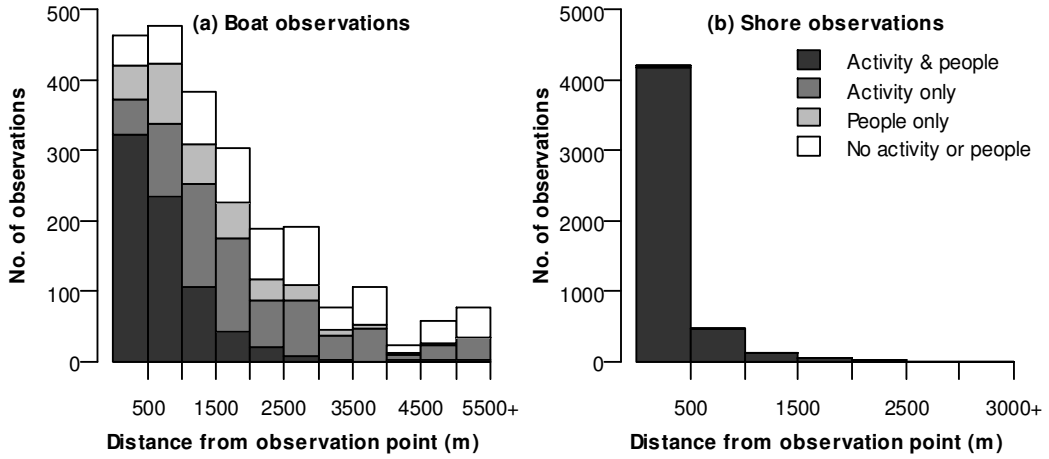


Figure 5-23 Distance from the observation point, in metres, for all (a) boat and (b) shore observations and the completeness of the observation in terms of identifying number of people and activity type.

5.5 Discussion

5.5.1 Spatial and temporal variability of recreational activities

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. This was partly due to difficulties in sighting objects from sea level as waves break on the reef crest and obscure vessels. This may result in underrepresentation 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. Data may be self-reported, such as by respondents to boat ramp surveys by Sumner *et al.* (2002) and Worley Parsons (2006), which 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 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 on boats were found in higher numbers in sanctuary zones, and also within coral reef habitats. Other non-extractive activities such as snorkelling and wildlife viewing also occurred predominantly in sanctuary zones. This supports the idea that the participants in these activities are drawn to high levels of biodiversity, especially coral reefs, many of which are located within marine protected areas (Davenport and Davenport, 2006). 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 which are able to simultaneously introduce large numbers (with group sizes >10+ people at Ningaloo) into the marine environment. Permanent moorings, such as at Lighthouse Bay, have been installed to reduce anchor damage, but may also concentrate divers (and associated environmental damage) to a particular area.

Due to the restrictions placed on recreational fishing in sanctuary zones, the majority of shore and boat-based fishers were located in other zone types. Mapping the geo-referenced location of these activities showed that vessels involved in fishing were generally constrained within these general use and recreational zones. This is likely to be a result of spatial displacement from other sites, however, lack of fine-scale data prior to the implementation of the current zones (in November 2004) means this cannot be validated. However, Northcote & Macbeth (2008) reported that 80.1% of campers interviewed at Ningaloo Station expressed some level of change in their activities as a result of sanctuary zone expansion. Ingram (2008) also found that 57.6% residents reported their recreational activity patterns were affected by these changes. In both studies these were predominantly due to changes in boating or camping behaviour (i.e. displacement to other sites).

Special purpose zones were introduced to Ningaloo in 2004 and are found in marine parks across Western Australia. Recent examples include the Jurien Bay Marine Park which has special purpose zones for scientific reference and aquaculture (DEC, 2005) and the proposed Capes Marine Park which have special purpose (surfing) zones (DEC, 2006). 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 more likely to be related to the coastal geomorphology at Lighthouse Bay, which comprises a rocky shoreline. It is also different to many other parts of the Ningaloo coast, as 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 their 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 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 foredune 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 which 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 which were widely dispersed, especially to the south of Tantabiddi, adjacent to CRNP. These vessels launched from Tantabiddi (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).

Research on recreational boating along the Florida coast by Sidman *et al.* (2004) found the three main reasons for selecting a favourite boating destination were fishing opportunities, scenic beauty and calm waters. Other reasons included preferences for entertainment /restaurants, undeveloped shoreline, avoiding crowds, swimming opportunities and beaches for picnicking. The Florida coast is far more populated than Ningaloo so the presence of entertainment/restaurants is not appropriate in this current study. However, the fringing reef crest at Ningaloo provides an environment sheltered from ocean swells. A study in Shoalwater Bay (Queensland) found the main reasons for choosing an area for boating were the amenity, proximity and fish stocks (Jennings, 1998). Proximity to boat launching sites appears to be a factor at Ningaloo, with clustering of vessels around these locations, as shown at Tantabiddi and Neds Camp.

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) which supports the findings of the current study. Air temperature, wind speed and direction were the only meteorological factors tested in this study due to the limited availability of other factors, such as cloud cover and rainfall, from external data sources although both have been previously found to reduce the number of visitors participating in some types of recreation with protected areas (Brandenburg and Arnberger, 2001).

5.5.2 Sampling error

Coastal surveys were conducted by travelling along the coast in a 4WD vehicle geo-referencing all activity from access and vantage points that were chosen for their clear fields of view. The sampling design 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). These roving-type surveys are usually land-based, however, in some cases it has been advantageous to use boats to move through a study area, although 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

to objects. This was further enhanced for the 14.5% of shore groups whose positional information was recorded at their actual location (i.e. not using an offset distance, which is more likely to introduce additional errors due to distance estimation and compass rounding). The result was comparable to research documenting a median positional error of 2.2 m for a GPS unit from a stationary land-based position (Zandbergen, 2008), although inherent biases can contribute up to a further 25 m error (Hulbert and French, 2001; Kowoma, 2005). These effects were mitigated by ensuring that compass readings were made away from magnetic objects (such as vehicles), and that a high number of satellites were acquired for GPS readings.

5.6 Conclusions

This was one of the first research projects to attempt land-based coastal surveys encompassing a study area of this size. The collected geo-referenced data points were used to explore the fine-scale patterns of recreational use in the NMP; complementing the synoptic overview provided by the aerial surveys. Analysis was focused on activities with the highest participation levels or spatial extent including; motoring, fishing and wildlife interactions for boating and relaxing, fishing and snorkelling for shore activities. Fishing was associated with general use and recreation zones while snorkelling and diving were aligned with sanctuary zones and coral reef habitats. Sandy beaches were the most popular location for shore activities such as swimming, sunbaking and beach games. Boating was also restricted by the fringing reef crest, with activities such as wildlife interactions occurring outside in the open ocean, while recreational fishing and diving occurred predominantly inside the sheltered lagoon waters. However, the difficulty of sampling vessels travelling offshore beyond the NMP (state waters) boundary needs to be considered in future research.

Chapter 6 Land tenure, user characteristics and their effects on patterns of recreational activity

6.1 Introduction

The exponential growth in visitation to protected areas in recent years has increased the importance of understanding visitor characteristics, along with their spatial and temporal patterns of use, to ensure sustainable management and visitor satisfaction (Newsome *et al.*, 2002; Cole and Daniel, 2003; English *et al.*, 2004; Arnberger *et al.*, 2005). However, this is challenging as visitors exhibit a diverse range of demographic characteristics, attitudes, preferences and behaviours and, as a consequence, have different requirements in terms of facilities, services and infrastructure. They also have varying levels of impacts on a protected area depending on factors such as length of stay and participation in recreational activities. This recreational use and provision of infrastructure must also be balanced with conservation objectives (Cessford and Thompson, 2002).

Data on recreational use and user characteristics can be collected using a variety of methods depending on the type of information required by managers (Watson *et al.*, 2000; Cessford and Muhar, 2003). These characteristics can be classified into five general categories; (1) demographics, (2) visit attributes, (3) motives and benefits, (4) perceptions, attitudes and behaviours, and (5) trends and projections (Roggenbuck and Lucas, 1987; Watson *et al.*, 2000). Demographic variables such as age, gender, occupation, origin and group type focus on the characteristics of the users themselves whilst visit attributes include length of stay, number of previous visits and activities undertaken during trips to a particular area. This also includes spatial characteristics of visitor use, such as the location of entry and departure points. Motives, perceptions,

attitudes and behaviours also contribute to further understanding of the reasons and factors which affect patterns of use. The identification of trends and projections are useful for management but can be difficult to achieve without accurate, comparable and longitudinal data collection. Although all these categories are important, this chapter focuses on developing an understanding of demographics, visit attributes and activity patterns of people utilising the Ningaloo Marine Park (NMP) for recreation. This can provide useful input to managers to support the allocation of resources, educational efforts, conflict minimisation, compliance and strategic planning (Hall and Shelby, 1998; Hornback and Eagles, 1999; Watson *et al.*, 2000; Cessford and Muhar, 2003).

These characteristics can also be used as a basis for classifying recreationalists as, although they exhibit a wide range of characteristics, it is often possible to identify distinct groups based on traits such as place of origin or participation in specific activities. The broad aim of classification is to identify any underlying structure in a dataset which can be used to explain or predict recreational use and user characteristics within a particular area. This technique is referred to as segmentation and it has been employed widely to classify users into coherent groupings (Wilkie, 1994; Moscardo *et al.*, 2001; Inbakaran and Jackson, 2005). Each group has similar characteristics (while being distinct from the other groups) and are expected to display similar behaviour. Such understanding assists with planning and management, and is also useful for condensing large datasets into manageable clusters. A broad range of multivariate techniques may be used to determine how close or distant these groupings are from each other. Although used traditionally in marketing and hospitality studies, there have recently been wider applications in tourism and recreation (Moscardo *et al.*, 2001), including studies relating to visitor behaviour (Sung *et al.*, 2001), attitudes (Zanon, 2005) and demographics (McVetty, 2002).

The coastal strip adjacent to the NMP is diverse not only in geomorphology but also in land tenure types. These consist of conservation areas, pastoral leases and gazetted townsites managed by a suite of local, state and federal government agencies along with pastoral leaseholders. This diversity of land tenure has resulted in an array of management controls within these areas, such as a maximum stay of 28 days at Cape Range National Park (CRNP) while pastoral leases have no stay limit or restrictions on fires or generators (Figure 6-1). These variations were the basis for the hypothesis that people with different characteristics would be attracted to different types of land tenure. This spatial variation has been previously suggested by Wood (2003a) who identified differences in characteristics between visitors to pastoral leases and service centres, such as Coral Bay and Exmouth. Such differences included a higher value on fishing, and lower expenditure, by people staying on pastoral stations when compared to the other sites. It was also believed that participation in specific activities would also be affected by these characteristics. Some evidence of this has been found in previous studies worldwide using characteristics such as travel mode and group type in Norway (Mehmetoglu, 2007), and age on the Great Barrier Reef (Moscardo and Green, 1999).

Nine land tenure units adjacent to the NMP were reduced to seven coastal regions based on access, land tenure and available types of accommodation (Figure 6-1). Although other factors (i.e. proximity to population centres, size of the area, type of ecosystem, time of establishment for the protected area, time of year and user traditions) are also known to cause variation in use patterns (Roggenbuck and Lucas, 1987), these three were sufficient to distinguish between the coastal regions of the NMP. This was based on the limited number of access points (nine main roads), land tenure boundaries (which were inextricably linked to the management authorities and controls) and limited accommodation options in most regions. A similar approach was applied on Vancouver

Island using districts defined by separate planning and development jurisdictions (Murphy and Keller, 1990).

	Region (Code)	Vehicle access (no. roads)	Available accommodation types	Examples of management controls
	Exmouth (Ex)	2WD (1)	Caravan parks, chalets, hotels, backpackers	No coastal camping
	North-West Cape (NWC)	2WD (1)	Caravan parks	No coastal camping
	Cape Range National Park (CRNP)	2WD (2)	Camping	Max. 28 day stay Camping fee No fires No generators (in some sites)
NS/DoD	Bombing Range (DoD)	4WD (2)	Camping	No maximum stay No camping fee Fires/generators permitted
NS/DoD	Ningaloo Station (NS)	4WD (2)	Camping, shearers quarters	No maximum stay Camping fee Fires/generators permitted
	Cardabia Station (CS)	4WD (2)	Camping	No maximum stay Camping fee Fires/generators permitted
	Coral Bay (CB)	2WD (2)	Caravan parks, chalets, hotel, backpackers	No coastal camping No dogs
	Warroora Station (WS)	4WD (2)	Camping, shearers quarters	No maximum stay Camping fee Fires/generators permitted
GN/Q	Gnaraloo Station (GN)	2WD (1)	Camping, self-contained	No maximum stay Camping fee Fires/generators permitted
GN/Q	Quobba Station (Q)	2WD (1)	Camping, safari tents, self-contained chalets	No maximum stay Camping fee Fires/generator permitted

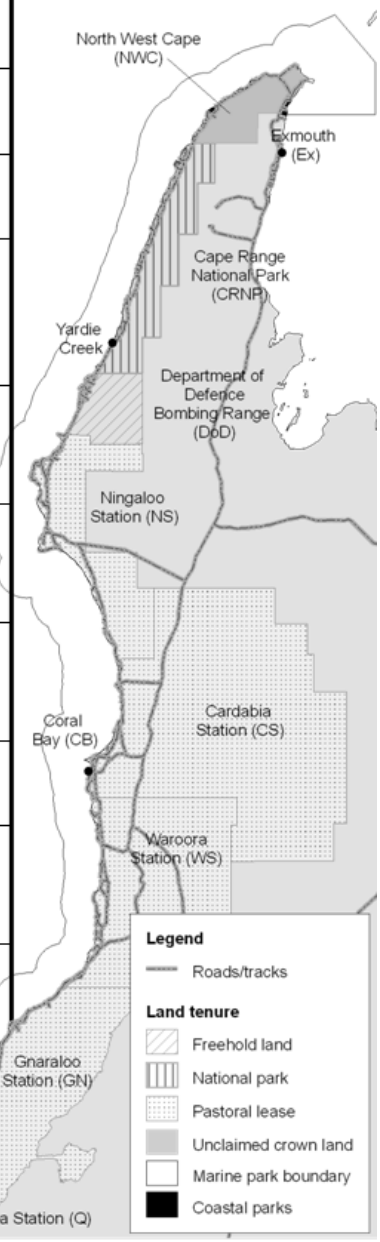


Figure 6-1 Summary of characteristics (land tenure, road surface, available accommodation types) used to define the distinct coastal regions located adjacent to the Ningaloo Marine Park (NMP), with examples of management controls.

North-West Cape (NWC) is only accessible along Yardie Creek Road (2WD) and is jointly managed by the local government authority (Shire of Exmouth) and Department

of Environment and Conservation (DEC). It is also closest to the town of Exmouth, with a population of ~2 000 people, which contains essential services such as a hospital, post office, retail outlets and a range of accommodation types (GDC, 2006). Exmouth (Ex) has been listed in Figure 6-1, even though it is located outside the Marine Park, as it is often used as a base for day trips by visitors. It is therefore included in analysis relating to a respondent's place of accommodation. Cape Range National Park (CRNP) is managed by DEC and is accessible along Yardie Creek Road (2WD) from the north and Yardie Creek Crossing (4WD) from the south. Coastal camping is available in 109 designated sites at a nightly rate (for a maximum 28-day stay).

The NS/DoD region consists of two separately managed land units, the Department of Defence Bombing Range (DoD) and Ningaloo Station (NS). These land parcels are accessible from the north (via the Yardie Creek Crossing), south (via the Coral Bay – Ningaloo Station Access Track) and east (via the Ningaloo Access Road and Brudoodjoo Access Track). Although the DoD area offers the only location for coastal camping with no fee along the coast, it was grouped with Ningaloo Station due to a paucity of interviews from this area. It covers a small section of coast (~14 km), with only four camping areas situated adjacent to a sanctuary zone. The basis for grouping these two land parcels was, as well as being adjacent to each other, they have shared (4WD only) access routes.

Cardabia Station (CS) is accessible along the Coral Bay-Ningaloo Station and Brudoodjoo Access Tracks only. There is only one camping area in this region although several beaches are frequently utilised as day use sites for visitors staying in Coral Bay. Coral Bay (CB) is surrounded by Cardabia Station but it was considered a separate entity as it is a small service town offering a range of facilities and accommodation

types. Warroora Station (WS) can only be accessed using the Warroora Access Road from the east and Similarly, Gnaraloo (GN) and Quobba Stations (Q) were grouped based on their limited access (via the Quobba Access Road only).

It is also important to consider residents living in the adjacent population centres of Coral Bay and Exmouth, who utilise the NMP for recreation, on either day or extended (overnight) trips. For this study, a resident was defined as an individual who lived within the postcode boundaries of the local government regions (Carnarvon or Exmouth) (Chapter 2; Figure 2-1). Although their attitudes to tourism planning (Dowling, 1991) and perceptions of park management (Ingram, 2008) have been investigated, the level (and frequency) of participation in recreational activities has not been explored. Residents are expected to have different attitudes and behaviours (Confer *et al.*, 2005) as well as views on conservation and tourism planning (Brown and Raymond, 2006) when compared to tourists. It is therefore pertinent for management to obtain data on these users to better understand any differences in their patterns of recreational use (Hornback and Eagles, 1999).

The synoptic and fine-scale patterns of recreational use were described in the previous two chapters using data collected during aerial and coastal surveys. These patterns were explored with respect to peak/off-peak periods, infrastructure and zoning. This chapter furthers the understanding of these patterns by describing demographics and visit characteristics of people interviewed while participating in recreational activities along the Ningaloo coast and linking this with land tenure. These characteristics were also explored with respect to tourists and residents as well as temporal factors, such as peak/non-peak seasons and school holidays, to corroborate findings from previous chapters.

6.2 Research objectives

The overarching aim of this chapter was to identify the effect of land tenure and user characteristics on patterns of recreational activity in the NMP using data collected during face-to-face interviews throughout 2007. This was achieved by addressing several research objectives including:

- identifying patterns in demographics, visit and visitor attributes of respondents with respect to land tenure and temporal factors,
- describing differences in the above characteristics between tourists and residents; and
- describing the level and pattern of recreational activity participation of respondents for different land tenure types.

6.3 Analysis techniques

The overall research design and questionnaire rationale were described in Chapter 3 (Methods) while the specific analysis techniques applied to this current chapter are described here. Pearson chi-squared tests (χ^2) and correspondence analysis were applied to describe the relationships between the regions and categorical variables (such as group type or origin). Tests were weighted by the frequency of cases with contingency tables (containing dichotomous and polytomous variables) and correspondence analysis used to summarise data. Pearson chi-squared tests compare an observed distribution with a hypothetical one, where greater departures from expected values produce greater chi-square values and therefore greater significance. However, this will not identify any further relationships between the categories of each variable (Agresti, 1990). Cramer's V statistic and correspondence analysis provided further measures of association (or correlation) between variables. These non-parametric tests, which are also based on the observed and expected frequency of occurrence, are not required to conform to

assumptions of normality although the expected frequency of each cell in a table should not be <5, as this may distort the result. However, this may be permitted in some situations (Agresti, 1990) and is noted in the text when it occurs.

Correspondence analysis is similar to Multi-Dimensional Scaling (MDS) and was used to graphically represent the relationship between polytomous categorical variables in a contingency table as a small number of derived variables (axis) in a bi-plot (Everitt and Dunn, 2001; Guinot *et al.*, 2002; Quinn and Keough, 2002). This is interpreted by examining the positions of the row and column categories as reflected by their respective co-ordinates. In addition, inferential analysis can reveal the percentage of variation described by these dimensions (Agresti, 1990).

Analysis of Variance (ANOVA) was used to test the significance between region and continuous variables (such as length of stay). These data were checked for normality and heterogeneity of variances. If these assumptions were violated, then the data were transformed using a square root transformation. For variables with multiple factor levels, *post-hoc* tests were used to identify the significant contributors to these effects.

6.4 Results

A total of 1 208 interviews were undertaken with recreational participants throughout the 12-month survey period from January – December 2007. There were 30 repeat interviews during this period (comprising 2.5% of all respondents) and, although the aim was to complete the same number of interviews every month, there were fewer in the off-peak months from January – March and November – December (Figure 6-2). Following the quota sampling protocol, the greatest number of interviews occurred in

regions with high use beaches, such as Coral Bay (CB), CRNP (which contains Turquoise Bay) and NWC (which contains Bundegi and Surf Beaches).

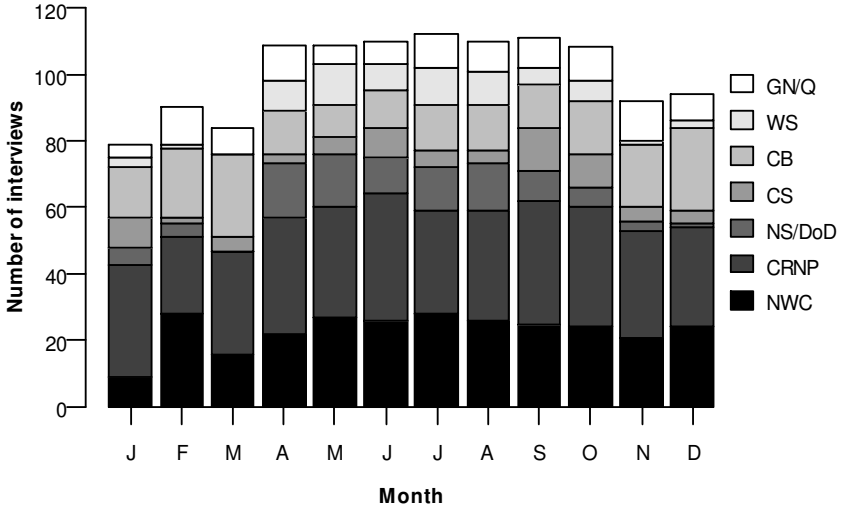


Figure 6-2 Number of interviews completed monthly in each of the seven Ningaloo coastal regions from Jan – Dec 2007 (n = 1 208).

6.4.1 Demographics

The mean group size was 2.9 people (*SD* = 2.2), with the largest group comprising 21 people. Data on the demographic variables of age, group type, origin and occupation were collected during interviews and chi-squared tests showed there were significant differences between each when compared to region (ρ<0.05). These relationships were explored using correspondence analysis to display the association between each variables and region (Figure 6-3).

The majority of respondents were in the 25-34 (27.4%) and 35-44 (27.9%) age categories. There was a significant difference between observed and expected values (χ^2 (24) = 93.82, ρ<0.05) with correspondence analysis showing that the relationship between age and region explained 87.3% of variation in two dimensions (Figure 6-3a). There was a positive association between interviewees in the 18-24 and 25-34 age

categories and regions of CB and CRNP. There was also a strong negative association between the 55+ age category and GN/Q indicating it was less popular with this age group (which comprised 16.9% of the total number of respondents).

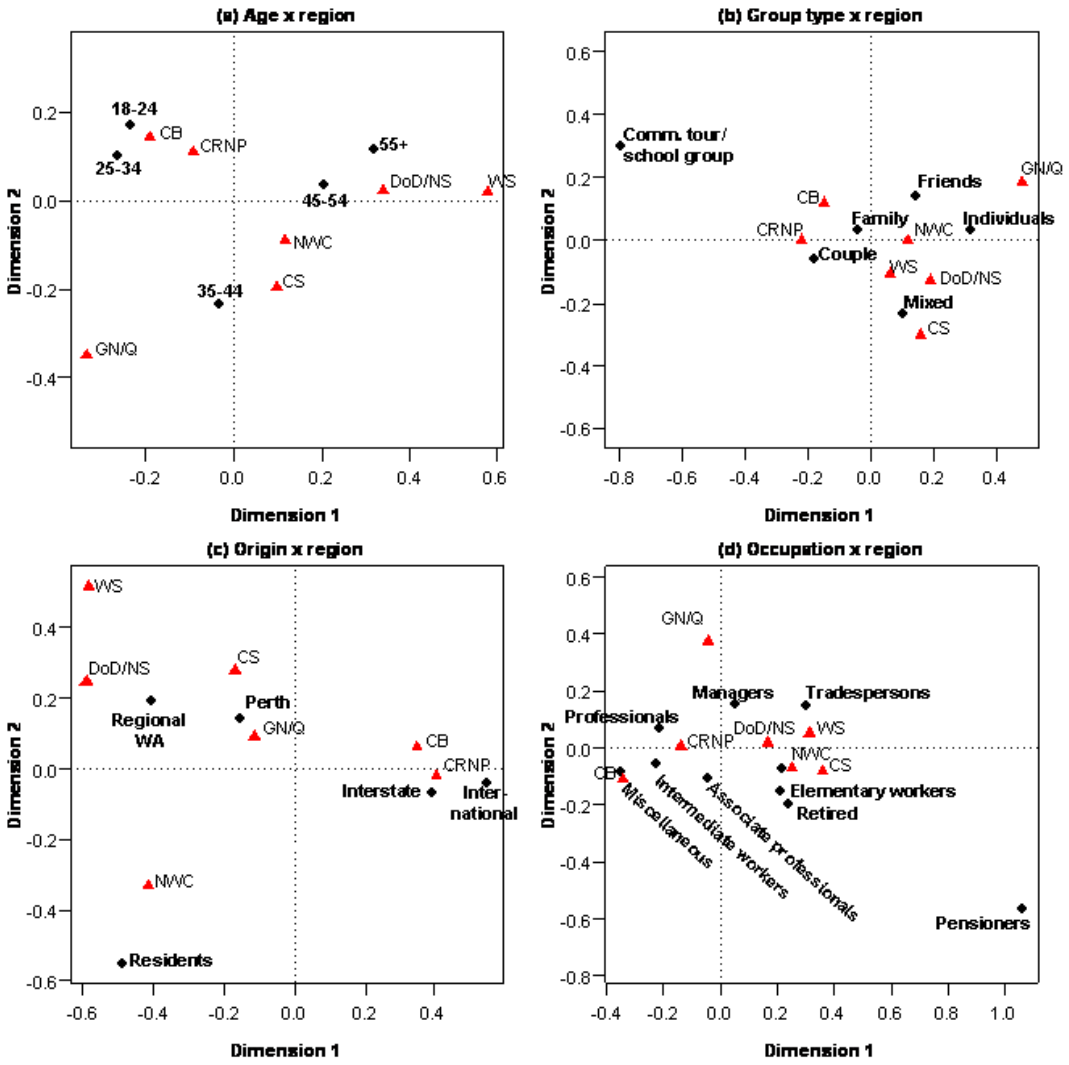


Figure 6-3 Correspondence analysis for each of the demographic variables (a) age, (b) group type, (c) origin and, (d) occupation by region.

The most frequently interviewed group types were couples (32.4%) and families (21.5%), many of whom had children <17 years of age. There was a significant difference between group type and region (χ^2 (30) = 77.45, ρ<0.05). Correspondence analysis showed the first two dimensions explained 89.9% of variation and positive

associations existed between commercial tour/school groups, families and couples with the regions of CB and CRNP (Figure 6-3b). This was to be expected with well-advertised sites such as Turquoise Bay and Coral Bay located within these regions attracting visitors. There was also an association with individuals and friends on the pastoral leases of GN/Q.

International and interstate visitors accounted for 23.5% and 14.0% of respondents, respectively. The remaining 62.5% were intrastate visitors, of which 11.5% were residents of Exmouth, Coral Bay or Carnarvon. There was a significant difference between origin and region (χ^2 (24) = 272.66, ρ<0.05). Correspondence analysis between the origin and region explained 90.1% of variation, with a particularly strong relationship between residents and NWC which was likely to be caused by this region being located adjacent to the town of Exmouth (Figure 6-3c). There were also strong positive associations between international and interstate visitors and the regions of CB and CRNP. Pastoral regions (NS/DoD, CS, GN/Q and WS) displayed an association with visitors from Perth and regional WA.

A chi-squared test showed significant differences between occupation and region (χ^2 (54) = 105.75, ρ<0.05) and correspondence analysis showed the two variables explained 80.4% of variation (Figure 6-3d). There was a negative association between retirees and GN/Q which showed they preferred other regions and is consistent with the results comparing the variables of age and region. CB and miscellaneous occupations (which comprised mostly students) had a strong affiliation. Professionals were the most frequently recorded occupation category and these respondents had a positive association with CRNP and GN/Q.

There was temporal variability displayed by these demographic variables, with age (χ^2 (4) = 41.41, ρ<0.05), group (χ^2 (5) = 13.92, ρ<0.05), origin (χ^2 (4) = 161.14, ρ<0.05) and occupation (χ^2 (9) = 38.37, ρ<0.05) showing significant differences between peak and off-peak months. Examination of residuals showed that the oldest age categories (45-54, 55+) had a positive association with peak months. Further supporting this was the additional positive association between retirees and peak months from April - October. International visitors had the strongest association with off-peak months.

Analysis of these demographic variables by school holiday periods showed the most significant result to be produced by group type (χ^2 (5) = 52.26, ρ<0.05). This was due to the positive association between families and school holiday periods. However, there was also a significant difference between holidays and age (χ^2 (4) = 21.33, ρ<0.05), with a negative association between 55+ aged respondents and school holiday periods.

A separate analysis investigated the effect of day type (i.e. weekend or weekday) on visitor type (i.e. resident versus tourist). This applied to those people interviewed north of Yardie Creek, as this was the only area where this stratification was incorporated into the sampling design. However, Chi-squared analysis found this effect to be non-significant (χ^2 (1) = 0.01, ρ>0.05), with many residents visiting the NMP on weekdays.

6.4.2 Visit attributes

Recreationalists were interviewed while on the shore in a particular region of the NMP, even though they may have been staying elsewhere. Analysis of this cross-boundary movement showed that 57.4% of visitors were interviewed while recreating in the region where they stayed, while the remainder were on day trips in another region on

the NMP (Table 6-1). The shaded cells indicate those interviewees who displayed no cross-boundary movement on their day of interview. The highest numbers of groups involved in cross-boundary movement were those tourists interviewed who had travelled from the town of Exmouth (located outside the NMP) to NWC (180) and CRNP (168) for recreation. In addition to this, there were also a substantial number of tourists interviewed that had travelled from CB to CS for recreation (61).

The movement of residents from their homes into the NMP for recreation was also explored, and is shown in brackets (Table 6-1). As with tourists, the majority of movement occurred from Exmouth into NWC (68) and CRNP (18). These numbers do not include residents who were staying (i.e. camping) in the NMP when interviewed.

Table 6-1 Cross boundary movement of interviewees from location of accommodation to place of recreation (i.e. interview) in the NMP (n = 1 153). Shaded cells indicate no movement while figures in brackets indicate movement of residents (which are also included in total).

		Recreation region						
		NWC	**CRNP**	**NS/DoD**	**CS**	**CB**	**WS**	**GN/Q**
Accommodation region	**Ex**	180 (68)	168 (18)	1 (1)	1	1	0	0
	NWC	66	58	0	0	1	0	0
	CRNP	6	148	1	0	0	0	0
	NS/DoD	0	0	87	0	0	0	0
	CS	1	0	0	9	0	0	0
	CB	8 (1)	9	1	61 (2)	183 (8)	3	0
	WS	0	0	3	0	0	62	0
	GN/Q	0	0	0	0	0	0	95

Once arriving in the NMP, 61.4% of interviewees had stayed, or were planning to stay, in only one location. The most popular accommodation types were caravan parks (34.1%) and coastal camping areas (33.4%). There was a significant difference between accommodation type and region (χ^2 (36) = 847.43, ρ<0.05) and correspondence analysis, which explained 91.1% of variation, had a positive association between private

accommodation and NWC due to the high number of residents (Figure 6-4a). CB also displayed a positive association with backpacker accommodation, which is only available at this location and in Exmouth, whereas camping was positively associated with the pastoral regions of GN/Q, WS and NS/DoD.

The majority of interviewees stayed at Ningaloo for 4-7 days (31.0%) or 8-14 days (31.2%). There was a significant relationship between this variable and region (χ^2 (30) = 129.96, ρ<0.05) of which correspondence analysis explained 97% of variation (Figure 6-4b). NWC, where the only available accommodation was two caravan parks which cater for long-term visitors, was associated with stays 28+ days in length, while short term stays (<7 days) were linked to CB and CRNP. The remaining pastoral regions had positive relationships with trips between 8-28 days in length. It was also interesting to note that the mean length of time lived in either Exmouth or Coral Bay by residents was 6 years (*SD* = 9.8 years), with 27% of the sample residing in the area for <1 year.

There was a significant difference in length of stay between off-peak and peak months (χ^2 (5) = 96.98, ρ<0.05). Trips that were 28+ days in length were more likely to occur in peak months with shorter stays, between 1-3 days, occurring more frequently in off-peak.

The main reason that the respondent chose their accommodation location was ascribed to 13 general categories (Chapter 3; Table 3-5). When analysed by region, there were significant differences between reasons and region (χ^2 (72) = 457.84, ρ<0.05), explaining 81.2% of variation. The clearest association was between activities and GN/Q (Figure 6-4c). This category was for interviewees who chose their particular accommodation location to pursue their recreational opportunities (i.e. near to

windsurfing, fishing or good snorkelling opportunities). Visitors to the other pastoral regions (WS and NS/DoD) chose management, ambience/crowding, environment, location and social attributes. Management included controls such as restricting (or allowing) generator use, while ambience/crowding referred to choosing locations because of its isolation. Environment included scenery and available shade or protection from wind. Location referred to a broad spectrum of reasons relating to the location of accommodation close to boat ramps and other facilities (i.e. shops), and being close to friends or family was described as a social attribute.

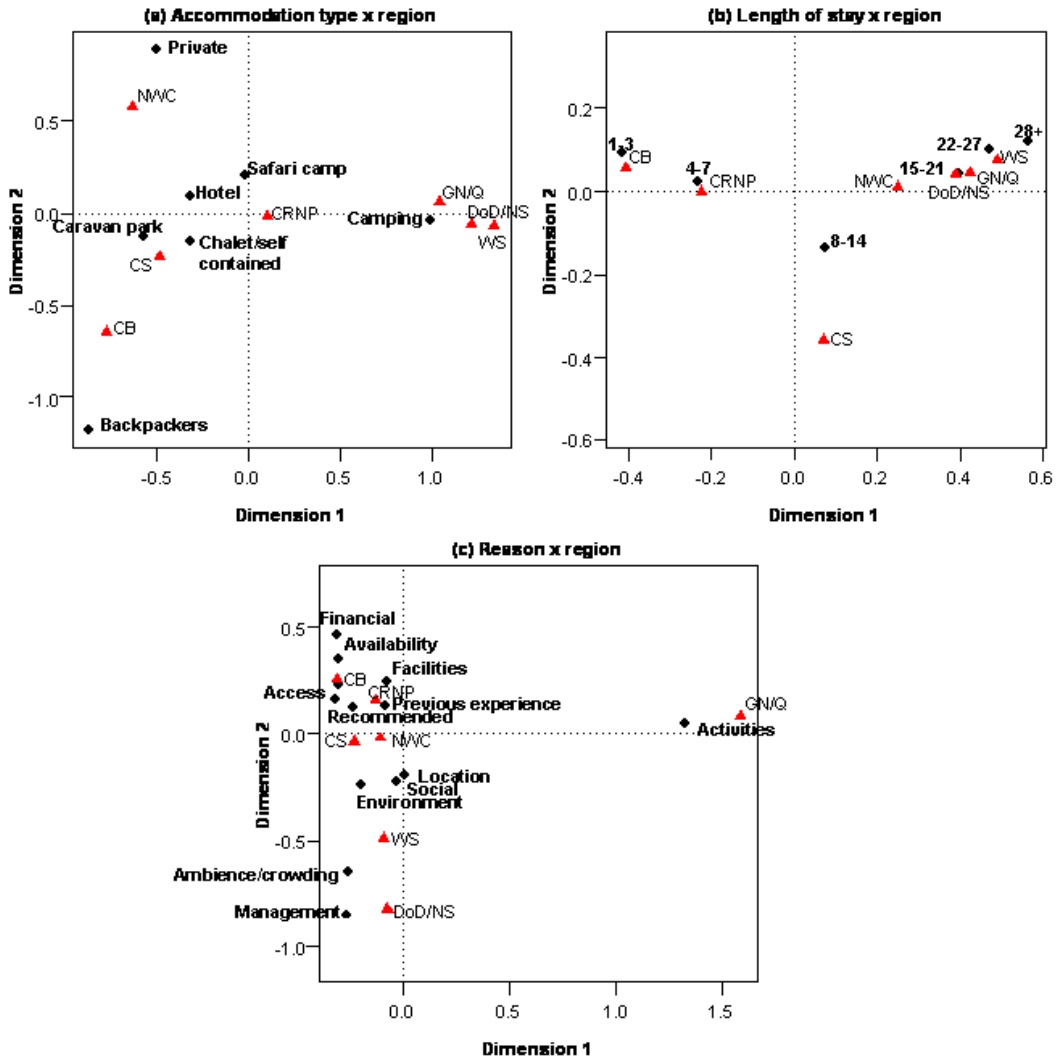


Figure 6-4 Correspondence analysis for each visit attribute of (a) accommodation type, (b) length of stay and, (c) main reason for choosing accommodation. Note: all had cells with expected frequencies <5.

Many areas of the coast were only accessible by sand or gravel tracks and 62.0% of interviewees had a 4WD vehicle on their trip. The highest frequencies of 4WDs were on pastoral stations (GN/Q, NS/DoD, CS and WS) (Figure 6-5a). When 4WD possession was compared with visitor origin, there was a significant difference between regions (χ^2 (4) = 2 664, ρ<0.05); reflecting the low number of international visitors (22.0%) and high number of residents (77.9%), interstate and intrastate visitors (73.6%) with 4WD vehicles. Boats were less common, although 22.6% of all respondents had one on their trip. Of these respondents, the residents of Coral Bay and Exmouth had the highest level of boat possession (44.8%) and international visitors the lowest (1.5%). A comparison between regions showed recreationalists visiting the regions of NWC, NS/DoD and WS exhibited the highest frequencies of vessel possession (Figure 6-5b).

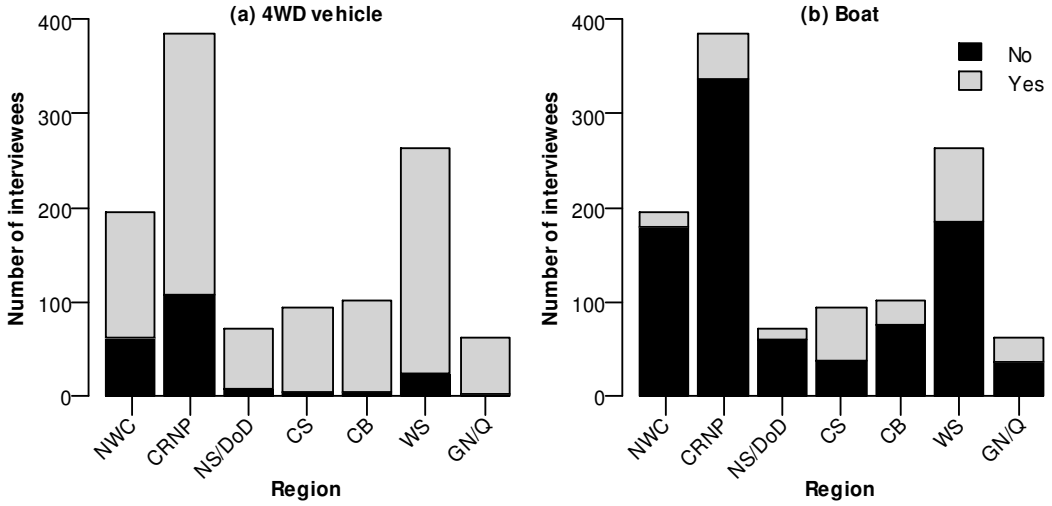


Figure 6-5 Frequency of respondents with (a) 4WD vehicles and, (b) boats in the NMP (n = 1 178).

There are nine access roads from which to access the Ningaloo coast and these have a strong association with each of the seven regions (Cramers' V = 0.793). Exmouth – Minilya and Coral Bay Roads were the two primary (sealed) access roads used by many respondents to access accommodation at Exmouth and Coral Bay, respectively (Figure 6-6). Yardie Creek Road is also sealed and respondents used this to access

accommodation along NWC and in CRNP. The other access roads were sand or gravel tracks and Quobba Access Road was the only access to accommodation on GN/Q stations. An additional 7.5% of respondents flew to Learmonth airport (located ~30 km south of Exmouth) and these groups stayed predominantly in Exmouth.

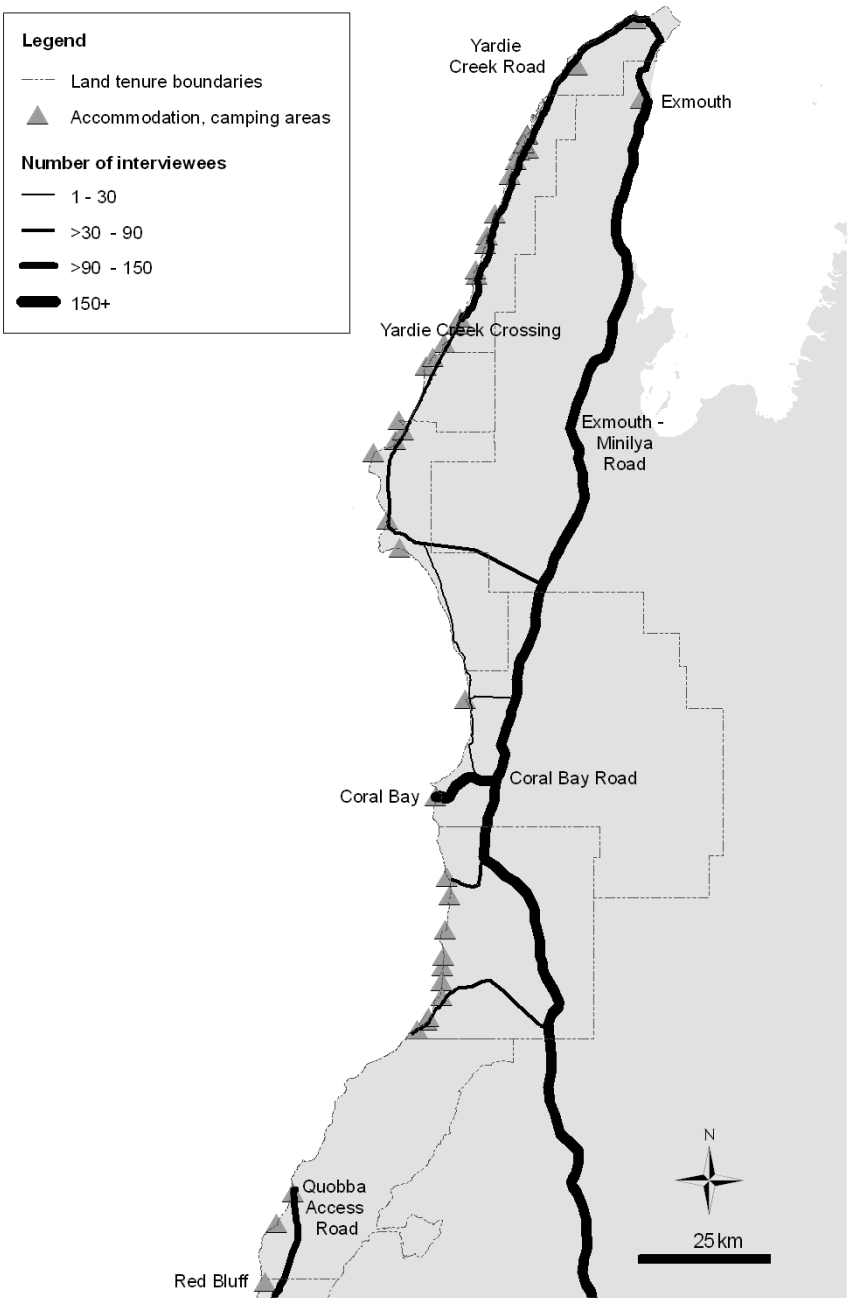


Figure 6-6 Number of respondents using each main access road to travel by vehicle to the different land tenure regions and associated accommodation locations (n = 1 033).

6.4.3 Previous visitation

Overall, 652 (55.2%) of respondents had visited the NMP on a previous occasion and there was a significant difference when analysed by region (χ^2 (6) = 130.12, ρ<0.05). The majority of visitors in CRNP and CB were on their first trip, while for all other regions the opposite was true (Figure 6-7).

When compared to visitor origin, there was also a significant difference (χ^2 (4) = 384.89, ρ<0.05) with many international and interstate visitors on their first trip to the NMP (81.2%), whereas the majority of intrastate visitors had visited previously (79.2%). There were significantly more first time visitors visiting the NMP in off-peak months when compared to peak months (χ^2 (1) = 12.41, ρ<0.05).

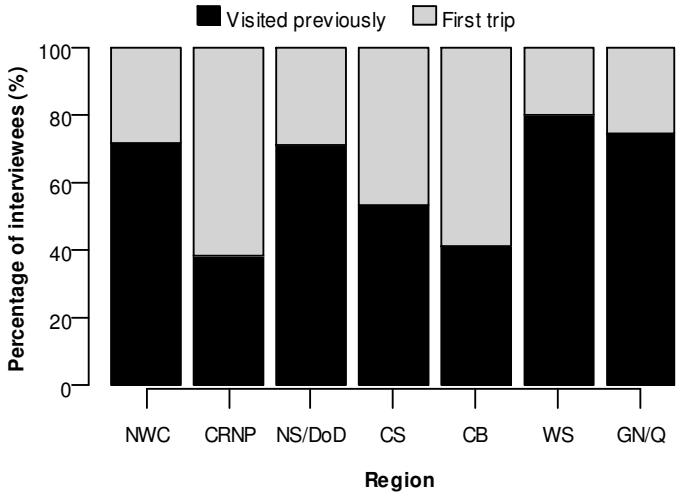


Figure 6-7 Percentage of interviewees in each region that were either visiting the NMP for the first time or who had visited on a previous occasion (n = 1 178).

Of interviewees who had visited the NMP previously, 43.8% always stayed at the same location, indicating strong site loyalty, and there was a significant difference when compared by region (χ^2 (6) = 38.42, ρ<0.05). This significant difference was the result of respondents interviewed within CRNP and NWC, who predominantly stayed at different locations when visiting Ningaloo (Figure 6-8).

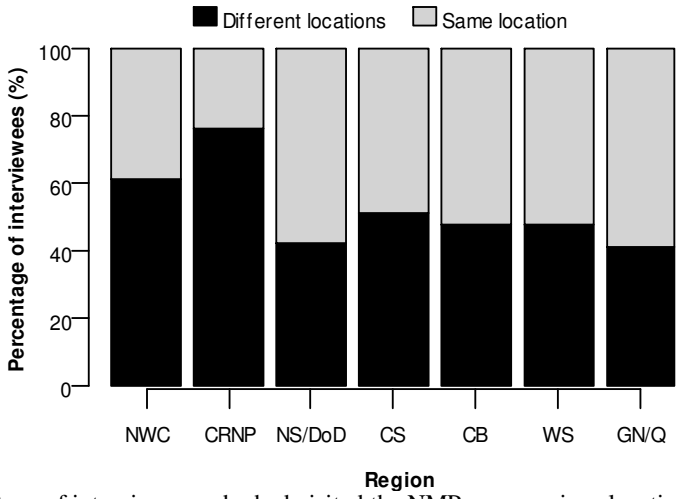


Figure 6-8 Percentage of interviewees who had visited the NMP on a previous location and always stayed at the same location on successive visits (n = 556).

The year of each interviewee's first trip to the NMP was analysed and this indicated that those in NS/DoD had been visiting for the longest period of time, with a median first trip in 1994 (Figure 6-9). However, there were several interviewees in other regions who had visited Ningaloo prior to 1970. Although there was not a significant difference between the year of the interviewee's first trip and region (χ^2 (24) = 36.36, ρ>0.05), differences were found relative to the number of trips to the NMP in the previous 12 months by region (χ^2 (30) = 121.57, ρ<0.05). This variable was also explored by visitor type, as residents would be expected to have different visitation patterns to those of tourists. Most tourists had only visited the NMP ≤1 time in the previous 12 months whereas the majority of residents had visited >11 times (Figure 6-10).

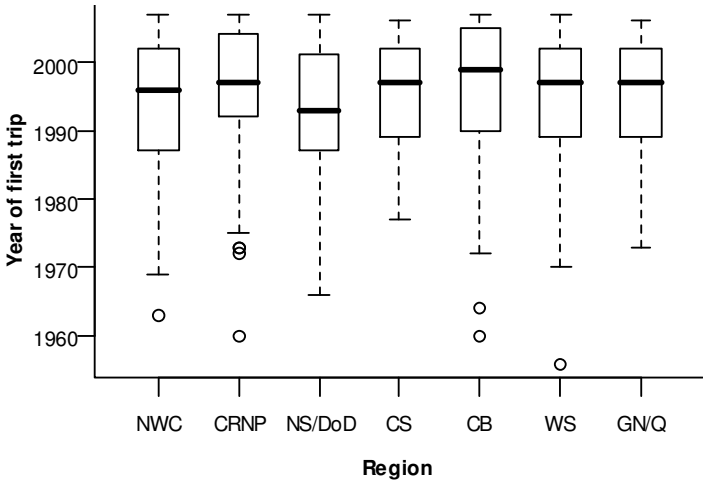


Figure 6-9 Year of first trip to Ningaloo for visitors to each region within the Marine Park displaying median, quartiles, maximum, minimum values and outliers (n = 1 178).

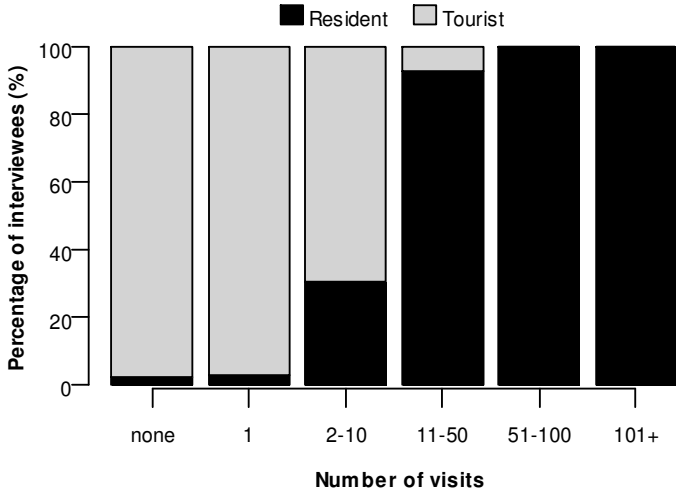


Figure 6-10 Number of visits to the NMP in the previous 12 months undertaken by each visitor type (resident or tourist) represented as a percentage of interviewees (n = 665).

6.4.4 Future visitation

Overall, 82.2% of respondents stated that they intended to visit the NMP again. Not surprisingly, 98.5% of residents responded affirmatively whereas only 53.5% of international visitors indicated that this was the case. A high proportion (67.8%) indicated that their next overnight stop outside of the NMP would be to the south in places such as Shark Bay, Geraldton and Perth (Figure 6-11). The remaining northbound respondents (32.2%) were predominantly international visitors along with regional intrastate visitors that lived in regional locations to the north-east of Ningaloo.

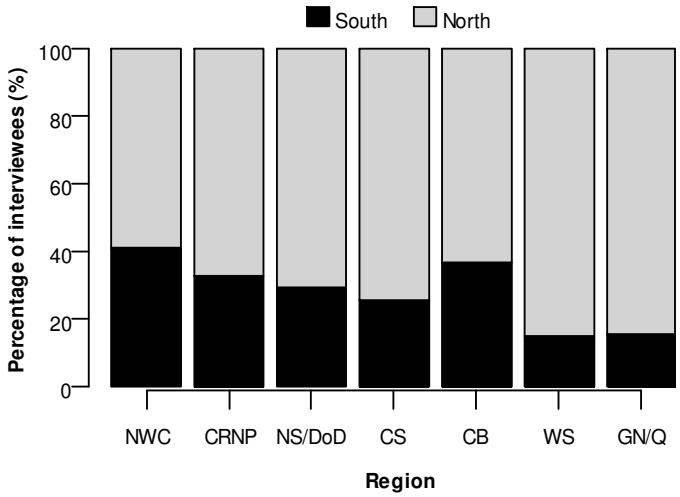


Figure 6-11 Proposed direction of travel (north or south) to their next destination by interviewees in each region of the NMP (n = 1 169).

6.4.5 Recreational activity participation

The mean time respondents 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. For respondents undertaking activities on boats, the mean time spent out on the water was 2.4 hours (*SD* = 1.6 hours). The maximum time spent at the beach within each region for all activities was 10 – 12.5 hours.

Due to the small sample size of respondents participating in boat activities (n = 42), regional variations will be considered for shore activities only (n = 1 166). The longest mean time spent at the beach and on main activities from the shore was in NS/DoD, WS and GN/Q (Figure 6-12). Significant differences were found for the length of time respondents spent on the beach ($F_{(1, 6)}$=14.68 ρ<0.05) and on their main activity ($F_{(1, 6)}$=4.49, ρ<0.05). *Post-hoc* testing revealed these effects were significant for each region.

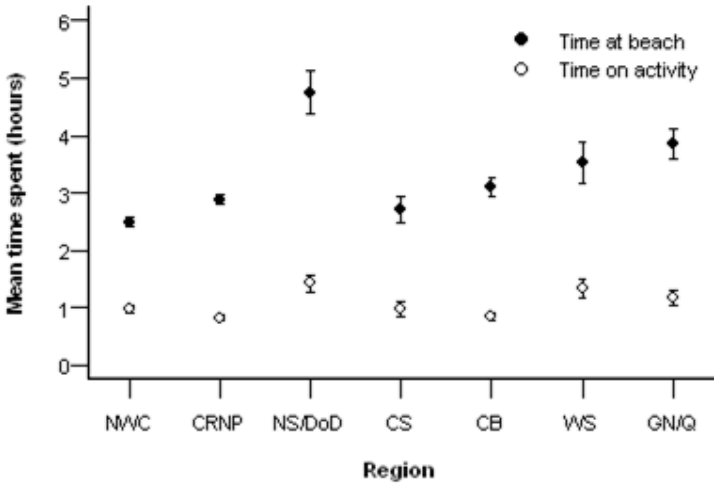


Figure 6-12 Mean time spent at the beach and time spent participating in their main activity from the shore (in hours) for respondents in each NMP region (n = 1 166) (±95% CI).

There was also variation in times of the day that people visited the beach for shore activities, with an overall median arrival time of 10 am, although this varied by region with respondents within GN/Q arriving later (12 noon) (Figure 6-13a). The overall median departure time was 2 pm, with respondents in GN/Q and CB leaving the beach the latest (4 pm) (Figure 6-13b).

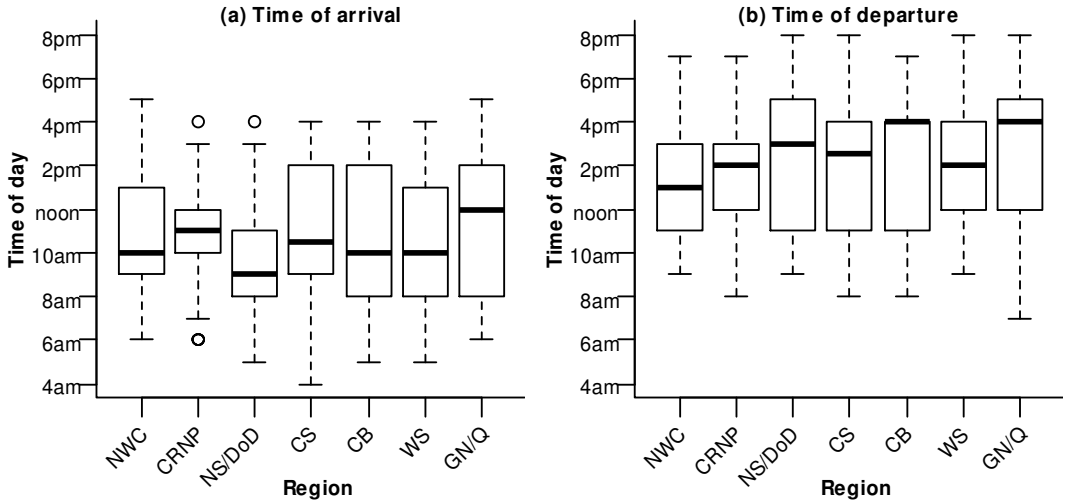


Figure 6-13 Time of (a) arrival at and (b) departure from the beach for respondents within each region of the NMP. Median, quartiles, maximum, minimum values and outliers are displayed (n = 1 166).

Tourists and residents on extended trips to the NMP had participated in a mean of three activities during their stay up until the time of interview. Residents on day trips were not included in this analysis, but they undertook a mean of two activities per trip. The maximum number of activities undertaken was 10 (in CB), with 1.9% of the sample not having participated in any activity other than their current one. There were significant differences between the number of activities undertaken by region (χ^2 (42) = 96.71, ρ<0.05). Correspondence analysis, explaining 73.9% of variation, showed that pastoral regions (NS/DoD, WS, GN/Q and CS) had a positive association with participation in a higher number of activities (Figure 6-14). NWC had an association with respondents who had only undertaken only one activity at the time of interview (which was predominately fishing or walking on the beach). There was no significant difference between number of activities undertaken when compared to age (χ^2 (36) = 47.91, ρ>0.05). Length of stay had some effect on activity participation (χ^2 (45) = 147.29, ρ<0.05), with respondents staying <7 days participating in a greater number of activities. Significant effects were also found for those respondents who had visited the NMP on a previous occasion (χ^2 (7) = 15.28, ρ<0.05), with first time visitors participating in a greater number of activities.

Overall, respondents participated in 18 different recreational activities on the shore or from boats in the NMP on their day of interview. The most frequently recorded shore activities being undertaken at the time of interview were relaxing on the beach (39.2%), fishing (23.1%), walking (13.5%), snorkelling (6.5%) and swimming (4.8%). Boat activities were dominated by fishing (69.3%), sailing sports such as windsurfing and kitesurfing (23.1%) and kayaking (17.3%). For shore activities, these percentages differed considerably from the main activity for which the interviewee had come to the

NMP on that day. These main activities were snorkelling (27.6%), fishing (25.1%), swimming (11.9%), relaxing (10.8%), walking (8.4%) and surfing (4.6%). For boating, these main activities were the same as the activity being undertaken at the time of interview.

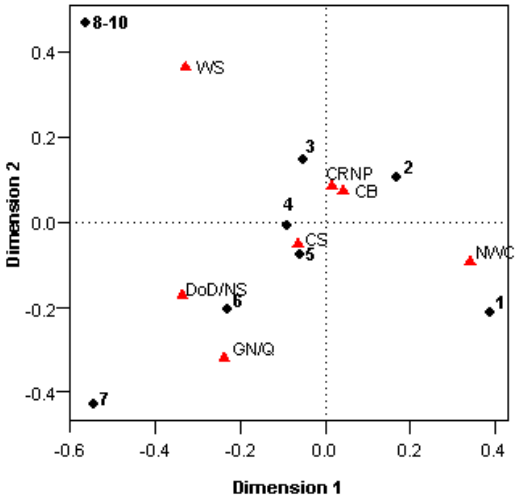


Figure 6-14 Correspondence analysis between regions and the number of activities undertaken by interviewees during their stay in each of the NMP regions (n = 1 060).

Investigating the main shore and boat activities undertaken by respondents in each region showed that fishing was the most frequently recorded activity in all regions except CRNP and CB, where snorkelling was dominant (Figure 6-15). Swimming and relaxing were also popular in CB while sailing sports, such as windsurfing and kitesurfing, and surfing were popular activities in GN/Q.

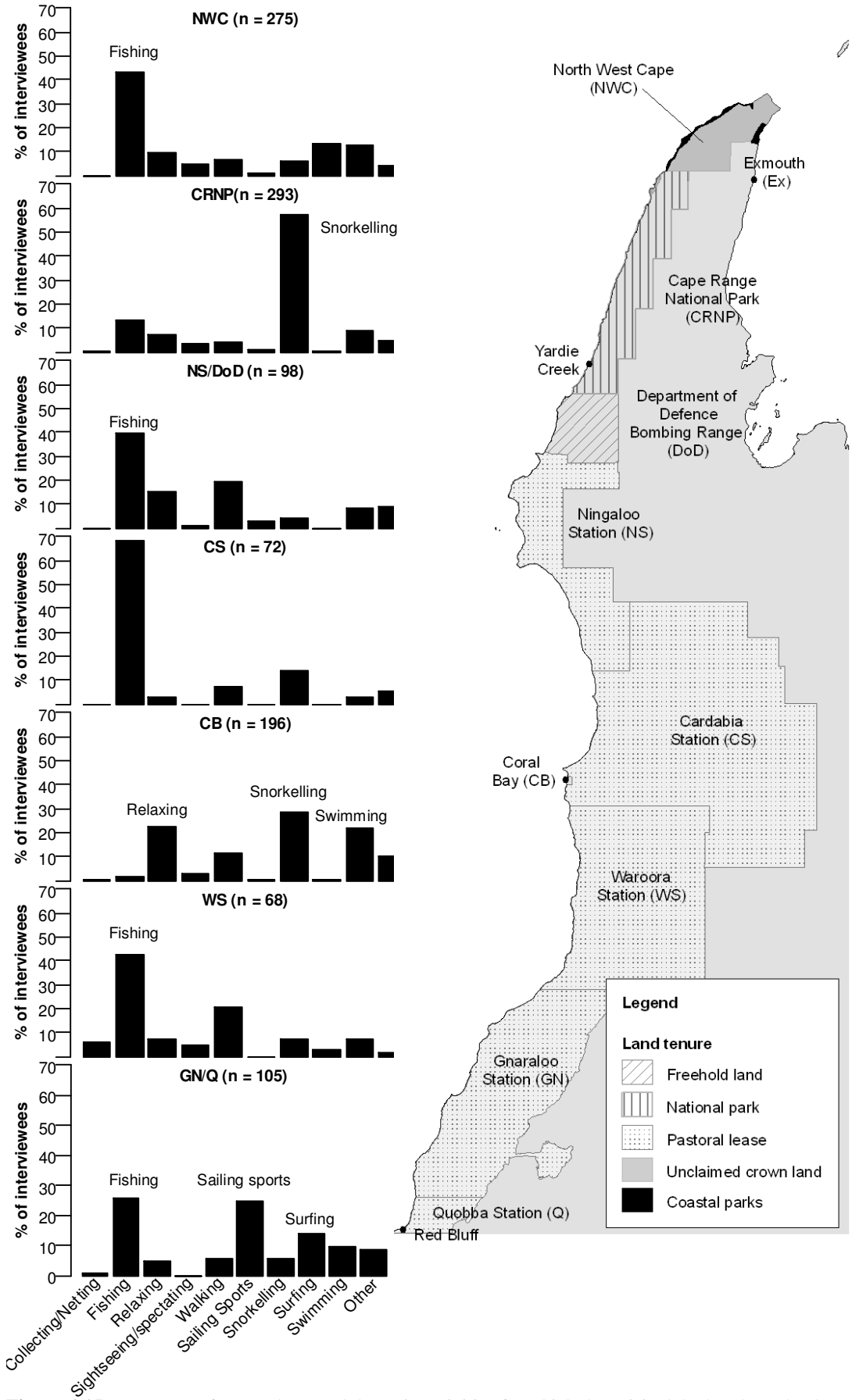


Figure 6-15 Percentage of respondents and the main activities for which they visited the beach on the day of interview within each coastal region of the NMP (n = 1 208).

6.5 Discussion

6.5.1 Survey design

The stratified sampling design, along with quota and purposive selection techniques, facilitated interviews with people participating in recreation on the shore and at the completion of boating trips across the entire sampling frame. This regime achieved 1 208 interviews over 192 surveys days, with 26 general categories of recreational activities participated in by respondents throughout the study area. Although these data cannot be interpreted as representative of the visitor population, they provide a subset of people who visited the region and participated in activities within the NMP.

Some biases may have been introduced into the study via interviewing groups or individuals undertaking sedentary activities such as fishing or sunbaking. These groups were more likely to be interviewed as they are present on the beach for longer periods than respondents who were engaged in active or water-based activities such as kitesurfing or snorkelling. This length of stay bias is similar to avidity bias, and is well-documented with respect to recreational fishing surveys (Pollock *et al.*, 1994). This effect 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 undertook every effort to interview people involved in a range of activity types, which is consistent with a purposive approach to group selection.

Another strength of these interview data was the collection of information on recreational activity participation, up until time of interview, as opposed to proposed

activity participation which is collected (and combined across sites) in many studies. Furthermore, the face-to-face interview approach, with the researcher completing the survey, resulted in a high response rate of 99% for the study period. This technique also reduced the effect of any biases caused via self-reporting, which have been previously identified (Tarrant and Manfredo, 1993; Beaman *et al.*, 2004).

6.5.2 Land tenure and user characteristics

This is the first study at Ningaloo to obtain information on visitor characteristics and activity participation over a 12-month period while also encompassing the entire 300 km coast. The use of geo-referenced spatial links to the regions was also a novel approach to data collection. Previous studies have taken a tenure-based approach to research at Ningaloo, focusing on specific regions, including; Exmouth (Dowling, 1991; Hollet, 2001; Ingram, 2008), North-West Cape (Wood and Dowling, 2002), CRNP (Wood, 2003b;a; Moore and Polley, 2007; Northcote and Macbeth, 2008), Coral Bay (Worley Parsons, 2006) and various pastoral stations (Remote Research, 2002; Wood, 2003b; Northcote and Macbeth, 2008). Although these studies provided the first indications of differences in visitor characteristics between these regions (Wood, 2003a) and assisted with developing the land tenure hypothesis; few collected data that were geo-referenced.

This study found that Coral Bay and CRNP had higher proportions of international and interstate visitors when compared to other regions. There has been an increase in the number of international visitors to Australia in recent years (TRA, 2007) and this has also been documented at Ningaloo (Wood, 2003a; Northcote and Macbeth, 2008). This

is most likely due to increased publicity and marketing (i.e. guide books, advertisements) especially at popular snorkelling sites, such as Turquoise Bay, Oyster Stacks and Coral Bay. The creation of reserves, such as the NMP and CRNP, are also known to attract more visitors to an area (Gurran *et al.*, 2007). Furthermore, sites in CRNP and at Coral Bay have 2WD access, and this type of vehicle was used by 78% of international visitors, thereby restricting them to regions with sealed roads. Most intrastate visitors (from Perth, regional WA and residents) had 4WD vehicles (79%) and were more likely to choose accommodation on pastoral leases, dominated by sand and gravel access tracks. Prior knowledge of an area also plays a role in this distribution, with more intrastate visitors having visited the NMP on a previous occasion (83.2%), as opposed to interstate visitors (24.4%).

Unlike previous research, this study found 82.4% of family groups (the second most recorded group type) had young children (<17 years of age) who were more likely to visit during school holidays. Although it was previously postulated that there were less families with young children at Ningaloo due to long travel times from population centres (Wood, 2003a), school holidays create a window of opportunity for these groups to travel away from home. This is known to have a significant effect on tourism, with increased visitation during these periods (Fernandez-Morales, 2003; Amelung *et al.*, 2007). Much of the analysis of interview data has supported the use of off-peak/peak periods to differentiate between patterns of recreational use (as applied to the observation surveys in Chapters 4 and 5), although school holiday periods are also important. However, the majority of school holidays (i.e. April, July and October) are embedded within the peak period, enabling the use of these broader off-peak/peak

categories for identifying significant differences in demographics and visit attributes, such as length of stay.

The remaining dominant group type found in the study was couples in the 55+ age bracket. This was largely due to the presence of 'grey-nomads' (equivalent to 'snowbirds' in North America) who are mostly retirees staying in caravan parks or coastal camping sites along the Ningaloo coast for up to 6 months between April - October. This group is distinct from others as they have relatively low expenditure on restaurants and accommodation (Prideaux and McClymont, 2006). Their presence has implications for local communities, which have to cater for this semi-permanent population (i.e. provision of health facilities) (Happel and Hogan, 2002) and, also for recreational activity participation, which has been found to decline with increasing age (Moscardo and Green, 1999). The current study at Ningaloo does not support this finding, with respondents in the 55+ age category regularly participating in activities such as walking and fishing. These activities, along with sightseeing, swimming and socialising were also popular with 'grey-nomads' on the east coast of Australia (Mings, 1997).

Length of stay was longer for visitors to pastoral leases (who were mostly from Perth and regional WA), which supports data from previous research at Ningaloo (Remote Research, 2002; Wood and Dowling, 2002). Although length of stay is an important choice for visitors (Decrop and Snelders, 2004), and is related to variables such as origin and familiarity with an area (Gokovali *et al.*, 2007), this study found these groups were more likely to be retirees in the 55+ age category who have a high level of repeat

visitation. These pastoral leases are also more difficult to access and longer trips support the time investment in accessing these remote areas (Lucas, 1990a).

The main reason for choosing a particular accommodation location also provided insight into the distribution of visitors to different regions. Although there were many factor levels, the association between Gnaraloo and Quobba Stations (in the southern extent of the Marine Park), and activities, was clear. The remaining pastoral leases were distinct from Coral Bay and CRNP, being more associated with management controls, ambience/crowding, environment, social and location. The separation of these regions supports the hypothesis of differences based on land tenure due to variation in management controls. It also highlights potential future issues of overcrowding and loss of ambience, as people choose to stay in the pastoral regions to avoid busier locations. The diversity of visitors to Ningaloo also supports a range of experiences being provided in remote and semi-remote areas to maintain visitor satisfaction, which is one of the aims of current planning (WAPC, 2004). However, at many of these coastal camping areas people must supply all of their own provisions and facilities, such as generators, portable toilets, rubbish disposal, drinking water and firewood, which may place a strain on the scarce supplies of bore water and firewood in this arid environment.

Central to this land tenure hypothesis is the issue of common property ownership and various rights of access to coastal and marine environments (Clark, 1997; Vorkinn, 1998; Agardy, 2000). Managing access to these areas is complicated, especially for pastoral leasees, who have traditionally allowed public access to the coast for recreation.

However, increasing demand and economic stresses have resulted in changed attitudes with access restrictions and user pays philosophy documented in places such as New Zealand (McIntryre *et al.*, 2001) and North America (McCool and Stankey, 2001). The management authority for the Bombing Range, also has the ability to restrict access to this area (located south of CRNP). Although rarely enforced, this would impact significantly on camping and travel movements throughout the NMP. Traditional land owners also need to be considered, both within the context of maintaining sites of cultural significance, such as burial grounds or archaeological material which are protected under the *Aboriginal Heritage Act 1972* and, for native title claims. A claim is currently being processed which covers a large area of the Ningaloo coast (National Native Title Tribunal, 2009) and, if successful, may grant rights for hunting or gathering of traditional resources, undertaking ceremonies or living in the area.

High levels of repeat visitation (55.2%) were found in this study, particularly at NWC and on pastoral leases, which corroborates previous research (Remote Research, 2002; Northcote and Macbeth, 2008). Lower levels of repeat visitation were found in CRNP by this study and Moore and Polley (2007). High repeat visitation shows strong site loyalty and is an indicator of a level of satisfaction with a location. Repeat visitors also have different visitor characteristics to first-time visitors (Oppermann, 1996; Darnell and Johnson, 2001) as do older retirees such as the 'grey-nomads' when compared to other group types (McHugh and Mings, 1996), with these groups able to form strong place attachments to these locations (Ormsby *et al.*, 2004).

Respondents in most regions arrived at the beach at 10 am and departed by 2 pm. This supported the survey design and analysis of observation data collected during the aerial flights (Chapter 4), which was based on the northbound flights from 10 am – 12 noon. However, the southernmost regions on Gnaraloo and Quobba Stations had later beach arrival and departure times at 12 noon and 4 pm, respectively. Activity in these regions had a different diversity to other regions, with sailing sports and surfing more popular. Such activities are highly weather dependent, and strong prevailing south-westerly breezes in the afternoon are suitable for sailing activities such as windsurfing or kitesurfing. The reversal of starting points for survey routes during the coastal 4WD surveys ensured this activity was documented during this study.

Visitors travelling to the NMP partake in a wide variety of recreation types, with a mean of three activities undertaken by respondents. Relaxing and fishing were the most popular activities being undertaken at the time of interview. Relaxing was also the most popular shore activity (37.7% of people) recorded during the coastal surveys (Chapter 5). Although fishers comprised 8.9% of the total people observed during the coastal surveys, this group would be expected to be interviewed more frequently due to the more sedentary behaviour of participants.

As stated earlier, this was the first longitudinal study of recreational use conducted in the NMP, and it identified significant levels of use occurring in off-peak months from November - March, which have not previously been explored. Time of year is one of the major factors which influences variation of recreational use due to variation in natural factors such as weather conditions (i.e. wind strength and temperature) (Ploner

and Brandenburg, 2003) and institutional factors such as day types or school holidays (Bhat and Gossen, 2004; Amelung *et al.*, 2007). Although these off-peak periods are not traditionally periods of high visitation due to high temperatures (mean of 38°C in January) and likelihood of cyclones (from November – April) (BOM, 2009), a significant proportion of these visitors are of international origin as these months coincide with the northern hemisphere winter.

These data also showed significant differences between people who reside in the local area (either in Exmouth or Coral Bay) and tourists, even though these tourists may stay for extended periods (>6 months). This was especially true around North-West Cape, which is located closest to the town of Exmouth and had the strongest association with this group type. This has been observed in some previous research at Ningaloo in terms of preferences for tourism planning (Dowling, 1991), however, this study expanded this understanding to incorporate user characteristics and recreational activity patterns. Behaviours by tourists and residents have traditionally been assumed to be homogeneous (Inbakaran and Jackson, 2005) but they are now realised as an important factor for consideration in management and planning (Confer *et al.*, 2005), as they reflect different experiences and meaning of beach use for these groups. Residents view the beach as a local leisure resource (which has a regular and routine element) while for tourists it is a special experience which may be repeated year after year (Tunstall and Penning-Rowsell, 1998). This pattern was identified in the current study with the majority of residents travelling to the Marine Park for recreation ≥11 times/year while there was a high level of repeat visitation by tourists. The expansion of nearby or adjacent populations centres near a protected area also needs to be considered, as this

can significantly increase the users of an area, who are able to visit on a regular basis (Arnberger and Brandenburg, 2002).

6.6 Conclusions

The 1 208 people interviewed participating in recreational activities along the NMP coast showed significant variation in user characteristics and activity patterns based on land tenure. Visitors to pastoral leases had similar demographics, being more associated with people in the 35+ age brackets from Perth and regional WA. This was distinct from respondents in Coral Bay and CRNP who were younger and more likely to be from interstate or overseas. However, within these groupings, people recreating on Quobba and Gnaraloo Stations were also distinct, with higher levels of participation in activities such as kitesurfing, windsurfing and surfing. There were very high levels of repeat visitation and site loyalty by visitors along the entire coast and, as would be expected, residents from Exmouth and Coral Bay also had a much higher frequency of visitation. These findings have implications for management of the Marine Park, with the different characteristics, behaviours and preferences of respondents within these land tenure regions supporting a need for maintaining the diversity of accommodation and recreational opportunities throughout Ningaloo.

Chapter 7 Identification and quantification of intra-regional travel networks

7.1 Introduction

A central part of tourism is the movement of people between destinations. These patterns, and their spatial relationships, can be complex because of the many facets involved (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 interactions with increasing distance from origin (McKercher and Lew, 2003) (Figure 7-1a). All tourism opportunities are assumed to be distributed uniformly, which is unlikely to occur in reality (McKercher and Lew, 2004). Actual distance 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 having a strong visitor attraction (Figure 7-1b).

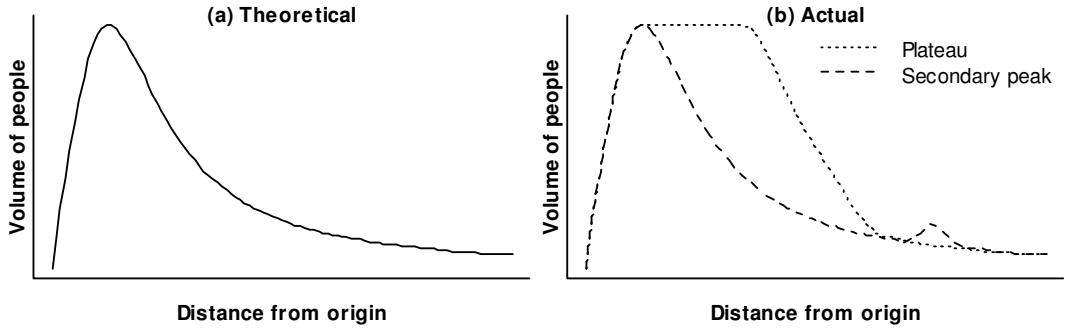


Figure 7-1 (a) Theoretical distance decay curve based on uniform distribution of tourism opportunities and (b) actual distance decay curves determined from empirical studies [adapted from McKercher and Lew (2004)].

The previous chapter focused on demographics, visit attributes and activity patterns of recreational participants in the Ningaloo Marine Park (NMP), which are important to understand for implementing sustainable management and planning practices. An appreciation of visitor flows is also important 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).

The movement of people to and from a particular destination has been studied extensively (Mings and McHugh, 1992) with several conceptual models developed to describe various itineraries and visitor flow patterns (Campbell, 1966; Matley, 1976; Mings and McHugh, 1992; Lew and McKercher, 2002). There are many commonalities between the multitude of itinerary types and these were summarised into four main categories by McKercher and Lew (2004) (Figure 7-2).

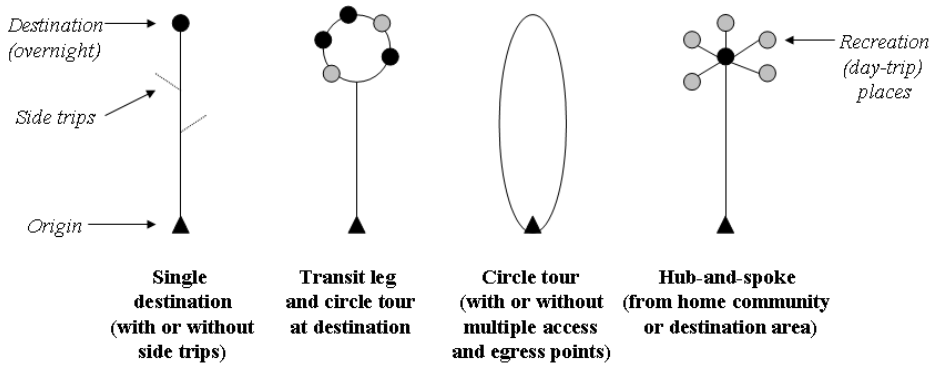


Figure 7-2 Summary of four main itinerary types [adapted from McKercher and Lew (2004)].

The first trip type comprises those with a single destination, which may or may not involve side trips while the second trip 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 trip type is a circle tour from which multiple side trips, overnight stays and recreational day trips can be incorporated. The fourth trip is a hub-and-spoke type, for which recreational (day trips) are the main element of the journey, forming a radial pattern from a home community or destination area. This fourth itinerary type 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. Although there are many models, the four trip itineraries described here fit well within the context of Ningaloo and are a useful starting point for examining the movement patterns of visitors.

These various itinerary types focus on describing the inter-regional travel patterns of visitors to, or from, a destination region, whereas this current study was focused on intra-regional visitor flows, represented by the second (transit and circle) and fourth (hub-and-spoke) patterns. Investigating the intra-regional movement of people once arrived at a destination area can provide additional insights into visitor behaviour. There has traditionally been less research focusing on this aspect of visitor flows (McKercher and Lau, 2008), although this has changed in recent years (Murphy and Keller, 1990; Kramer and Roth, 2002; O'Conner *et al.*, 2005; Gimblett *et al.*, 2007). 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 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, i.e. not located adjacent to any large population centre, with limited coastal access restricting interactions with people visiting from nearby destination areas.

Collecting data on intra-regional movement patterns can be challenging because of the potentially large numbers of people, unconstrained choices and need for accurate tracking of movements without affecting normal behaviour (O'Conner *et al.*, 2005). Mapping techniques are one available data collection option, whereby an interviewee traces their current, previous or proposed travel routes along roads, walking trails or waterways, which are then digitised into a Geographic Information System (GIS) framework. This technique has 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 *sans* map by using face-to-face interviews to gather data on exit and entry points along with destinations visited (Murphy and Keller, 1990; Tideswell and Faulkner, 1999). Observation techniques such as aerial surveys (Deuell and Lillesand, 1982) and image recording (Sacchi *et al.*, 2001) have been used to document movement patterns. Visitors have also been monitored using GPS tracking devices on both land (O'Conner *et al.*, 2005) and water (Deng *et al.*, 2005; Pelot and Wu, 2007). 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 (known as travel gateways),

associated arrival and departure times, length of stay and location of actual (or proposed) visits to 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 programs such as RBSim (Itami *et al.*, 2000). RBSim is a tool that allows simulation of movement patterns, based on data collected from individuals or groups, to explore interactions between humans and the environment which can be utilised by managers to improve planning and development (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 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 or seabed 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 (which validate the best placement of travel routes) 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 boaters provides advantages for modelling, evaluating management strategies and determining likely areas of impact from these groups.

Currently, no data exist on visitor flows or movement patterns of people participating in recreational activities within the NMP. Previous analyses in this thesis and by others (Holt and Kearsley, 1998; Coombes *et al.*, 2009) found access points and infrastructure influence the distribution of visitors. However, there are few studies that quantify travel distance or dispersion between different coastal components (i.e. from the hinterland, represented by an accommodation location, to a beach access point) or around a marine park (i.e. from boat launching site to recreation location). These will be highly specific to a particular study area but may provide useful data for market segmentation and supporting management decisions (Zhang *et al.*, 1999).

7.2 Research objectives

The main aim this chapter was to investigate the movement patterns and geographic range of people participating in shore and boat activities throughout the NMP. This was achieved by addressing several research objectives including:

- identifying and quantifying the travel networks of recreational participants as they dispersed from;
    - accommodation to beach access points by vehicle,
    - accommodation to boat launching sites by vehicle,
    - beach access points to shore recreation locations by foot along the beach; and
    - boat launching sites to boat recreation locations by boat.
- identifying areas with highest shore and boat-based recreational use in off-peak and peak periods; and
- investigating and discussing the factors which drive these movement patterns.

7.3 Analysis techniques

There were nine main access roads from which to enter or exit coastal regions adjacent to the NMP (Figure 7-3). From these, there were a wide variety of subsidiary roads and tracks from which recreation and camping areas could be accessed. These were mapped during fieldwork via the use of a data logger and the information was imported into ArcGIS 9.3 where attributes such as road type, road surface and length (km) were added. In total, 1 480 km of roads and tracks were mapped along the Ningaloo coastline and several options were available for classifying these according to their function, level of traffic and surface type. For the purpose of this project, the Western Australian classification was adopted (ICSM, 2006) and incorporated with that used in the regional planning strategy (WAPC, 2004) with the addition of a 'beach' category (Table 7-1).

Table 7-1 Road type classification with description and speed limit assigned as an attribute for network analysis [adapted from ICSM (2006) and WAPC (2004)]. Note: * indicates derived during fieldwork.

Road type	***Description***	***Speed limit (km/hr)***
Highway	Major connecting roads between cities and towns which are the principle avenue for high volume traffic (i.e. North-West coastal highway). Sealed.	110
Main road	Distributes traffic between highways and from a principal avenue 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 e.g. lookout. Sand or gravel.	40*
Beach	No fixed road, vehicle travels along a sandy beach if tides permit. Sand.	20*

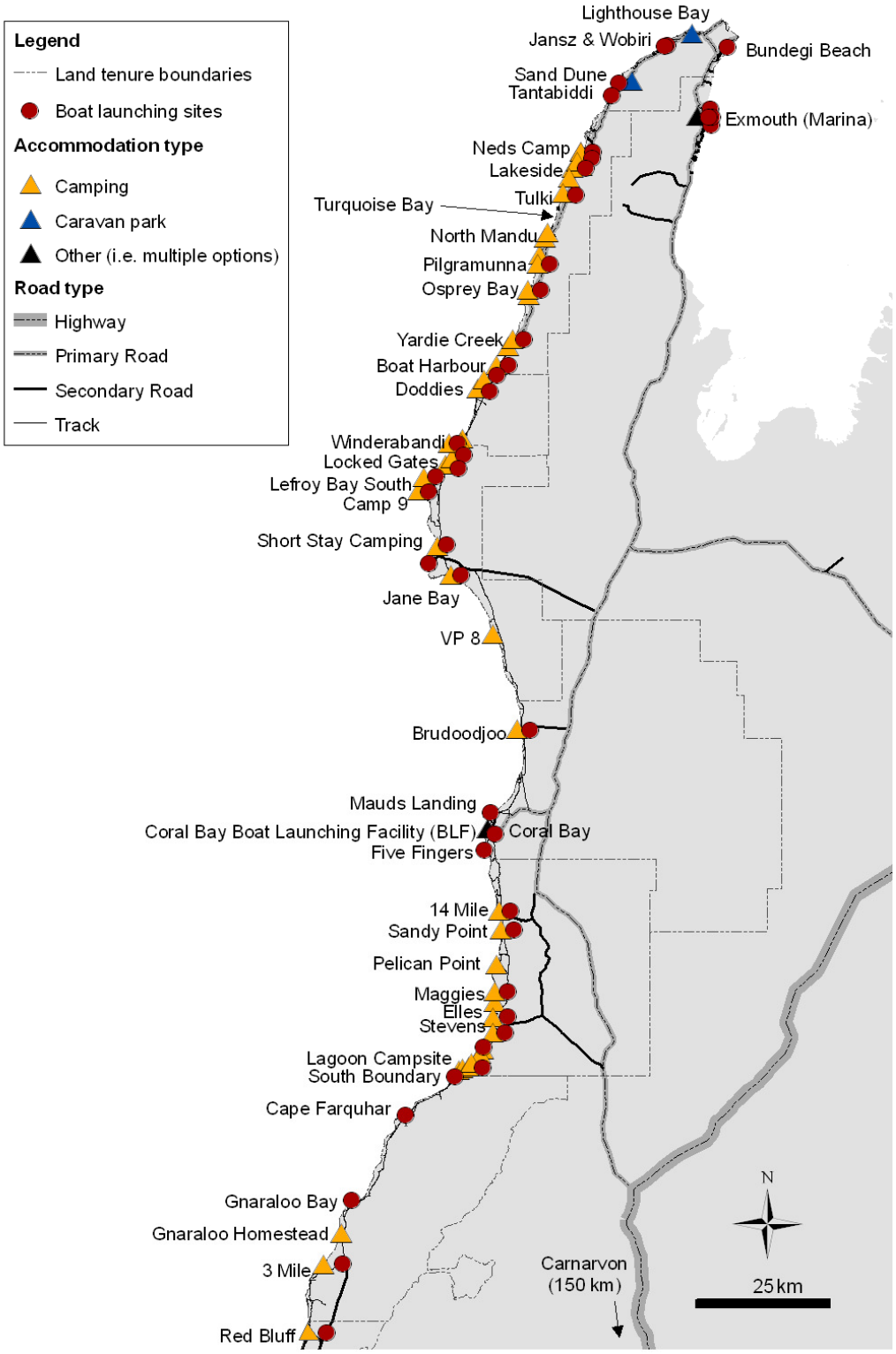


Figure 7-3 Location of main access roads [classification adapted from ICSM (2006)], accommodation and boat launching sites situated adjacent to the NMP.

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. Such points generally originated at the end point of a road (i.e. path leading from a carpark) and often have multiple accesses. The 336 beach access points recorded during the survey were dominated by designated carparks, sand or gravel tracks which were developed either formally (by management) or informally (by users). This distinction is the basis for a classification of beach access types, adapted from Leung and Marion (1998) (Figure 7-4). Two additional beach access types entitled 'formal (marine)' and 'non-fixed' were also developed. Due to the large number of beach access points they are not specifically demarcated on a map in this thesis, however, many names correspond to accommodation or boat ramps identified in Figure 7-3 (or in analysis from previous chapters).

Formal (marine) locations were similar to formal accesses in that they were structures constructed with approval from management, however, they 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 were movable features, such as campsites and vehicles from which respondents were able to directly access the beach for recreation. This category was created due to the proliferation of camping or driving directly onto the beach in many sections of the 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 groups participating in shore-based recreation. The features of these tracks, such as surface type, were also described and where possible conformed to the criteria of walking trails established by DEC (R. Weir, 2009, DEC, *pers. comm.).*

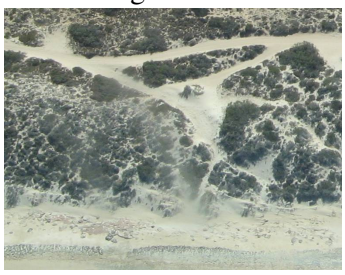
Track type (n)	*Description*
Formal (56)	Roads and tracks created by management using some form of demarcation, normally bitumen or compacted gravel.  
Informal (67)	Tracks, with no camping at the endpoint, which were created and perpetuated by uncontrolled and unmanaged visitor use.  
Formal (marine) (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.  
Non-fixed (209)	A non-fixed location such as campsite or car from where interviewees could directly access onto the beach.  

Figure 7-4 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.

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 (also applied in the previous chapter) included coastal camping, caravan parks, hotels, chalet/self-contained units, backpackers, safari 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 combined to a single location). This aggregation was also undertaken for separate sites within a coastal camping area and, once completed, 56 accommodation locations remained for analysis (Figure 7-3), of which respondents were recorded staying at 49 locations. Although the majority of these coastal camping areas were demarcated at some level (i.e. informal sign erected by pastoral leaseholder), due to the undeveloped nature of large tracts of the coast, it was also possible for camping to occur in locations arbitrarily selected by the camper. These locations were geo-referenced during surveys and assigned to a consecutive numbering system (Camp 1, 2 etc.). Respondents newly arrived at the NMP, and who had not yet determined a place to stay, were excluded from this analysis.

There were 45 places recorded during the study where vessels could be launched, including three constructed boat ramps (Exmouth Marina, Coral Bay Boat Launching Facility (BLF) and Tantabiddi) while the remainder of vessels were launched from beaches with no constructed facilities (Figure 7-3). Collectively, these locations are referred to throughout the chapter as boat launching sites. The Coral Bay BLF was

completed partway through the survey with boats launching directly off the beach within the townsite of Coral Bay prior to October 2007.

Interviewed boat users were asked questions relating to their boat type and characteristics (length, engine size and fuel tank capacity) as well as their furthest distance travelled from their primary launch location. They were able to answer this question in several ways, by providing;

- a destination name (number of respondents = 73),
- a travel direction (e.g. north) and distance (number of respondents = 82) or,
- a travel radius (number of respondents = 51).

These data were standardised to a travel radius (km) and linked using ArcGIS 9.3, from which the maximum potential travel distance from a launch location could be determined. 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 and, 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 current 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 (Table 7-1). Barriers were also used to indicate roads that could not be used due to road closures or limited access (i.e. authorised personnel only). This was undertaken to calculate the distance travelled by following the road network between accommodation, beach access points and boat launching sites (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. Although straight lines between points were used for preliminary analysis to validate and verify the large number of geographic co-ordinates collected during fieldwork, it was advantageous to use Mean High Water Mark (MHWM) to account for curvature of the coastline. The relationship between these two methods was clarified using correlation techniques which found a strong positive relationship found between the two distances (Spearman's *rho* = 0.935, $\rho<0.05$). For the purposes of this analysis, network distance calculated from the MHWM was selected as the most appropriate due to its ability to take into account 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 boat launching site to a boat recreation location could not be calculated using network analysis, as vessel movements are not restricted to linear features. Therefore, features such as exposed reefs were taken into account to identify

locations where vessels could not travel. The bathymetry available for Ningaloo is very broad and, combined with the small size (and shallow draft) of many vessels, this was not a suitable feature by which to restrict travel movements of vessels. There are also few channel markers or navigation aids at Ningaloo, and although these were available for specific locations at Exmouth Marina, Tantabiddi and Coral Bay, similar reasoning resulted in these features being excluded. Due to this, generating a route based map of boating activity was impractical, and a raster-based technique was 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 overlayed by a 1 km^2 grid to determine areas where vessels were likely to occur, similar 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 chosen 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.

7.4 Results

7.4.1 Accommodation to beach access

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 along North-West Cape (NWC) and Cape Range National Park (CRNP). Informal tracks were also located in highest abundances in NWC and CRNP, as well on Gnaraloo and Quobba Stations (GN/Q) (Figure 7-5). Coral Bay (CB) had <10 beach access points which were all categorised as formal. Formal (marine) locations were only in NWC and on Cardabia Stations (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 Ningaloo Station and the Bombing Range (NS/DoD) and Warroora Station (WS), due to the wide availability of camping on the beach.

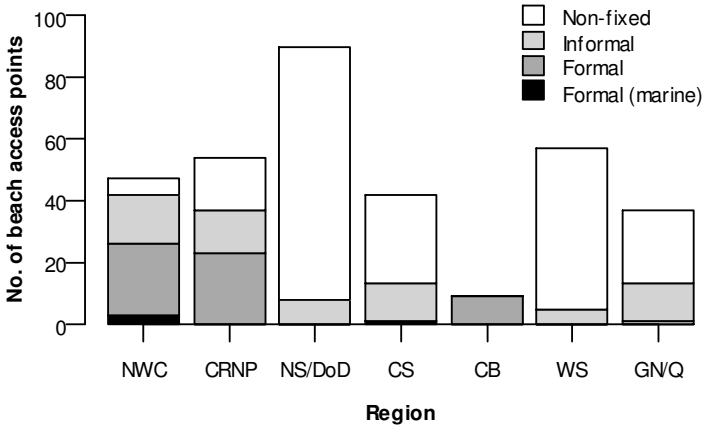


Figure 7-5 Number and type of beach access points within each region of the NMP (number of beach access points = 336).

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 7-6). 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, 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 (GN/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 highest numbers at Jansz, Wobiri, Bundegi and Surf Beaches situated 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.

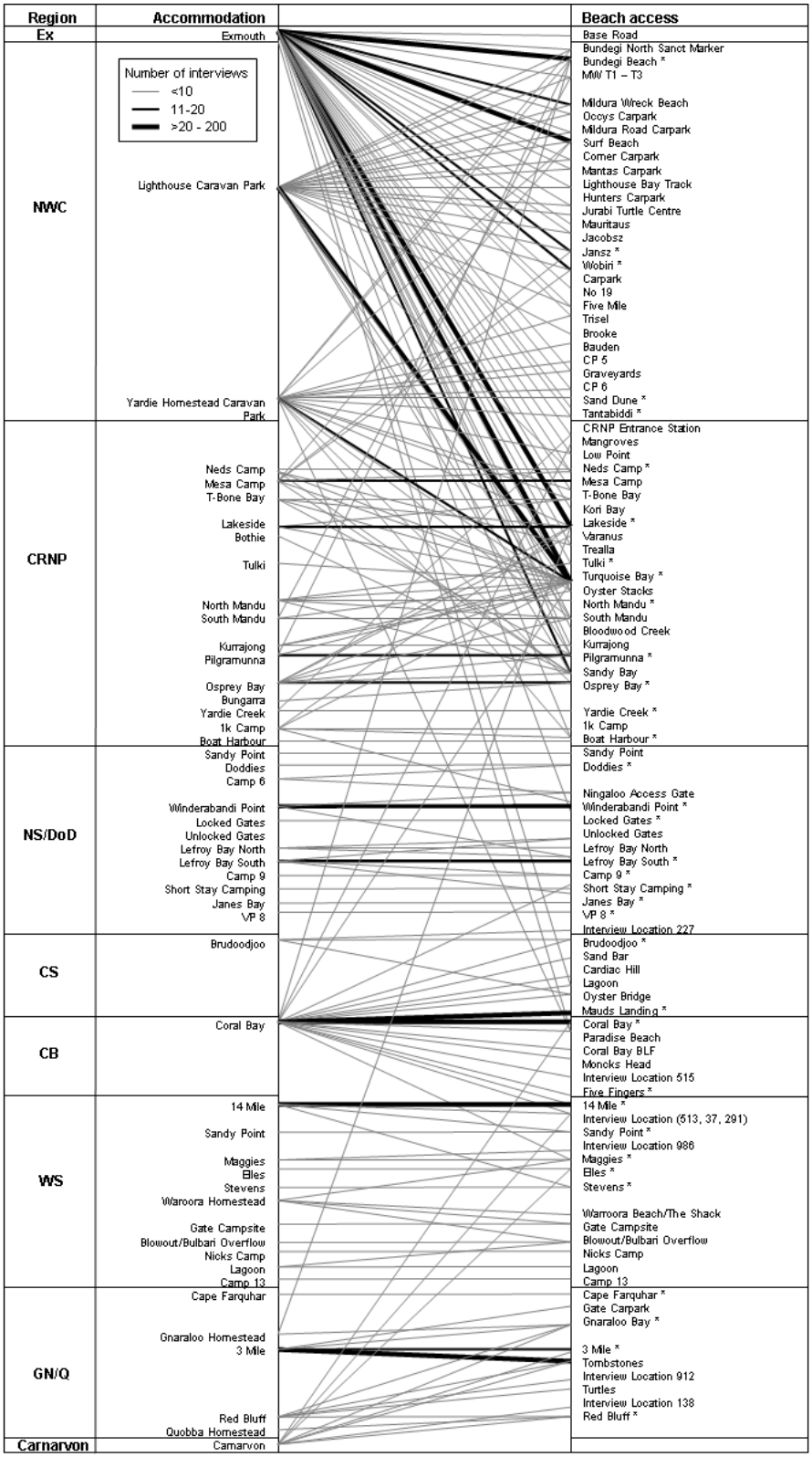


Figure 7-6 Travel flows and their frequency between accommodation and beach access points for interviewees on their current trip to the NMP (number of interviews = 1 188). Note: * indicates shown in Figure 7-3.

At the time of interview, 66.5% of respondents had away travelled from their accommodation location for shore recreation. This highlighted a sedentary trend by the remaining 33.5% of respondents 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) was situated on NS/DoD (Locked Gates, Jane Bay and Doddies) and WS (Stevens, Elles and Maggies).

The distance travelled by an interviewee along the road network between their 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 7-7). 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 7-8). The mean distances of these pathways for each NMP region were significantly different (assuming unequal variances, $F_{(1, 1153)} = 192.84$, $\rho<0.05$). 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, $F_{(1, 1160)} = 15.83$, $\rho<0.05$). 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, $F_{(4, 1157)} = 6.53$, $\rho<0.05$). *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 ($F_{(1, 4)} = 1.44$, $\rho>0.05$).

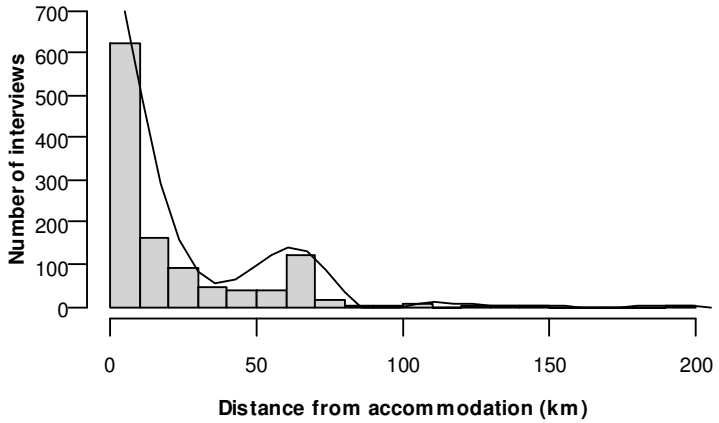


Figure 7-7 Number of interviews associated with increasing distance (in 10 km increments) travelled by road from accommodation with an interpolated spline representing the distance decay curve (number of interviews = 1 163).

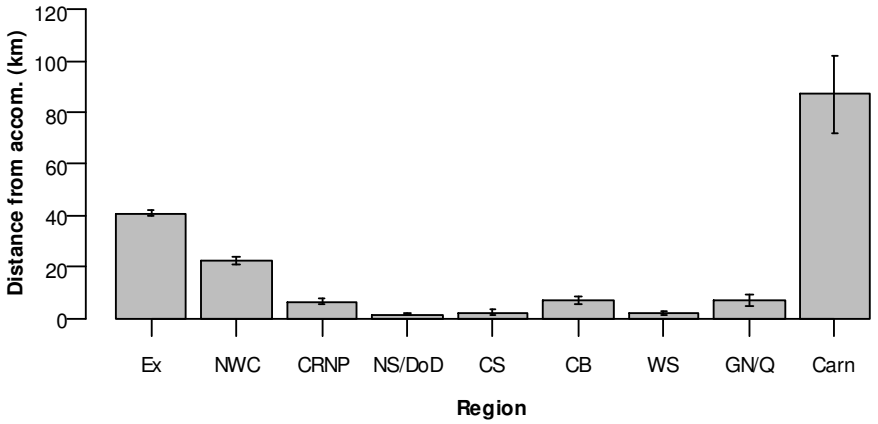


Figure 7-8 Mean distance travelled from accommodation (km) to beach access points in each NMP region (± 95% CI) (number of interviews = 1 163).

Group type 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 revealed individuals produce significantly different results from other group types at the 0.05 level. Individuals travelled a mean distance of 8.9 km, the smallest distance of any group type, while commercial tour/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 between 1-3 days ($\bar{x}$ = 24.5 km) travelled greater distances than those staying longer (who travel shorter distances). 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, $F_{(17, 1143)} = 11.79$, $\rho<0.05$). *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 they had travelled from their accommodation for shore recreation. From the same 48 accommodation locations listed above there were 123 sites recorded as furthest places travelled to by respondents during the survey. 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 when interviewed, 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 7-9). A secondary peak was still evident at ~70 km from accommodation.

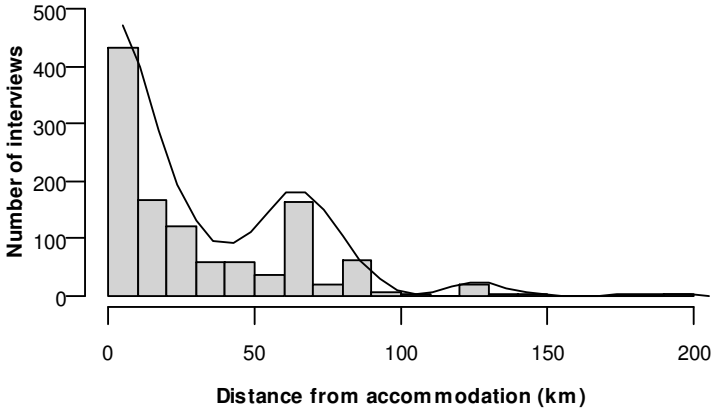


Figure 7-9 Number of interviews by furthest distance from accommodation during a trip, until time of interview, in 10 km increments (number of interviews = 1 163).

7.4.2 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 co-efficients between 0.79 – 0.87 (Figure 7-10). Histograms showed that the majority of vessels were 3 - 4 m in length with engines <50 hp and fuel tanks <50 L in size.

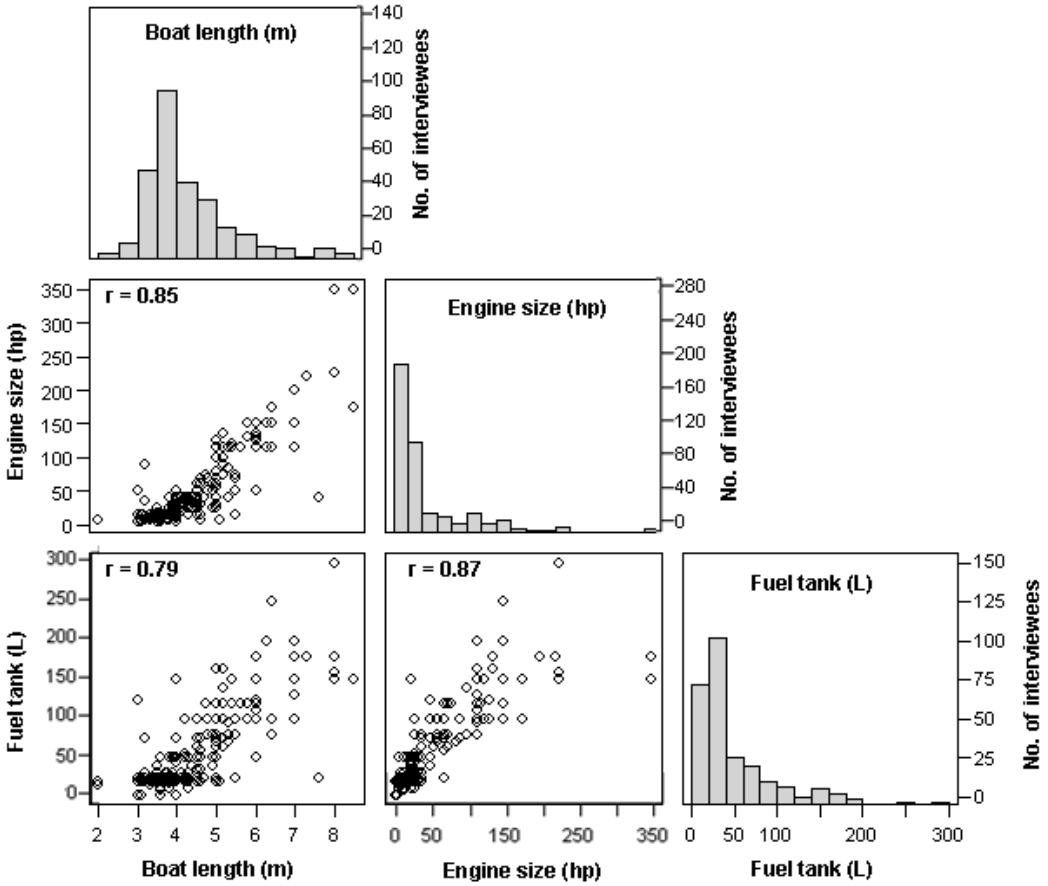


Figure 7-10 Histograms of number of interviewees (diagonal) and scatterplots with correlation co-efficients (r) (bottom left panels) between each of the boat characteristics (number of interviews = 267).

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 7-11). The 41 respondents who had not yet launched their boat were excluded from this analysis. Of the 45 boat launch sites situated 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 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).

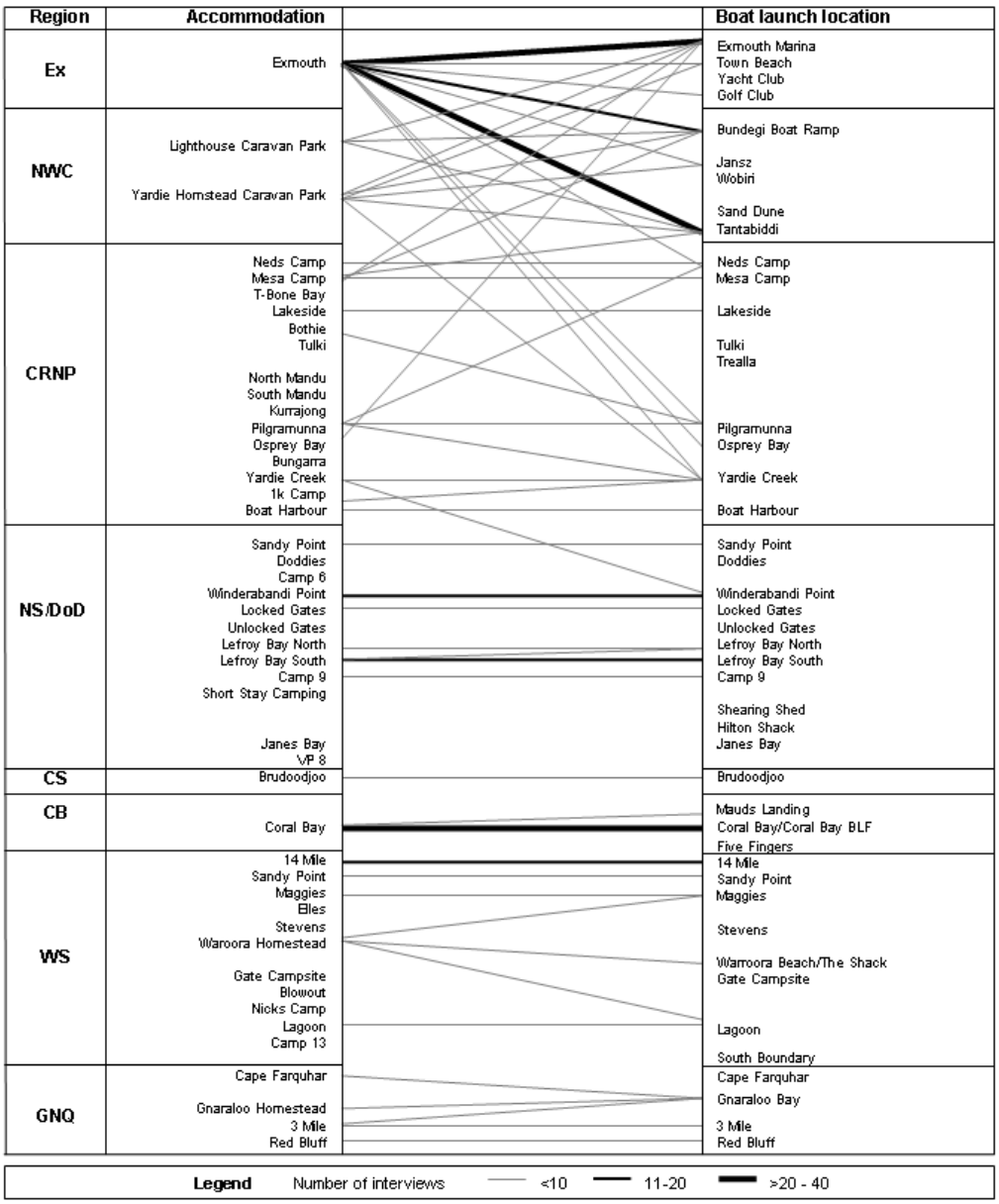


Figure 7-11 Travel flows between accommodation and boat launch locations, and their frequency, for interviewees with motorised vessels on their current trip to the NMP (number of interviews = 267).

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 7-12). 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, Tantabiddi and Bundegi boat ramps which were located 1.8 km, 38.3 km and 15.7 km by road from Exmouth, respectively.

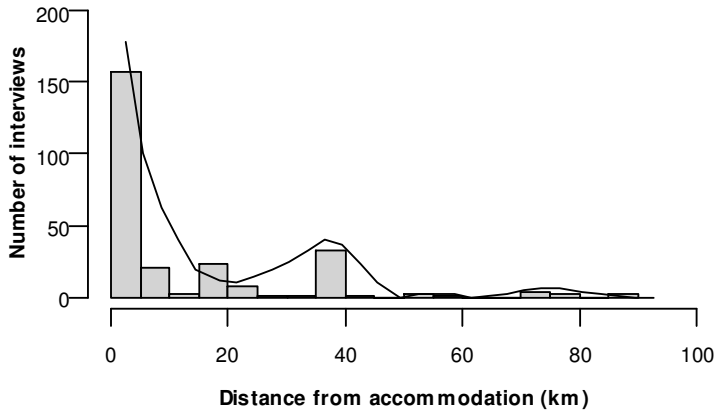


Figure 7-12 Distance travelled (km) by respondents with motorised vessels from accommodation to boat launch locations by road in 5 km increments with an interpolated spline representing the distance decay curve (number of interviews = 267).

There were 34.5% 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, $F_{(1, 256)} = 38.75$, $\rho<0.05$). Respondents on these leases exhibited the shortest mean distances travelled (<6.3 km), except for CB, which had a mean travel distance of 1.0 km (Figure 7-13). Unsurprisingly, significant differences were found between the type of boat launching site and vessel length (assuming equal variances, $F_{(1, 262)} = 24.76$, $\rho<0.05$), with vessels launched at sealed ramps having a greater mean length ($\bar{x} = 4.8$ m).

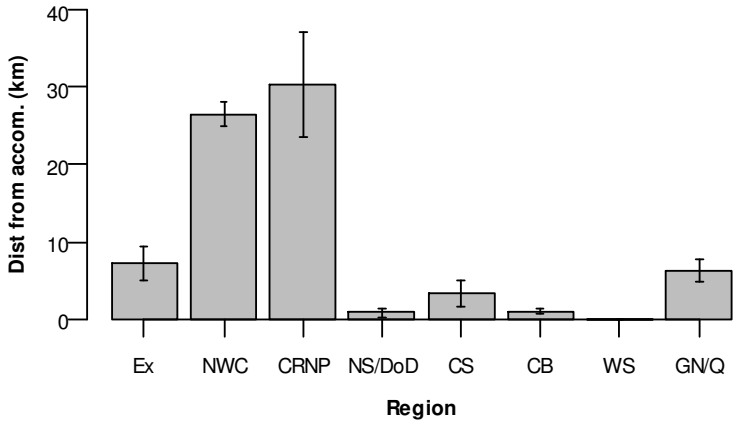


Figure 7-13 Mean distance travelled (km) from accommodation to a boat launch location for motorised vessels in each region of the NMP (±95% CI) (number of interviews = 267).

The 15 respondents with kayaks on their current trip to the NMP were also briefly considered in this analysis. Of these, eight respondents had not yet launched their kayak and the remaining seven were distributed in the NWC (1), CRNP (3), NS/DoD (1), CB (1) and GN/Q (1) regions of the Marine Park. However, only three had travelled away from their accommodation location to launch their kayak, which was the respondent staying in NWC and two staying in CRNP. Based on these data the median distance travelled to launch a kayak was 0.1 km (*SD* = 14.1 km).

7.4.3 Beach access to shore recreation location

There were 321 beach access points used by respondents to access their shore recreation location (out of a total of 336 access points documented). 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 7-14). 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 7-14. The mean distance of these pathways for each region was significantly different (assuming unequal variances, $F_{(1,}$

$_{1171)}$ = 6.50, ρ<0.05) with visitors staying at accommodation on NS/DoD walking furthest from access points to recreation locations (0.2 km) (Figure 7-15).

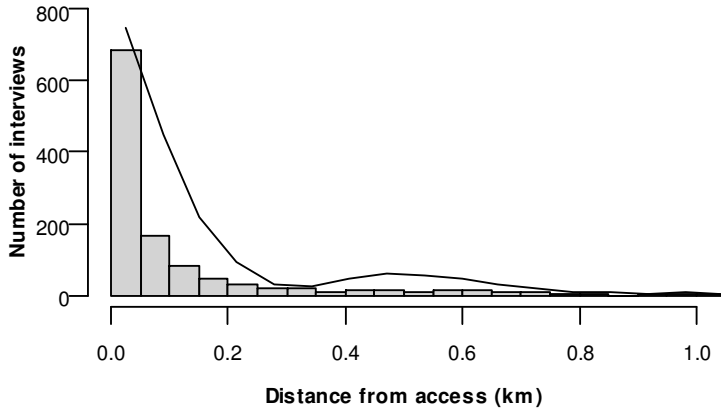


Figure 7-14 Distance walked (in km) from beach access point to shore recreation location based on coastline (network) distance in 0.05 km increments, with an outlier (4.7 km) removed and an interpolated spline representing the distance decay curve.

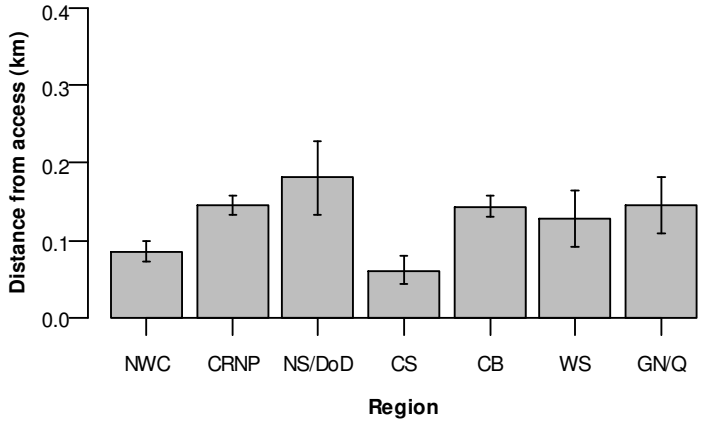


Figure 7-15 Mean distance walked from beach access point to shore recreation location in each NMP region (±95% CI) (number of interviews = 1 163).

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 Mauds Landing recorded high levels of use in both periods (Figure 7-16).

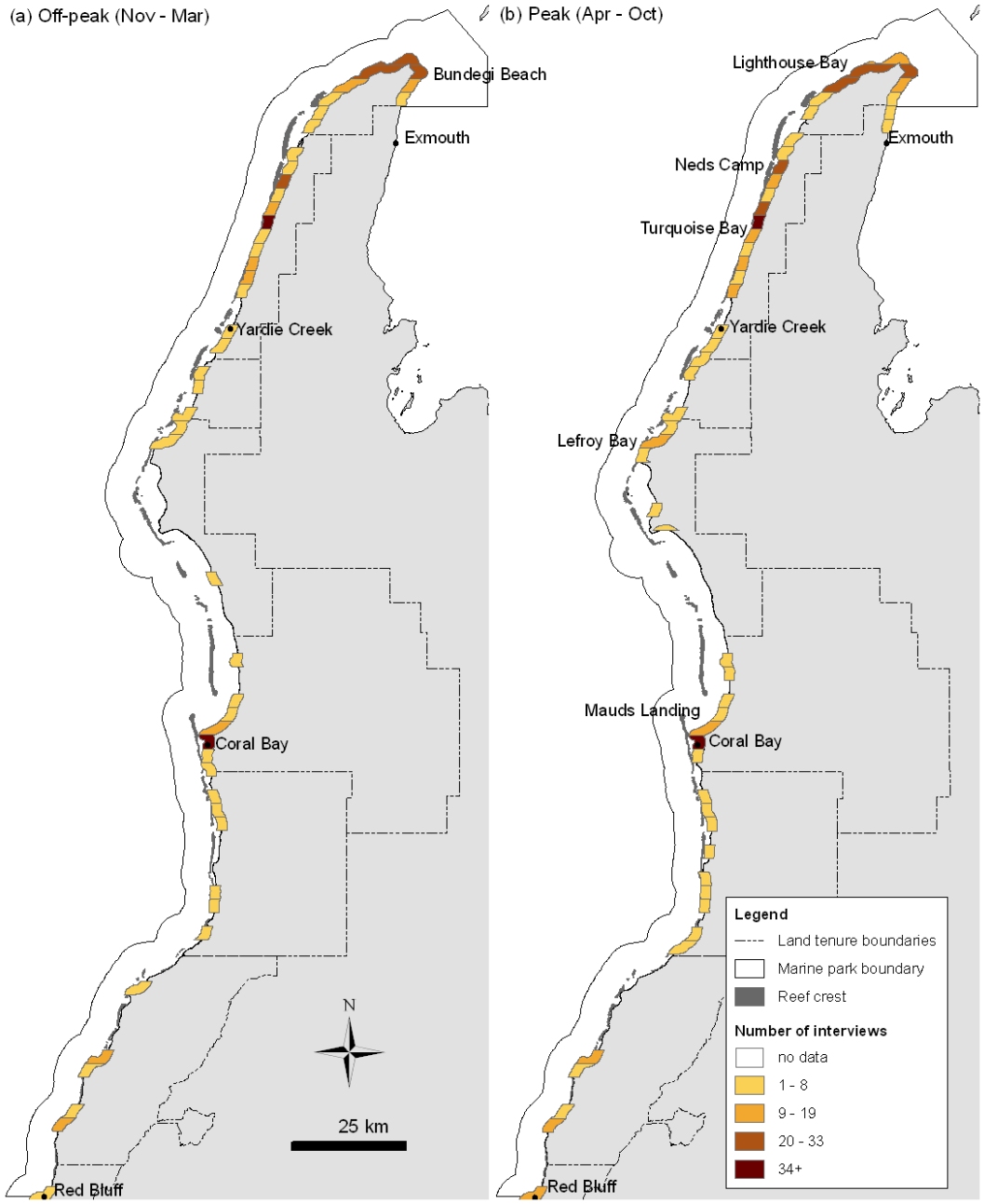


Figure 7-16 Coastal areas exposed to the highest density of recreational usage by interviewees travelling on foot from a beach access point to shore recreation location based on distance calculated from interview location in (a) off-peak and (b) peak months (number of interviews = 1 208).

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. There were no significant differences between distances travelled on foot by 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, $F_{(1, 1171)} = 0.89$, $\rho>0.05$) when comparing the distance walked from a beach access location. 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 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).

7.4.4 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 boat recreation location. However, there was also rapid decline in the number of vessels travelling >10 km from their launch location (Figure 7-17).

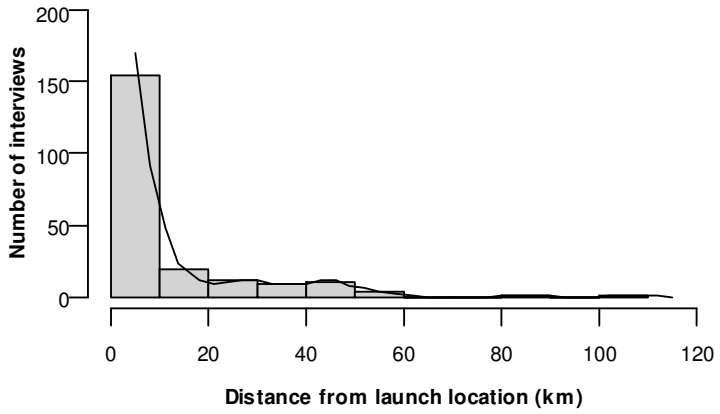


Figure 7-17 Radius (km) travelled by motorised vessels from boat launch location to furthest boat recreation location in 10 km increments with an interpolated spline representing the distance decay curve (number of interviews = 210).

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 ($\bar{x}$ = 4.9 m).

When the radius of furthest distance travelled by boats was mapped using overlapping polygons centred on their nominated launch site, it was clear that many vessels did not move far from these locations (Figure 7-18). However, based on the positive correlation between travel distance and boat length, the largest radii are likely to be larger vessels (>5 m in length). These boats covering longer 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 km^2 grid cell to indicate areas expected to have the highest density of 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 7-19). 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 latter this 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.

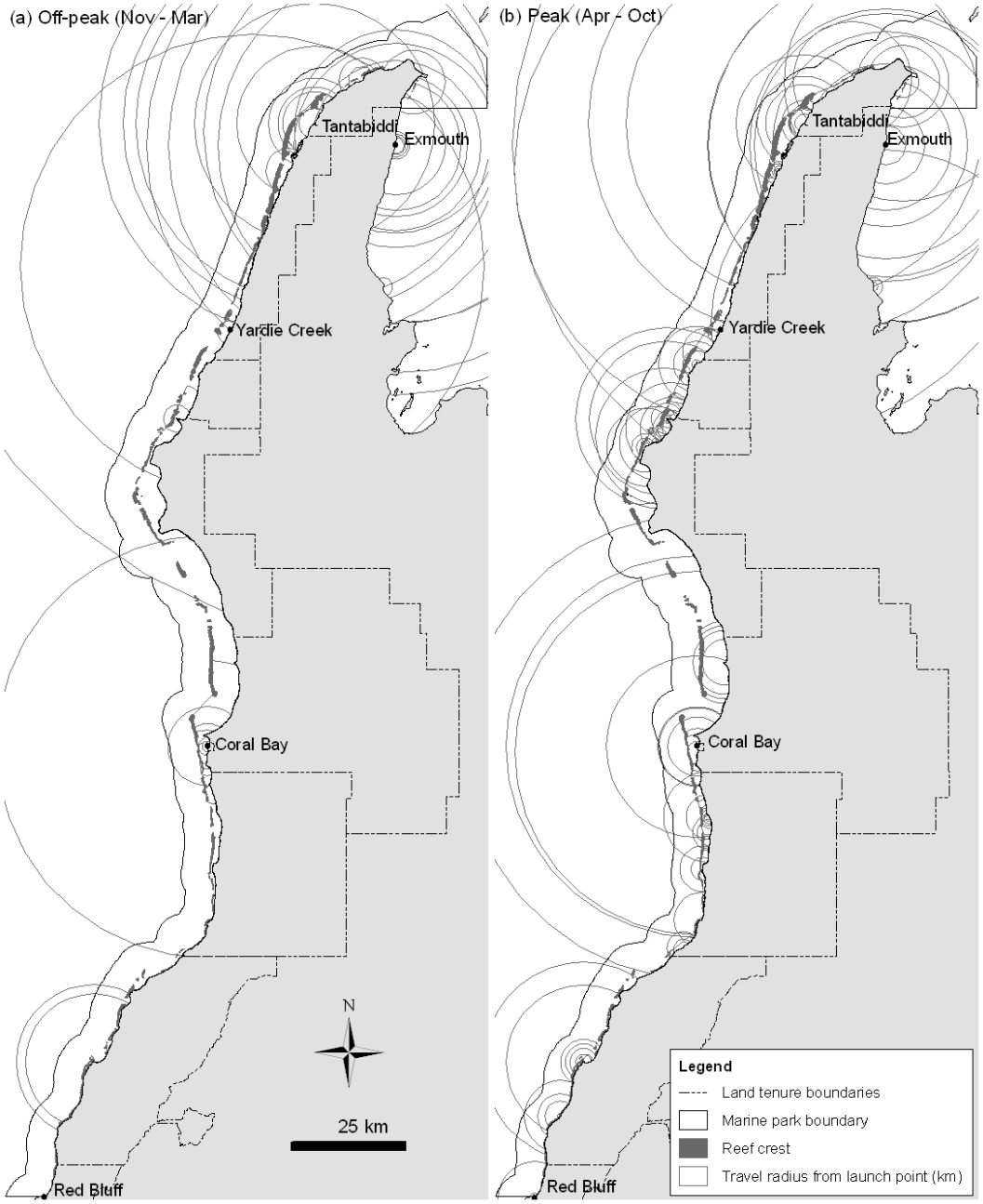


Figure 7-18 Maximum travel radius of boats (in km) from a nominated launch site without clipping to the fringing reef crest (number of interviews = 210).

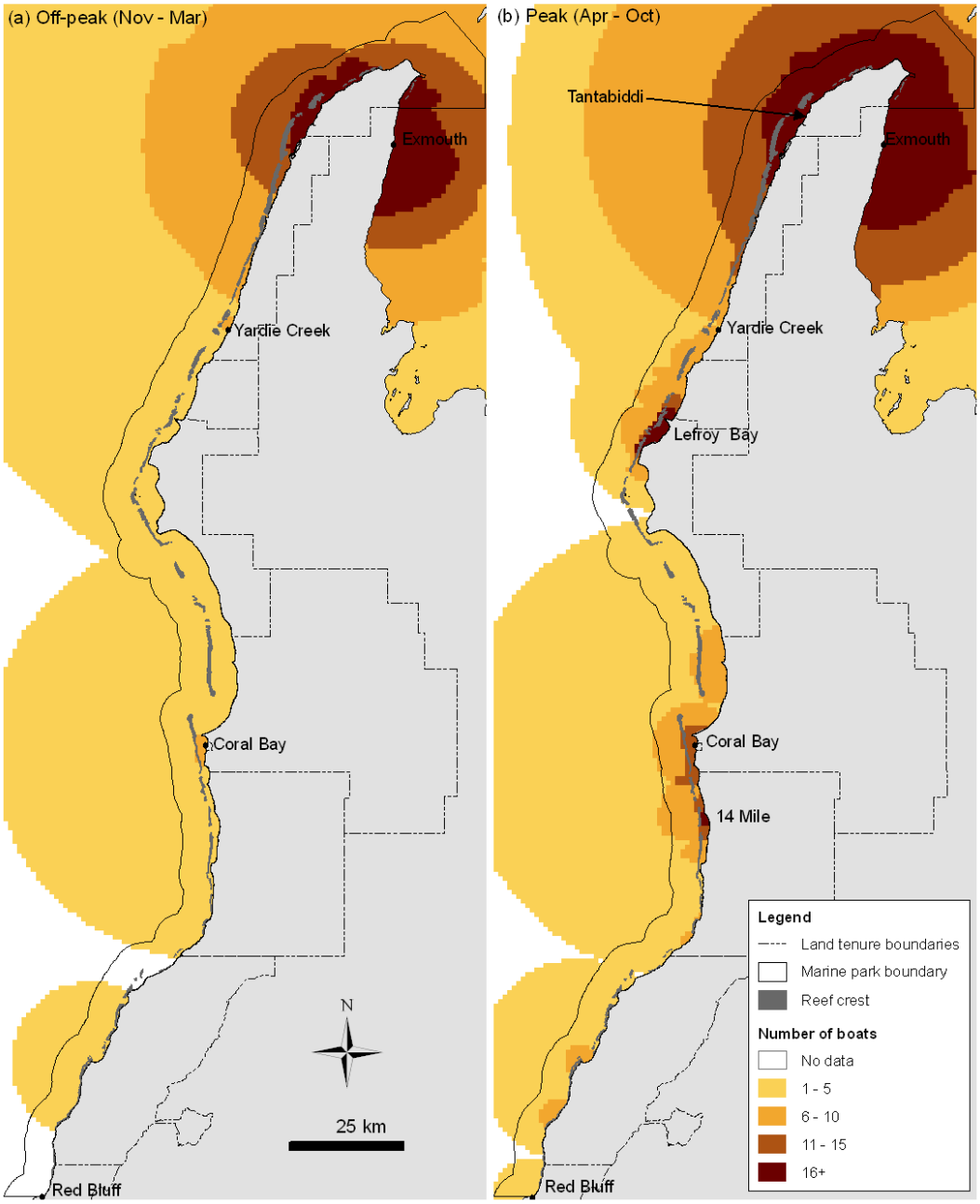


Figure 7-19 Areas with highest potential level of usage by recreational boats, based on respondents indicating furthest travel radius from a boat launching site to boat recreation location and adjusted to the fringing reef crest (number of interviews = 210).

7.5 Discussion

7.5.1 Survey design

This study used a questionnaire (*sans* map) to collect information on travel pathways and geographic extent of recreational participants within the NMP. Although a map-

based approach can provide additional data, especially for boat-based recreation, in terms of the specific route followed for outbound and return trips, this would have been difficult to implement in the NMP due to the large study area. Such an approach would have necessitated either the use of a broad-scale map, which would have reduced the spatial resolution of documented routes, or a series of interlocking fine-scale maps to cover the entire study area, which would be logistically challenging in on-site interviews. This issue of scale is important as the higher the resolution, the less ambiguity is introduced into the identified features. This scale issue has been highlighted by McKercher and Lew (2004) and in previous studies by Brown (2005) in Alaska, who used stickers representing areas up to 12.5 miles (~21 km) in width to identify important places for recreation, and by Sidman *et al.* (2004) in Florida, whose travel routes marked by respondents equated to ~136 m in width.

Due to the limited number of access routes that can be travelled to a particular beach in the NMP, little additional information could be garnered by using a map during the survey process. 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. Extensive proliferation of informal tracks has occurred in regions to the south of Yardie Creek with flooding or erosion resulting in tracks becoming impassable to visitors. A replacement track is often created along side the original and it therefore still restricts the number of possible travel routes to a destination; supporting a non-map based approach to data collection.

7.5.2 Factors influencing distribution along travel networks

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 could 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 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 this 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.

Many factors influence the spatial flow and distribution of visitors conducting recreational activities from boats and the shore. In turn, this may affect the shape of the theoretical distance decay curve (Figure 7-1). Such factors investigated in this study included the proximity of recreation sites to access points (Van Wagtendonk, 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 point and boat ramp 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 are more likely to be visited, highly attractive or publicised locations, such as Turquoise Bay (for coral viewing) and Tantabiddi (for boat launching), are selected as a destination, even though they are 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 the southern extent of the NMP. However, there is also an opposing trend of sedentary behaviour by people choosing a location for recreation (especially in the southern regions of the NMP) which 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 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 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, which was highly clustered. 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. Previous research has also found that both easy connections facilitate higher visitation and that distance from the nearest access point (Jimenez *et al.*, 2007; Coombes *et al.*, 2009) and road networks (Reed-Anderson *et al.*, 2000) were strong predicators 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.

This 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 on flyers), 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 in 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 confirm 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 remain inside the sheltered lagoon environment, as would be expected. 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 the boat launching sites to support vessels of increasing size is another factor which affects the spatial extent of recreational activity. At Ningaloo, larger vessels were launching from Exmouth Marina, Tantabiddi and Coral Bay BLF which were all sealed ramps, except at Coral Bay, where, prior to construction of the BLF in October 2007, a tractor was provided to facilitate the launch and retrieval of larger vessels from the beach. However, the construction of the Coral Bay BLF may still impact on 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 afield for recreation.

The distribution of vessels at Ningaloo was concentrated within the fringing reef crest, which provided a sheltered environment for boating, and also by characteristics, such as boat length. Previous research identified the most frequent reasons for boaters selecting a preferred departure site were that it was close to home, close to a favourite boating locale or had easy launching and retrieval (Sidman *et al.*, 2004). This same study found the most cited reasons for selecting a travel route were easy access to favourite boating locale, scenic beauty, avoiding shallow water and avoiding congested areas. This demonstrates that visitor flows, although often aimed at minimising travel distance, are also influenced by other factors. 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, isolated and located near features such as safe anchorages or reef passages. This contributes to the small median distance (4.6 km) travelled by boaters to their launch sites within the NMP. Although some

vessels travelled >100 km, this median 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 mins (Sidman *et al.*, 2004), which is again considerably longer than the <5 mins documented in this current study.

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 a trend also found by Murphy and Keller (1990) on Vancouver Island, Canada. However, a study into recreational potential ascertained that, when provided with several options, visitors would willingly travel >200 m but <500m for a recreational opportunity (Chhetri and Arrowsmith, 2008), therefore supporting the small distance travelled by respondents from beach access points to a recreation location in this study.

Implications of length of stay and group type were discussed in the previous chapter relating to the broad spatial distribution of visitors between the *a priori* regions defined within the NMP. 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 limiting the sale of tickets to attractions, issuing a limited number of permits to visitors, redirecting access to areas if overcrowding is occurring (i.e. at Turquoise Bay where there are a limited number of carpark 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).

There is potential for the information presented in this analysis to be used in models or simulation programs such as RBSim, which can model visitor movements, providing an effective decision support tool for managers. However, the questionnaire was designed to complement data collected in the observation surveys and focused on identifying recreational activity patterns and the factors which influenced the distribution of respondents throughout the NMP. There is also a lack of data on travel movements of visitors (i.e. all sites visited) and total visitor numbers which are required to calculate arrival curves and also complete trip information from which to derive typical trip

itineraries necessary for this type of modelling. Therefore, although modelling the movement patterns of visitors was beyond the scope of this project, and some additional data are required, it would be an interesting avenue for future research.

7.6 Conclusions

This was one of the first studies to quantify the distance travelled by users as they move through a protected area for recreation. The analyses showed there was spatial variability in the distances interviewees travelled along a road network for recreation between the various coastal regions. These patterns were influenced by attributes such as demographics, length of stay and repeat visitation which corroborated some of the trends identified in the previous chapter. 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 position of the fringing reef crest.

Chapter 8 Data integration and comparative analyses

8.1 Introduction

The application of multiple datasets in recreation research has several benefits as studies tend to be isolated in space and time, as well as being largely cross-sectional, which make it difficult to draw comparisons and evaluate changes over time (Manning and Vaske, 2006). This is reflective of the current knowledge of recreational use at Ningaloo, where the majority of previous studies have been highly localised in terms of their spatial and temporal extents. Analysis using multiple datasets draws on a broader research base to cross-validate and enhance the quality of survey outcomes, thereby allowing patterns and causal factors to be identified which cannot often be exposed in a single localised study (Vaske and Manning, 2008).

Several labels can be assigned to these integrated approaches including meta-analysis, comparative analysis, time series analysis and cross-validation analysis (Manning and Vaske, 2006). Although there is some argument on how to clearly differentiate between these techniques, especially comparative and meta-analysis, they all facilitate the examination of multiple datasets based on either identical variables or comparable methods (Shelby and Vaske, 2008). It should also be noted that such analyses can be performed to investigate changes over time at a single location (Legare and Haider, 2008), multiple locations (Donnelly *et al.*, 2000; Vaske and Shelby, 2008) or for the same individuals (Kuentzal and Heberlein, 2008). Such approaches are not limited to primary data but may incorporate secondary sources such as reports and unpublished datasets. Integrated analysis techniques have developed strongly in recent years due to the accumulation of multiple datasets focusing on facets of crowding (Shelby and Vaske, 2007), norm settings (Donnelly *et al.*, 2000; Vaske and Donnelly, 2002;

Manning *et al.*, 2005; Krymkowski *et al.*, 2009), perceptions (Hammitt *et al.*, 2001) and motivations (Manfredo *et al.*, 1996; Legare and Haider, 2008).

Integrated approaches have identified the advantages of working with datasets drawn from different investigations although there have been few studies which have contrasted the outcomes of various survey techniques applied concurrently at a study site. Examples of such studies include web-based versus mail surveys (Cole, 2005b), counts of visitors to a protected area using observers and video systems (Arnberger *et al.*, 2005), comparing on-site boating surveys with a database of vessel registration information (Swett *et al.*, 2009), calculation of fishing catch and effort between two on-site survey techniques (Steffe *et al.*, 2008), and, on-site and household surveys investigating travel costs for river recreation (Loomis, 2003). This type of comparative analysis can be effective for deriving recommendations and strategies for more effective approaches to visitor monitoring and management (Arnberger *et al.*, 2005).

The aerial and coastal surveys mapped the distribution of recreational activities throughout the Ningaloo Marine Park (NMP), identifying areas of high and low recreational use, based on mean number of people/survey (Chapters 4 and 5). Network analysis, based on information collected during face-to-face interviews, quantified the distance travelled and locations visited by respondents, thereby identifying areas most likely to be influenced by their activities (Chapter 7). These datasets were compared to explore the spatial and temporal congruence of outputs from each survey type. The most effective options for future research, monitoring or assessment of recreational use can therefore be ascertained, given a particular management requirement or financial constraint.

Further investigation was undertaken using outputs from the current study (in terms of the spatial distribution of recreational use), by contrasting them against a Tourism Pressure Index (TPI). This index was developed by Hadwen *et al.* (2003) to assess relative pressure of tourism at a number of dune lakes on Fraser Island, Queensland, based on factors relating to accessibility, publicity and distances to facilities. These factors were not linked to on-site data collection and were employed to provide an alternative cost-effective option to such regimes. The TPI was applied to all recreation sites from the current study at Ningaloo with the aim of contrasting the highest scores (and therefore highest tourism pressure) with data from the observation surveys.

8.2 Research objectives

This chapter compares data collected during aerial and coastal surveys as well as from face-to-face interviews conducted at Ningaloo throughout 2007. This was achieved by addressing several research objectives, including:

- comparing the spatial and temporal congruency of data collected on recreation from boats and the shore using each survey technique, as well as hourly observations at Ningaloo beaches by Neiman (2007),
- adapting (and critiquing) the TPI developed by Hadwen *et al.* (2003) to determine relative pressure of tourism at shore recreation sites in the NMP; and
- discussing the possibilities and limitations associated with integration and comparative analysis of these datasets.

8.3 Integration and comparative analyses

8.3.1 Overview of sampling regimes

Aerial and coastal surveys collected >18 000 observations of shore and boat activity undertaken along the entire length of the NMP. Vantage points and recreation sites (i.e.

beaches) were visited at different times of day depending on the survey type and time of year (Figure 8-1). Aerial flights were completed between 8 am – 10 am in a southbound direction (from Exmouth Marina to Red Bluff), while the return flight was from 10 am – 12 noon. Coastal surveys commenced between 7.30 am – 11 am and ended between 4 pm – 6 pm, so the time of visit to each site was varied as much as possible given the logistical challenges of surveying ~300 km of coastline. The start and finish locations for the coastal surveys were Exmouth Marina, Yardie Creek, Coral Bay and Red Bluff. These were visited by the researchers at the extremes of the survey day, while those located mid-way through a survey route, such as Turquoise Bay and Lefroy Bay, were commonly visited during the middle of the day. The observation times of aerial surveys generally complemented those for the coastal surveys, providing an additional reference point of recreational use at an alternative time of day.

Hourly counts of shore activities were conducted on peak days during 2007 at Bundegi Beach (not shown), Turquoise Bay and Coral Bay (Neiman, 2007) (Figure 8-1). These data were used to corroborate the number of people counted during aerial and coastal observation surveys. Turquoise Bay was regularly sampled between 10 am – 2 pm during both observation survey types. It would therefore be expected that similar counts of people would be attained using all three techniques. Hourly counts at Turquoise Bay by Neiman (2007) on the 16 and 17th of July coincided with coastal surveys from the current study, thereby allowing direct comparison of results. Neiman (2007) recorded peak numbers of people at 2 pm and shaded confidence intervals indicated the large variability in these hourly counts (Figure 8-2a). The corresponding coastal survey counts on these two dates fell within these confidence limits, indicating good correlation between techniques. However, data points for many other observation surveys fell outside these confidence intervals, indicating variability in number of people.

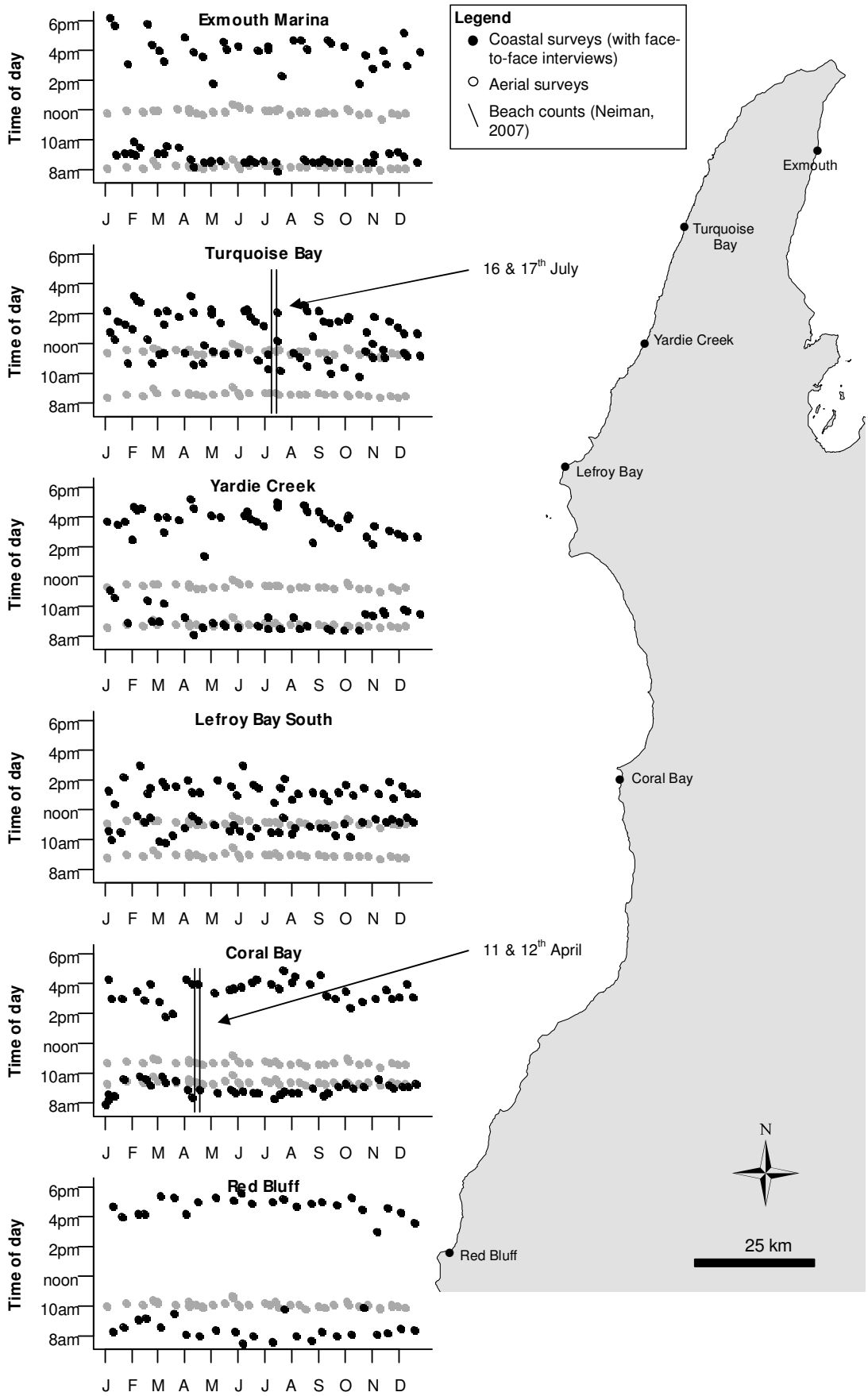


Figure 8-1 Time of day selected locations were visited during each aerial and coastal observation survey undertaken throughout Ningaloo in 2007, as well as dates of hourly beach counts by Neiman (2007).

Coral Bay was sampled predominantly prior to 11 am and after 2 pm during the aerial and coastal observation surveys (Figure 8-1). These counts could be corroborated by data from Neiman (2007) collected on the 11 and 12th of April. Direct comparison could only be made on the 11th April and, on this date, the coastal survey obtained very similar results to that of Neiman (2007) (Figure 8-2b). The confidence intervals for Neiman's hourly beach count data at Coral Bay were very small, indicating low variability. Coastal survey data obtained for July were clustered around the hourly beach counts, however, the aerial flights showed much lower numbers of people.

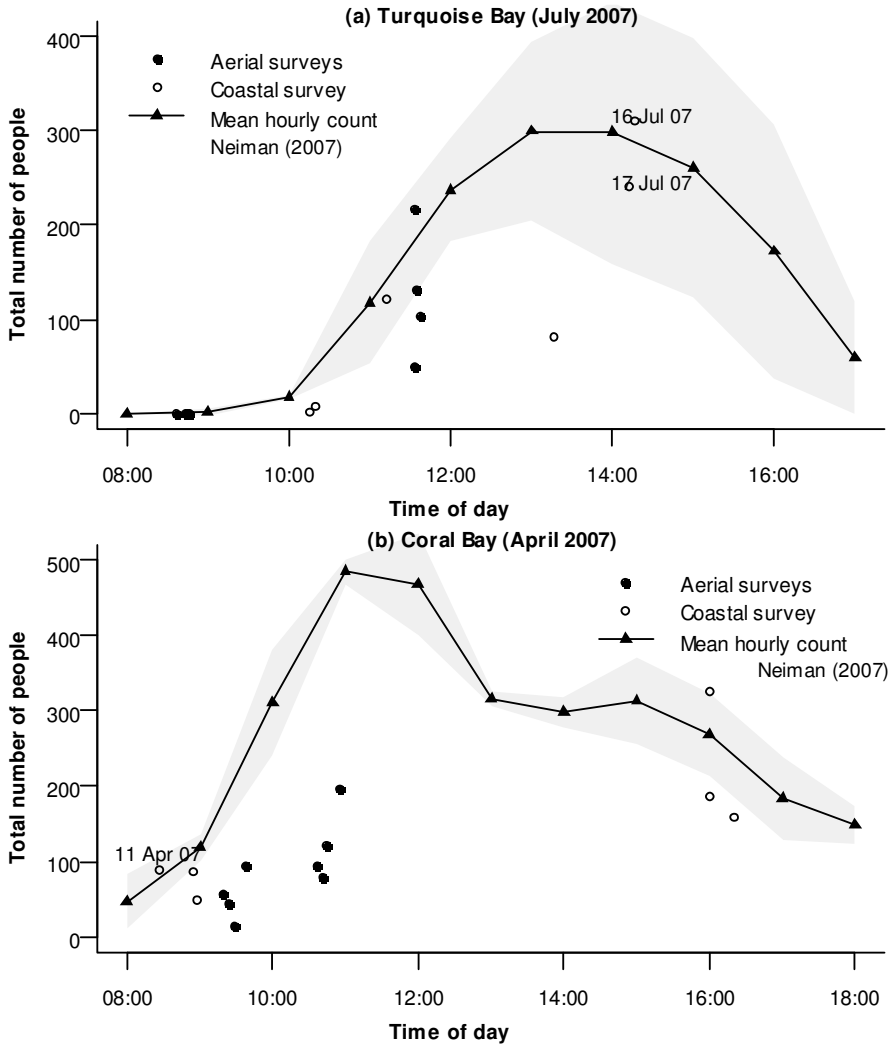


Figure 8-2 Total number of people counted during aerial and coastal surveys at (a) Turquoise Bay in July 2007, and (b) Coral Bay in April 2007, overlayed with hourly count data of beach use and confidence intervals (shaded areas) within the same time periods from Neiman (2007).

8.3.2 Boat-based activities

Outputs from the aerial and coastal surveys were compared with respect to the overall use patterns for boat-based activities in off-peak and peak months. To create a visual comparison between surveys, 9 km^2 grid cells used in previous analyses were overlayed and presence/absence of observations was used to indicate the level of congruency for boat activities (Table 8-1).

Table 8-1 Definition of each level of congruency between aerial and coastal survey techniques applied to the presence (Y) or absence (N) of observations of shore and boat-based activities within a particular grid cell or coastal segment.

Survey type		***Definition***
Coastal	***Aerial***	
Y	Y	Full congruency (or consistency) between aerial and coastal survey techniques based on presence of observations.
N	N	Full congruency (or consistency) between aerial and coastal survey techniques based on absence of observations. Can only occur within the Ningaloo Marine Park (state waters) which was the outer extent of the observation area.
Y	N	Partial congruency (or consistency) between survey techniques based on presence of observations from coastal surveys only.
N	Y	Partial congruency (or consistency) between survey techniques based on presence of observations from aerial surveys only.

This analysis that showed in off-peak and peak months there was full congruency in 84.1% and 73.7% of grid cells, respectively (Figure 8-3). The cells with full congruency (presence) were concentrated inside the reef crest and adjacent to the coast. South of Jane Bay was one of the few areas adjacent to the coast that, in peak months, there was full congruency (absence). The remaining cells, in which activity was observed by only one of the survey techniques, were generally located further offshore or in parts of the

coast isolated from major infrastructure or camping areas. Aerial surveys were particularly effective in achieving partial congruency in areas such as to the west and north-west of Jane Bay and around Gnaraloo Bay.

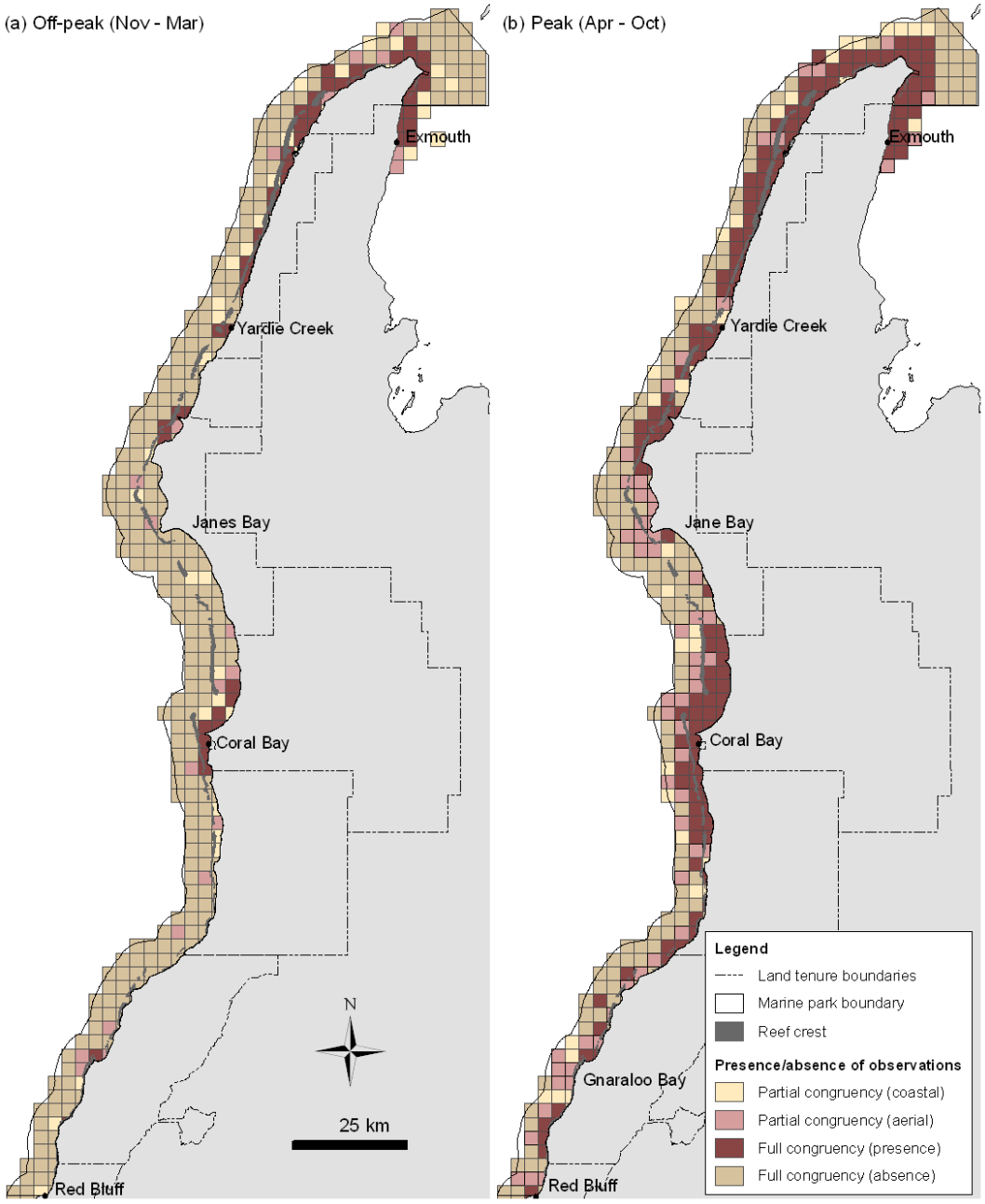


Figure 8-3 Level of congruency between aerial and land-based coastal surveys for boat-based activities in (a) off-peak and (b) peak months based on the presence or absence of observations within each 9 km^2 grid cell.

Identifying areas with similar densities of people undertaking recreation in a particular grid cell cannot be determined using these levels of congruency. Using the mean number of people/survey obtained within each 9 km^2 grid cell, for each survey type, allowed exploration of this relationship via regression. Off-peak months exhibited a slightly stronger relationship (R^2 values = 0.781) when compared to peak months (R^2 values = 0.731) (Figure 8-4). Further investigation indicated that grids cells with higher mean densities (>5 people/survey) were highly congruent between survey techniques (>97%) although this became lower with decreasing densities, indicating increased variability in results for those grid cells with less recreational use.

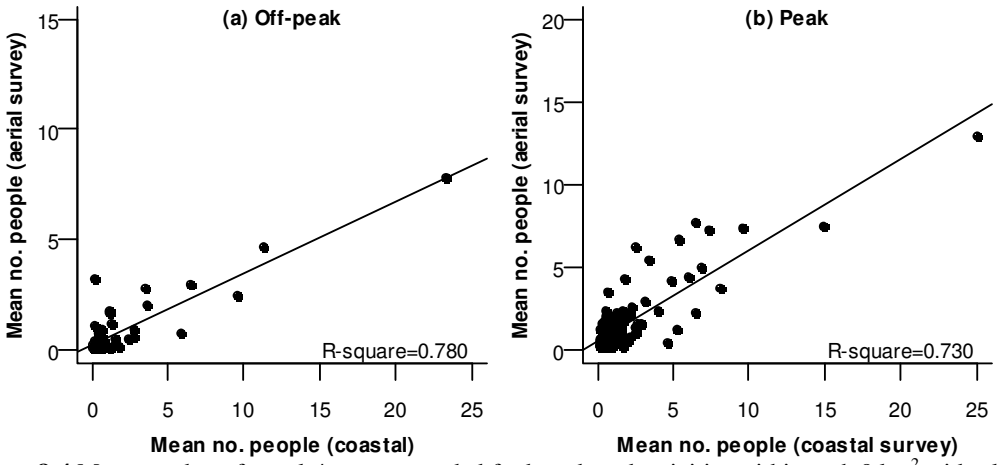


Figure 8-4 Mean number of people/survey recorded for boat-based activities within each 9 km^2 grid cell for both aerial and land-based observation surveys in (a) off-peak and (b) peak months with regression line and co-efficient (R^2).

Aerial surveys obtained more data on boating (2 906 observations) and also achieved a greater coverage outside the lagoon (29.6%), in terms of total number of observations, than coastal surveys (with 2 567 observations of which 14.9% where located outside the lagoon). In terms of completeness of observations (discussed in earlier chapters), coastal surveys obtained more data on activity type and people due to the information being recorded from a stationary platform (rather than a fast moving plane).

Areas of potential boat use, based on the radius of travel from a launch location, were described in Chapter 7 using data collected in face-to-face interviews. This analysis identified a large area offshore from Exmouth, North-West Cape and Tantabiddi with the highest levels of use in off-peak and peak periods. A representation of congruency between all three survey techniques was completed by incorporating travel radius into the presence/absence of observations in each 9 km^2 grid cell used to create Figure 8-3. As the travel radii data were self-reported by respondents, they can extend beyond the NMP (state waters), which was the outer boundary for the observation techniques. Although this complicated the levels of partial congruency, which must now include areas where only interview data was attained, it was important to understand how this survey technique may provide coverage of offshore marine environments. There was also partial congruency for grid cells where observations from two techniques were recorded (i.e. travel radius and aerial or coastal surveys).

Inside the reef crest there was a high level of congruency between all three survey types, especially adjacent to the coast in peak months (Figure 8-5). Although this pattern is similar to that in Figure 8-3, the travel radius data provided by respondents indicate it is possible for boating activity to occur in regions of the NMP where no observations was recorded. However, given the high level of clustering in the travel analysis (Chapter 7), this is unlikely, as these areas are predominately situated far from launching sites. The interview data also showed boating activity clearly extending offshore into, and beyond, the NMP (Commonwealth waters) in off-peak and peak periods. The only areas where full congruency (absence) was achieved between all three techniques was west of South Boundary and Red Bluff in off-peak months and, west of Jane Bay in peak months.

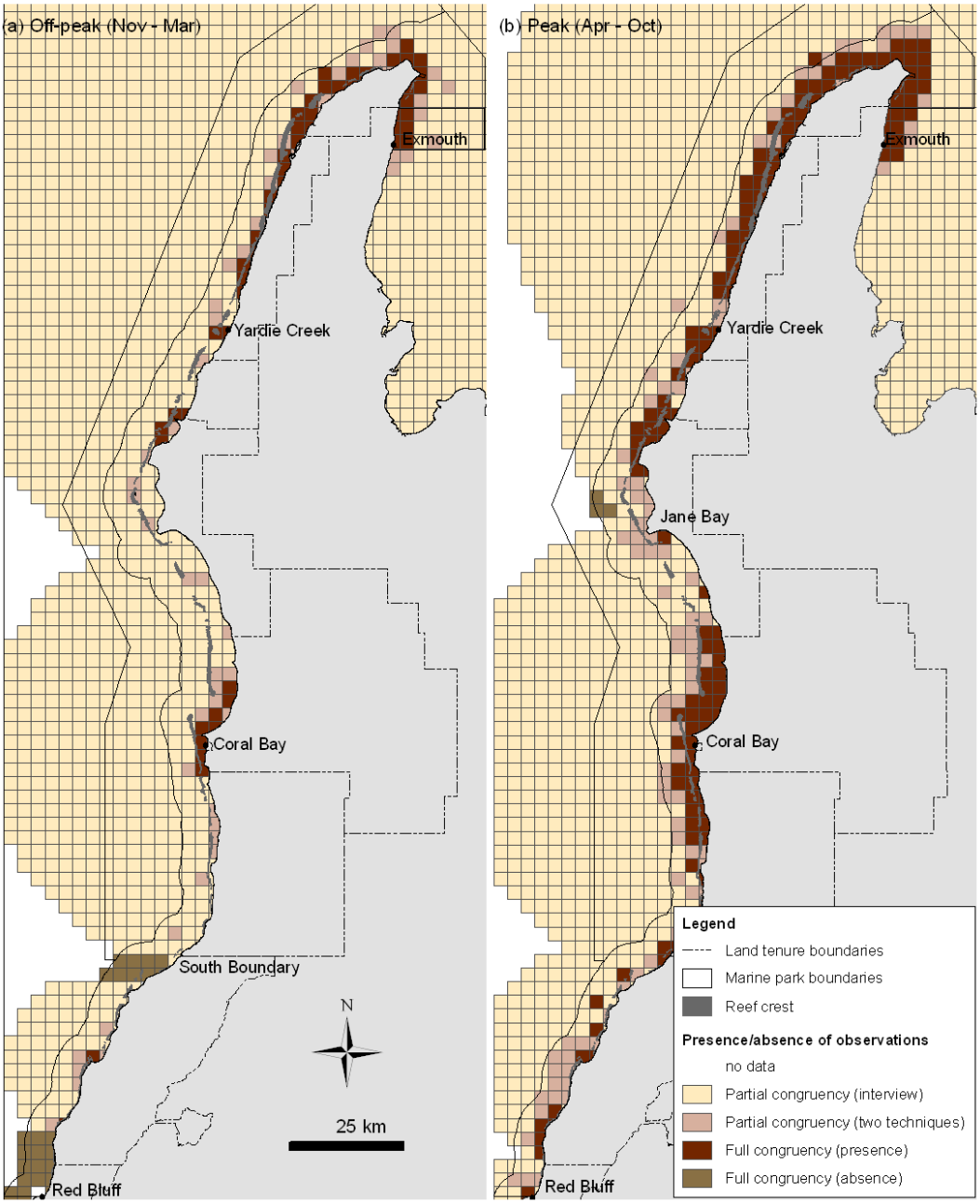


Figure 8-5 Level of congruency between all three survey types for boat-based activities in (a) off-peak and (b) peak months based on the presence or absence of observations within each 9 km^2 grid cell.

8.3.3 Shore-based activities

Outputs from aerial and coastal surveys were compared with respect to the overall use patterns for shore-based activities in off-peak and peak months. Coastal segments were used to visually represent the levels of congruency between surveys using the same definitions as for boating (Table 8-1). This identified full congruency (presence) in

81.5% and 90.2% of coastal segments in off-peak and peak months, respectively (Figure 8-6). These segments were located along the entire coast, apart from areas surrounding Jane Bay (Ningaloo Station) and north of Gnaraloo Bay (Gnaraloo Station). Although there were segments with partial congruency, these were infrequent.

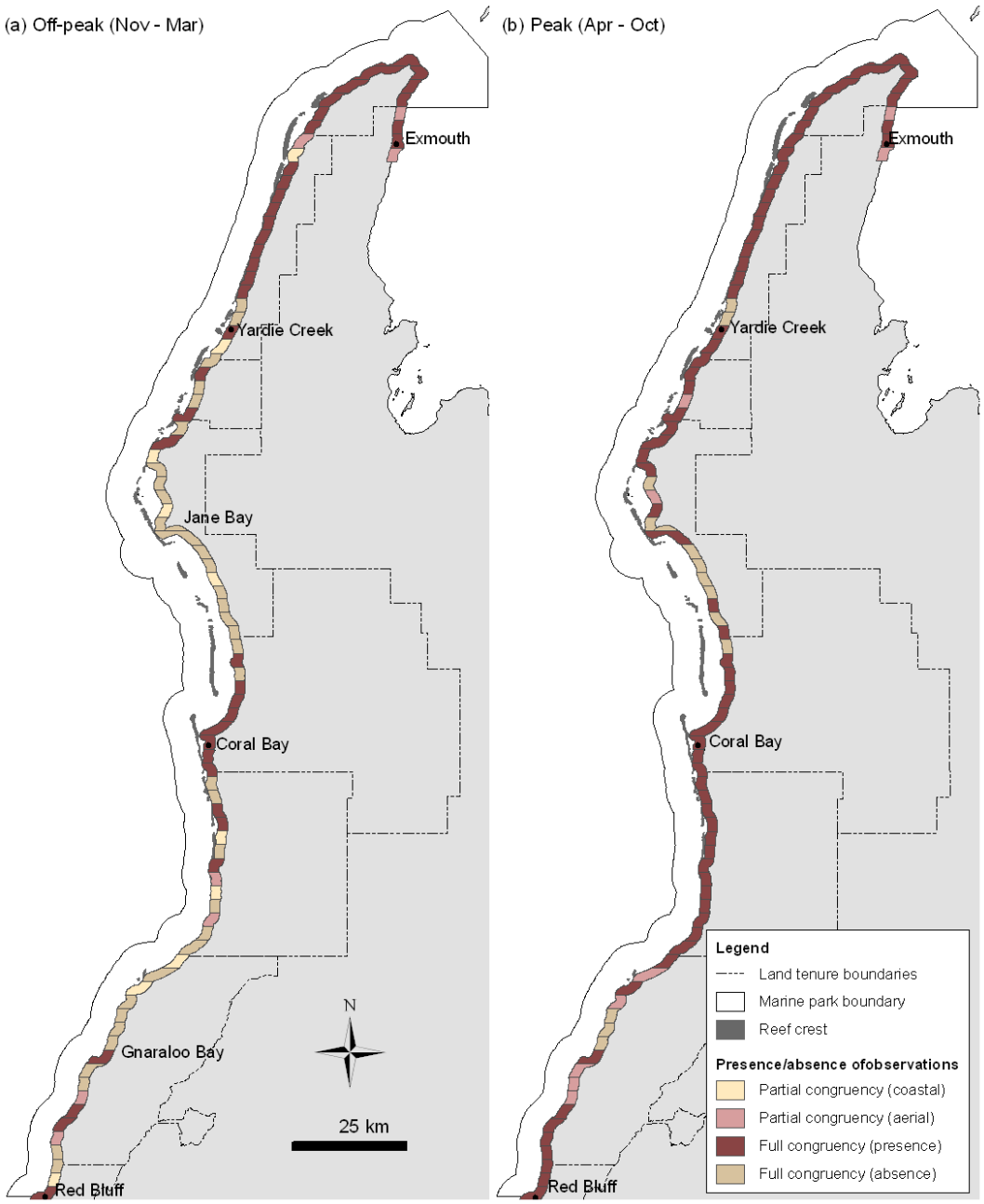


Figure 8-6 Level of congruency between aerial and land-based coastal survey results for shore-based activities in (a) off-peak and (b) peak months based on the presence or absence of observations within each 3 km coastal segment.

The density of people in coastal segments was explored by plotting the mean number of people/survey for each survey type. Unlike boat-based activities, peak months exhibited a slightly stronger relationship (R^2 values = 0.983) when compared to off-peak months (R^2 values = 0.938) (Figure 8-7). Coastal segments with higher mean densities (>5 people/survey) were highly congruent between survey techniques (>94%), and this did not decline with lower densities of people.

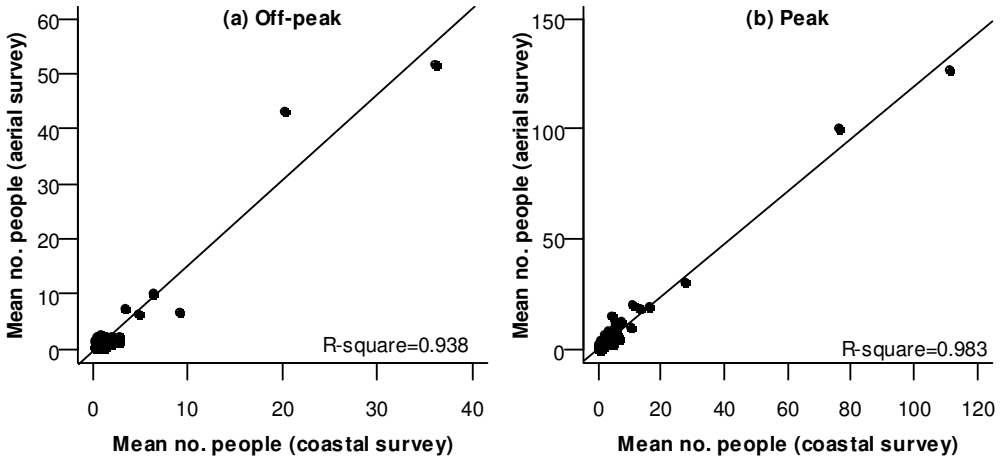


Figure 8-7 Mean number of people/survey recorded for shore-based activities within each 3 km coastal segment for both aerial and land-based observation surveys in (a) off-peak and (b) peak months with regression line and co-efficient (R^2).

Aerial surveys obtained more data on shore activities than coastal surveys, although this difference was not as distinct as observations of boating. In terms of completeness of observations (discussed in earlier chapters), coastal surveys obtained slightly more data on activity type and people. This was due to the information being recorded from a stationary platform (rather than a fast moving plane) and also the ability of the researchers to approach much closer to groups or individuals participating in activities.

Areas with the highest level of recreational use based on the travel distance from a beach access point were also described in Chapter 7. However, unlike the boat-based activities, overlaying information with that from the observation surveys would not add

another dimension to this analysis as the geo-referenced location of the interviewee was linked with the observation information collected during the coastal surveys. However, if only interviews were being used, this information would provide a reliable indication of the distribution of recreational use, as these data are quantifiable and information is collected by the researchers.

The relationship between the number of vehicles and beach users was explored using information from aerial and coastal surveys. Counts at Turquoise Bay in CRNP, demonstrated a strong positive relationship with a R^2 values >0.901 for both survey types (Figure 8-8). However, those counts at Bundegi Beach on North-West Cape had R^2 values <0.796 for aerial and coastal surveys (Figure 8-9). This was likely to be due to the number of cars left by passengers participating in trips on charter vessels which depart from this location, which are difficult to verify. It was not possible to conduct this analysis for locations such as Coral Bay or 3 Mile (on Gnaraloo Station) where campsites are located directly adjacent to a beach recreation site, as users are likely to travel by foot, and vehicles are therefore not strong predictors of beach use.

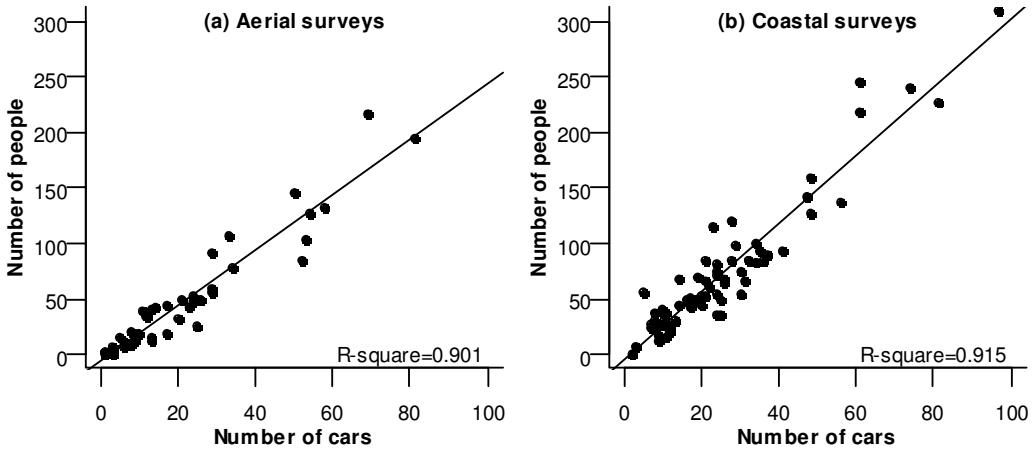


Figure 8-8 Relationship between number of cars and number of people recorded during each (a) aerial survey (number of flights = 34) and (b) coastal survey (number of surveys = 72) at Turquoise Bay during 2007 with regression line and co-efficient (R^2).

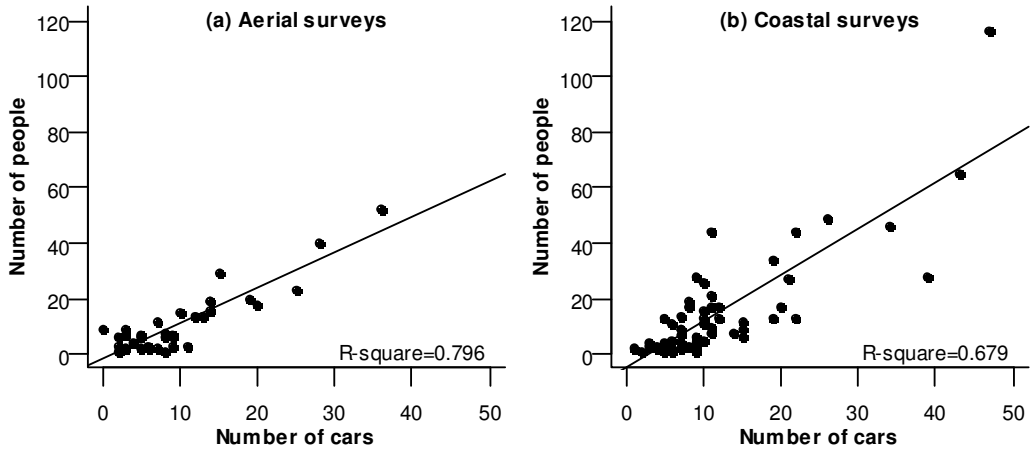


Figure 8-9 Relationship between number of cars and number of people recorded during each (a) aerial survey (number of flights = 34) and (b) coastal survey (number of surveys = 72) at Bundegi Beach during 2007 with regression line and co-efficient (R^2).

Aerial surveys obtained a lower mean number people per car, when compared to coastal surveys, with 2.2 and 2.9 people per car at Turquoise Bay, respectively. This was also true at Bundegi Beach; however, group size was even smaller, with a mean of 1.1 people per car for aerial surveys and 1.3 people per car for coastal surveys. A mean group size of 2.8 people is used to calibrate vehicle counters at the entrances to CRNP, and also at Turquoise Bay (DEC, unpublished data). However, investigation of group size for the entire NMP, based on observations (and not calculated as an average per car) showed differences depending on temporal factors such as school holidays and off-peak periods. Larger groups were recorded during aerial and coastal surveys during school holidays, with 4.0 and 4.4 people, respectively, when compared to 3.2 and 3.3 people outside these periods. There was not a consistent result for off-peak and peak periods, with coastal surveys recording a larger group size (3.8 people) in off-peak periods, compared to peak (3.6 people).

8.3.4 Tourism Pressure Index (TPI)

The TPI is based on six key factors identified as responsible for influencing visitation to a particular site (Hadwen *et al.*, 2003) (Table 8-2). The numerator values are measured

on ordinal scales, while the denominators are interval scales (in kilometres). Distance to settlement (S) could be defined as either distance to nearest settlement (i.e. townsite with service facilities such as Exmouth or Coral Bay) or park access point. Distance to settlement was applied for application of the index at Ningaloo.

Table 8-2 Summary of the Tourism Pressure Index developed by Hadwen *et al.* (2003) along with a description of each of the six key factors and associated scales of measurement.

TPI = [(P+R+A) / (S+C+T)] x 100		
Factor	***Description***	***Measurement scale***
P	Amount of publicity surrounding the site and its reputation	0 = unknown 1 = on postcards, flyers 2 = extremely well known
R	Quality of vehicular road/track access	0 = closed road 1 = used road 2 = scenic drive
A	Accessibility of key site features, e.g. type and length of walking track from carpark	0 = no track 0.5 = long track 1 = medium length track 2 = short track
S	Distance to nearest settlement or park entrance	Kilometres
C	Distance to nearest accommodation	Kilometres
T	Distance to nearest toilets	Kilometres

Applying the TPI from Table 8-2 to recreation sites at Ningaloo found the highest scores at Coral Bay, 3 Mile on Gnaraloo Station as well as Hunters, Jurabi Turtle Centre and Mantas (south) which are located along North-West Cape (Table 8-3). These scores were higher than values obtained by Hadwen *et al.* (2003), whose top score was 61.2, and were the result of short distances to campsite (C), settlement (S) and toilets (T). In contrast, sites with the lowest TPI scores (Bungalup, Amherst Point, Cape Farquhar and Vantage points 3 and 4), had large distances in their denominators. With the exception of Bungalup, in CRNP, the remaining sites were on Gnaraloo Station and have limited access to the public (i.e. closed or access to authorised personnel only) as well as low

values for road quality and publicity. Other sites expected to have high TPI scores (Turquoise Bay, Surf Beach, Winderabandi Point, 14 Mile and Lakeside) were lower than expected for these sites and reflect the large distance values in their denominators.

Table 8-3 Recreation sites in the Ningaloo Marine Park with the highest and lowest Tourism Pressure Index scores, along with scores for selected sites known for high visitation, calculated using the formula developed by Hadwen *et al.* (2003). Note: * based on historical datasets and results from this study.

Location	***P***	***R***	***A***	***C***	***S***	***T***	***TPI score***
Highest TPI scores							
Coral Bay	2	2	2	0.1	0.05	0.05	3 000
3 Mile	1	2	2	0.05	0.3	0.05	1 187
Hunters	0	2	2	1.1	1.1	1.0	129.3
Jurabi Turtle Centre	1	2	1	1.6	1.6	0.05	125.8
Mantas (South)	0	2	2	1.4	1.4	1.4	92.7
Lowest TPI scores							
Bungalup	0	1	0.5	0.05	64	0.05	2.3
Cape Farquhar	0	0	2	13.8	66.0	25.8	1.9
Amherst Point	0	0	0.5	0.6	61.7	18.3	0.8
Vantage point 3 (Gnaraloo)	0	0	0.5	16.5	68.8	28.6	0.4
Vantage point 4 (Gnaraloo)	0	0	0.5	20.4	72.7	32.4	0.4
*Selected locations with known high levels of visitation**							
Surf Beach	1	2	2	3.4	3.4	0.05	72.5
Lakeside	2	2	2	0.05	34.8	0.05	17.2
Turquoise Bay	2	2	2	5.2	43.9	0.05	12.2
14 Mile	1	1	2	0.05	17.2	17.2	11.6
Winderabandi Point	1	1	2	0.05	66.1	18.7	4.7

Previous analyses in this study showed features of the Ningaloo coast, such as the road network and coastal geomorphology, affected the distribution of visitors throughout the Marine Park. These features could therefore be incorporated into Hadwen's TPI (and other factors could be modified) to obtain a meaningful result for the Ningaloo region (Table 8-4). Road condition was found to be important in previous research undertaken in the CRNP (Moore and Polley, 2007) and road quality (R) was modified to reflect

differences in access according to vehicle type, while a road accessibility (RA) factor was added to include areas closed to public access or restricted to authorised employees and campers (i.e. coastal camping areas which have locked gates). Shoreline habitats and beach geomorphology (G), which are known to affect beach usage patterns (Vousdoukas *et al.*, 2008), were incorporated to reflect the highly variable Ningaloo coast (Short and Woodroffe, 2009). The categories were based on those applied during previous analyses in Chapter 5 (Bancroft and Sheridan, 2000). Distance to toilet (T) was removed due to the number of sites located adjacent to camping areas where people must provide their own portable toilet facilities (Remote Research, 2002).

Table 8-4 Summary of the modified Tourism Pressure Index along with a description of each of the key factors and their associated scales of measurement [adapted from Hadwen *et al.* (2003)].

TPI = [(P+R+RA+A+G) / (S+C)] x 100

Factor	***Description***	***Measurement scale***
P	Amount of publicity surrounding the site and its reputation	0 = unknown 1 = on postcards, flyers 2 = extremely well known
R	Quality of vehicular road/track access	0 = 4WD (difficult) 1 = 4WD (easy) 2 = 2WD
RA	Accessibility of the road	0 = closed road 1 = limited access 2 = public road
A	Accessibility of key site features, e.g. type and length of walking track from carpark	0 = no track 0.5 = long track 1 = medium length track 2 = short track
G	Coastal geomorphology (Bancroft and Sheridan, 2000) ranked in increasing order of attractiveness for visitors	0 = rocky cliffs 1 = mangroves 2 = rocky intertidal 3 = mixed rocky shore and sandy beaches 4 = sandy beach
S	Distance to nearest settlement or park entrance	Kilometres
C	Distance to nearest accommodation	Kilometres

Applying these changes to Hadwen's TPI at Ningaloo produced an outcome similar to the original formula, with high scores driven by small denominator values associated with distance from campsite and settlement (Table 8-5). Coral Bay, 3 Mile, Hunters and Jurabi Turtle Centre and Mantas still achieved the highest TPI scores while locations such as Cape Farquhar and Vantage points 3 and 4 still recorded the lowest TPI scores.

Table 8-5 Recreation sites along the Ningaloo coast with the highest and lowest Tourism Pressure Index scores, along with scores for selected sites known for high visitation calculated using a formula modified from Hadwen *et al.* (2003). Note: * based on historical datasets and results from this study.

Location	***P***	***R***	***A***	***RA***	***G***	***C***	***S***	***TPI score***
Highest TPI scores								
Coral Bay	2	2	2	2	4	0.1	0.05	8 000
3 Mile	1	1	2	2	3	0.5	0.3	2 424
Hunters	0	2	2	2	2	1.1	1.1	374.7
Mantas (South)	0	2	2	2	3	1.4	1.4	312.9
Mantas	0	2	2	2	3	1.6	1.6	274.4
Lowest TPI scores								
North Winderabandi Zone	0	0	2	1	3	1.9	76.6	7.6
Cape Farquhar	0	0	0	2	4	13.8	66.0	7.5
Vantage point 4 (Gnaraloo)	0	0	0	0.5	4	16.5	68.8	5.3
Vantage point 3 (Gnaraloo)	0	0	0	0.5	4	20.4	72.7	4.8
Amherst Point	0	0	0	0.5	2	0.6	52.9	4.7
*Selected locations with known high visitation**								
Surf Beach	1	2	2	2	3	3.4	3.4	146.0
14 Mile	1	0	2	2	4	0.05	17.2	52.1
Lakeside	2	2	2	2	4	0	34.8	34.5
Turquoise Bay	2	2	2	2	4	5.2	43.9	24.4
Winderabandi Point	1	0	2	2	4	0.05	66.1	13.6

It was evident that the denominator values (consisting of distances from facilities such as campsites and settlements) strongly affected the TPI scores. Therefore, a final modification of Hadwen's TPI was applied using only the numerator factors (P, R, RA, A and G) of the equation shown in Table 8-4. This resulted in an outcome where sites

that were known to have high visitation, but were located away from campsites and settlements (i.e. Turquoise Bay), scored very well (Table 8-6). Coral Bay still scored highly while there was some similarity in the lowest TPI scores, with Amherst Point continuing to score poorly due to lack of publicity and restricted access. Furthermore, by applying the TPI formula without the denominator values, the extreme TPI scores (>1 000) did not occur.

Table 8-6 Recreation sites along the Ningaloo coast with the highest and lowest Tourism Pressure Index scores calculated using a formula modified from Hadwen *et al.* (2003) with denominators removed.

Location	***P***	***R***	***A***	***RA***	***G***	***TPI score***
Highest TPI scores						
Coral Bay	2	2	2	2	4	12
Lakeside	2	2	2	2	4	12
Turquoise Bay	2	2	2	2	4	12
Yardie Creek	2	2	2	2	4	12
Bundegi Beach	2	2	2	2	4	11
Lowest TPI scores						
Lagoon LO	0	0	2	1	1	4
Nicks Camp	0	0	2	1	1	4
Vantage point 1 (Quobba)	0	0	2	1	1	4
Vantage point 2 (Gnaraloo)	0	0	2	1	1	4
Amherst Point	0	0	0	0.5	1	2.5

8.4 Discussion

This study used face-to-face interviews, aerial and coastal observation surveys to map recreational use undertaken from boats and the shore throughout the NMP. These results were compared to determine the level of spatial and temporal congruency between each technique. Several issues which should be considered with respect to this analysis include the inherent biases of each sampling regime, unit of measurement and spatial scale of analysis. These data were also compared with a TPI developed by Hadwen *et al.* (2003), which requires few resources and no ongoing data collection of visitor

numbers. This index was applied at Ningaloo as an alternative method to determining recreation sites exposed to varying levels of visitor use.

Inherent biases associated with the survey techniques applied in this study include possible recall bias during interviews (Pollock *et al.*, 1994), which were minimised by respondents only providing details of their current trip. There was no randomisation of start/finish locations (Hoenig *et al.*, 1993) in the coastal surveys due to the large scale and linear nature of the travel network in the study area. However, survey start times were varied to minimise this lack of randomisation and include a greater proportion of the sampling frame. Plotting the time of observation for each survey (at a particular site) over the 12-month study period highlighted the increased sampling coverage and complementary nature of the aerial and coastal observation techniques. The high speed of travel during aerial surveys resulted in instantaneous counts while coastal surveys were slower, progressive counts. Exploring the spatial distributions of observations obtained during these survey types revealed that they were able to provide highly congruent results, even with variation in speed of travel.

Validation of the observational surveys using hourly beach count data (Neiman, 2007), showed that some of the data points were located within 95% confidence intervals of the hourly data. Counts from the observation survey at Turquoise Bay were representative of periods of peak use, while those at Coral Bay were representative of activities occurring early in the morning or later in the afternoon. Although Neiman (2007) only conducted surveys on a few days during peak periods (as opposed to the 14 data points obtained from observation survey types), these data could be expanded to develop a scaling factor to attain an estimate of the maximum number of people on the beach for a particular day. This technique would be suitable for application to both

aerial and coastal surveys. Care would have be taken with respect to weather conditions (i.e. rain, strong morning easterlies, afternoon seabreezes or extreme heat) which have a dramatic effect on beach use and may shift periods of peak use away from the middle of the day. However, both Coral Bay and Turquoise Bay are north facing beaches and are sheltered from strong afternoon seabreezes which would limit the impact of these effects. Although hourly beach counts were useful, they are still localised in time and space, whereas data from this study was all encompassing of beaches in the Marine Park throughout the 12-month study.

Although the aerial and coastal surveys had different sampling regimes, analysis revealed many 9 km^2 grid cells and 3 km coastal segments with full congruency (presence) during both off-peak and peak periods. Congruency was especially high in areas with high densities of people participating in shore and boat activities as well as within the lagoon environment. Full congruency, based on absence of observations from both techniques, occurred in a few areas adjacent to the coast that were situated away from infrastructure, access points or boat ramps. Partial congruency (where observations occurred from only one observation survey type) also generally occurred in isolated areas. Such variation may have been caused by different sampling strategies (i.e. aerial surveys picking up more observations outside the reef crest) or may also have been due to the high variability in recreational use at these remote locations, whereby it would have been difficult to obtain regular sightings of activity.

Shore activities had a much higher correlation than boat activities in off-peak and peak months (R^2 values >0.901), indicating that the aerial and coastal surveys provided similar results for the number of people observed within each coastal segment. Coastal surveys provided more completeness of observations for shore and boat activity, while

aerial surveys had greater coverage of areas outside the lagoon environment, making these both viable options for future monitoring. Much of the data from the face-to-face interviews was inextricably linked with the coastal surveys via geo-referenced interview locations, and provided the same distribution pattern for shore activity. The distance travelled by vessels was based on responses from interviewees and may be exposed to recall bias (Pollock *et al.*, 1994). Even so, there was a high level of congruency within the lagoon between survey types although the distribution of vessels obtained from interviewees extended well offshore beyond the NMP (state waters) compared to those identified by the observation surveys. This may support the use of self-reported information to gather data on boat use in these areas, although it may not be as reliable.

In this study, data analysis was carried out using standardised units of measurement (i.e. mean number of people per survey) and scales of analysis (9 km^2 grid cells or 3 km coastal segments) which facilitated easy comparison between techniques. Moreover, all data points were geo-referenced, with a total error of ~30 m (comprising sampling error and inherent GPS biases). Comparisons with other studies or variables (coastal geomorphology and marine habitats) are often confounded due the range of scales and units used for measurement. The high resolution of this study permits comparison with external datasets as the data points can be aggregated to the required spatial or temporal scale. Standardisation is also important when implementing research with respect to survey design and scale-dependence of results. These issues have been explored in ecological research (Wiens, 1989; Levin, 1992; Sale, 1998) but only recently been considered within the context of human activities, where mismatched scales make it difficult to quantify pressure from multiple activities (Eastwood *et al.*, 2007; Coombes *et al.*, 2009).

The TPI developed by Hadwen *et al.* (2003) was applied to recreation sites at Ningaloo but did not produce scores that were representative of the patterns identified using quantitative data from observation surveys. The purpose of the index was to provide a relative scale of tourism pressure, where, in the absence of data on visitor numbers, these scores can be used as a surrogate for identifying sites with the highest pressure. Although it was designed for widespread application, the authors qualified this by stating that modifications may be necessary to achieve this across a broad range of natural systems. Removing the TPI denominator values (distance to settlement, toilets and campsite) did result in a more representative outcome for recreation sites along the Ningaloo coast. The isolation of known high use recreation sites, such as Turquoise Bay and Lakeside, from facilities represented by these denominator values (i.e. located >50 km distance from the settlement of Exmouth) resulted in extremely low TPI scores. Similar outcomes will occur if the index is applied in any area in which recreation sites are widely dispersed or have few facilities in close proximity. Previous literature identified the proximity of facilities as an important factor contributing to the distribution of recreation, with visitors generally clustered around a point of origin (Lue *et al.*, 1996; Bruce and Eliot, 2006). Findings from the current study also found clustering around the point of origin (i.e. people travelling a median of <6.8 km from accommodation to a beach access point) which is representative of the distance decay curve. However, a secondary peak in many of the travel network analyses due to the strong attraction of well publicised locations located far from settlements also support the removal of denominator values from the TPI.

The use of indices is common in recreation and tourism research (Leung and Marion, 1998). Environmental and social factors, such as impacts on soils and vegetation (Cole, 1982; Monz and Leung, 2006) or apparent naturalness and remoteness from access

(Leslie *et al.*, 1993), are often used as variables. Although there are numerous concerns regarding the validity of adding ordinal-scale variables to create a single meaningful index (Cole, 1989; Leung and Marion, 1999), they are still widely utilised, especially in the absence of other quantitative data. Similar techniques have been developed using GIS-based modelling of recreational potential, although these have been based largely on qualitative data. For example, using predictors based on scenic attractiveness as well as factors such as elevation, vegetation and proximity to water to determine areas of high recreational potential (Chhetri and Arrowsmith, 2008). Applying such GIS-based techniques would allow further exploration of recreation potential, although much of this information is not yet available for Ningaloo. However, projects currently underway, such as hyperspectral mapping of coastal and marine habitats (Kobryn *et al.*, 2008), will provide high resolution data to fill gaps in this knowledge and facilitate some of these analyses.

The TPI was also problematic with ambiguities in definitions of some factors, such as what constitutes a settlement. There are only three gazetted towns within the Ningaloo region (Carnarvon, Coral Bay and Exmouth). However, locations such as 3 Mile and Lighthouse Bay Caravan Park provide a small shop and/or fuel facilities which may affect the distribution of users, who can travel shorter distances to access supplies. Thus, the definition of a settlement, will also affect TPI scores.

Although the TPI provides a score for a particular site, it does not define a spatial extent, which creates uncertainty as to the dispersion of the tourism pressures being measured. Travel network analysis quantified the median distance travelled from a beach access point to shore recreation site as <0.1 km (Chapter 7), indicating that these pressures are highly localised. However, the different impacts and spatial dispersion of

people undertaking assorted recreational activities should be taken into account, as should temporal factors. These temporal factors, such as off-peak/ peak periods, have significant effects on patterns of variation, with greater dispersion (across a larger number of sites) in peak periods. The TPI is unable to take these temporal variations into account and does not substitute for robust and quantified data such as collected during the current study. It should also be considered that less visitors to a site is not necessarily representative of less impact (Hammitt and Cole, 1998) and, an understanding of the types of activities undertaken is important.

8.5 Conclusions

This study provided a unique opportunity for comparative analyses of three survey techniques applied concurrently along the Ningaloo coast for a 12-month period. This revealed that results were similar in terms of their survey coverage, with a high level of congruency between techniques for both off-peak and peak periods. These results were corroborated by localised studies previously conducted at Ningaloo. Data from the observation surveys also provided similar results in terms of the density of use, expressed as mean number of people/survey, especially with shore activities. These quantitative data also provided a more robust and accurate determination of recreational use when compared to a TPI, developed by Hadwen *et al.* (2003). Determining areas exposed to highest levels of use will identify locations most likely to benefit from increased resources to improve visitor experiences and mitigate impacts from recreational use. Furthermore, outcomes from comparative analyses will assist with developing frameworks for monitoring and assessment of recreational use.

Chapter 9 Applications and conclusions

9.1 Introduction

There is little debate that humans have the ability to profoundly impact ecosystems (Sanderson *et al.*, 2002). This is also true for protected areas, which continue to experience increased levels of pressure from visitors participating in recreation and tourism activities (Buckley, 1998; Hammitt and Cole, 1998; Wardell and Moore, 2005). This increasing visitation creates challenges to managing these natural features for biodiversity conservation while providing opportunities for recreation (Newsome *et al.*, 2002). To achieve this dual mandate it is essential to use monitoring programs to identify the trends in recreational activities and their associated impacts, as well as to develop proactive management initiatives for the protection, sustainable use and greater visitor enjoyment of these areas.

The importance of capturing and understanding variability of recreational use patterns has been discussed throughout the thesis. Activities that occur over greater spatial extents and longer time periods are likely to be of concern for managers. Conversely, activities focused on narrow spatial and temporal frames, such as recreational fishing targeting spawning aggregations (Sadovy and Domeier, 2005) or high densities of divers over corals (Hawkins *et al.*, 2005), result in an intense pulse of activity that may be detrimental to a site or target species. Information on temporal variation, such as frequency and timing of visitation, with respect to factors such as seasonality or time of day, are also essential for determining visitor use levels (Hadwen *et al.*, 2007; Jimenez *et al.*, 2007; Sarda *et al.*, 2009). However, until recently, the spatial context of recreational use has often been overlooked in recreation research. This has resulted in data being aggregated throughout an entire protected area and often across time, even

though use patterns are known to be highly heterogeneous and often clustered around features such as campsites (Marion and Farrell, 2002), nodes of infrastructure (Tideswell and Faulkner, 1999; Skov-Petersen, 2001) or access tracks (Priskin, 2003).

Traditionally, monitoring of visitors to protected areas has been a low priority and, if undertaken, inadequate to support proactive management (Eagles *et al.*, 2000; Newsome *et al.*, 2002; Cessford and Muhar, 2003; Cole and Wright, 2004). Data on visitor numbers are frequently the only available figures, and are often unreliable (Griffin *et al.*, 2008). Such unreliability stems from the lack of standardised methodologies applied to the collection, analysis and storage of visitor information (Horneman *et al.*, 2002; Wardell and Moore, 2005). In some cases, this deficiency has forced managers to rely on anecdotal evidence and personal experiences to draw conclusions about trends in visitor numbers (Cole, 2006; Griffin *et al.*, 2008). However, there has been a move towards developing standard methods and operational guidelines for monitoring visitors (Hornback and Eagles, 1999; Horneman *et al.*, 2002) and for managing the storage and application of these data (Wardell and Moore, 2005). These guidelines offer options for data collection using standard terminology, variables and measurement scales across different land tenures while highlighting the importance of validated and geo-referenced data kept in easily accessible storage systems.

In Western Australian marine parks, including the Ningaloo Marine Park (NMP), monitoring is identified as one of the seven generic strategies applied to assist with achieving management objectives by determining trends and measuring the effectiveness of management actions. Other generic strategies are management frameworks (including zoning), education, enforcement, monitoring, direct management intervention, public participation and research (Simpson *et al.*, 2008). Such strategies

are applied to ecological and social 'values' identified in the management plan developed for each marine park. In this context, ecological values are defined as intrinsic physical, chemical, geological and biological characteristics while social values are cultural, aesthetic, recreational and economic attributes. At Ningaloo, the social values aligned with recreational activities are water sports, marine nature-based tourism, coastal use and fishing. However, the extent and intensity of these recreational activities are also closely linked to maintaining ecological values such as coral reef communities or finfish stocks.

Specific management strategies developed for each social and ecological value within the NMP are prioritised to indicate their relative importance, with those considered critical to the long-term objectives designated as key management strategies. Key management strategies for social values in the current management plan include zoning, assessment of spatial and temporal patterns of activities, development of a recreation and tourism masterplan, and surveillance to ensure compliance with recreational fishing regulations (CALM and MPRA, 2005). Other highly prioritised strategies include minimising conflict between user groups, establishing baselines and developing detailed site plans in areas of intense recreation and tourism use. Such strategies for managing recreation are relevant not only to Ningaloo but marine parks more generally.

It is important to implement a system to determine if management strategies are effective and, if not, have the ability to adapt and improve these strategies (Hockings *et al.*, 2004; Jones, 2005). Systems for assessing management in protected areas have undergone significant development in the last decade (Hockings *et al.*, 2000; Leverington *et al.*, 2008) and, although more focused on nature conservation than visitor management (Moore and Walker, 2008), they are still relevant to the current

study. The three main components of management effectiveness are design and planning, adequacy and appropriateness, and delivery (Hockings *et al.*, 2000). The data collected in this study relate to delivery, which is the assessment of the management of protected areas with respect to their stated objectives (Hockings *et al.*, 2004). These assessments may be qualitative (based on subjective perceptions of managers and stakeholders) or quantitative (monitoring methods derived from the measurement of some resource or activity) (Hockings, 2003). The current study relies on quantitative data, although both assessment types are suitable for determining management effectiveness.

Historic levels of visitation and development pressure at Ningaloo have been low, when compared to other iconic Australian destinations such as the Great Barrier Reef, due to its isolation from major population centres. This has shielded the area from many impacts of recreation and tourism which, to date, have been managed without structured monitoring or assessment of management strategies. However, the creation of national and marine parks, such as the Cape Range National Park (CRNP) and the NMP, have acted as a focal point and, with increasing publicity, have exposed the area to increases in visitation. Tourism is currently the highest earning industry along the Ningaloo coast (GDC, 2006), and recognition of the area's unique natural features now occur at a national and international level. The region has also recently been nominated for listing as a world heritage site based on its unique geo-evolutionary history, biological evolution and biodiversity (World Heritage Consultative Committee, 2005) which, if successful, will further encourage visitors.

These increases in visitation make it imperative to employ monitoring to obtain quantified data on recreational use and determine the effectiveness of current

management strategies. Current indicators for ecological values focus on measuring changes in diversity, abundance or biomass, and their long-term targets pertain to achieving no reduction in these values as a result of human activities. However, performance measures have not been developed for many social values due to inadequate information (CALM and MPRA, 2005). This chapter provides an overview of findings from the current study, which used a robust and multi-faceted sampling regime to quantify patterns of recreation. These findings are used to provide recommendations for monitoring and managing recreation throughout the NMP. The thesis concludes with suggestions for future research.

9.2 Overview of study findings

This study had the broad aim of describing the spatial and temporal patterns of recreational use in the NMP. The objectives which directed the study are listed below, along with a brief overview of the key contributions of each to the overall research aim.

a) *determining the patterns of recreational usage using different survey techniques*

The patterns of recreational use at Ningaloo were described using observation and interview techniques conducted over 226 survey days. Aerial flights provided a synoptic overview, and although activity was observed in off-peak periods (November – March), there were higher densities of activity and greater spatial distribution in peak months (April – October) for activities from boats and the shore. Boat activities expanded beyond the fringing crest during peak months although they continued to be concentrated around infrastructure such as boat ramps and coastal camping areas. Coastal surveys focused on the distribution of specific recreational activities, such as recreational fishing, snorkelling and sailing sports (e.g. windsurfing). Snorkelling and diving were concentrated in sanctuary zones and coral reef habitats. Recreational line

fishing occurred predominantly in general use and recreation zones, although some non-compliance with sanctuary zones was observed. Sandy beaches were the most popular locations for shore activities while the majority of observed boating activity occurred inside the sheltered lagoon environment.

b) *describing the characteristics of recreational participants*

Face-to-face interviews were conducted with 1 208 people participating in recreational activity along the coast to gather information on their characteristics and use patterns. The hypothesis that different land tenure (with diverse management controls) would attract people with different characteristics, was supported. Respondents on pastoral leases tended to be people >35 years of age from Perth or regional WA, and were distinct from those at Coral Bay and CRNP who were generally younger and more likely to be from interstate or overseas. Although there were some differences in activity patterns between land tenures, with higher levels of participation in kitesurfing, windsurfing and surfing in the southern extent of the Marine Park, this distribution was also dependent on a number of other factors, such as weather conditions and geomorphology, and was often site specific. The residents of service centres (i.e. Exmouth and Coral Bay) located adjacent to the NMP also used this area for recreation and, as would be expected, they had a higher frequency of visitation than tourists.

c) *identifying and quantifying the intra-regional travel networks of recreational participants*

This is one of the first studies to quantify the distance travelled by respondents moving through a protected area for recreation and is central to understanding use patterns of the Ningaloo region. These data were obtained using face-to-face interviews and identified that shore activities were closely linked to the vast road and track network, while the

distribution of boating was affiliated with the location of launch sites. It was also found that, although some respondents travelled large distances to reach a beach, their dispersion from these access points for shore recreation was highly clustered. Pathways were also identified for boat-based recreation, with factors such as boat length and the fringing reef crest influencing the distribution of vessels from launch locations. These data can be used to predict areas which will be influenced by future coastal developments (i.e. accommodation nodes, beach access tracks and improved boat launching facilities) as well as those areas likely to be exposed to high recreation pressure.

d) *testing the congruency of data from all survey techniques and determining their effectiveness in identifying nodes of recreational pressure*

The findings of the three survey techniques applied in this study were compared to determine their spatial and temporal congruency. Aerial and coastal surveys provided similar outputs for off-peak and peak months throughout the NMP (state waters) for activities conducted from boats and the shore, especially in high use areas. Vehicle counts at some locations, obtained using both observation methods, exhibited a strong correlation with number of people on the beach and may be used as an indicator of recreational use. The spatial accuracy of observations, when considering sampling errors and inherent GPS biases, was ~30 m for each data point. This was also comparable between the two survey methods. Self-reported data on the distribution of boating activity collected during face-to-face interviews indicated boating activity dispersed beyond the extent recorded during the observation surveys in off-peak and peak periods. Although there was a high level of congruency with the aerial and coastal surveys within the NMP (state waters), this finding highlights both the difficulty in surveying offshore waters and biases that may be introduced by using data self-reported

by respondents. Further comparisons were made with a Tourism Pressure Index (TPI), developed by Hadwen and Arthington (2003). This index, calculated without intensive field surveys, did not provide results which were representative of known high use areas or data collected in this study unless extensively modified.

e) *identifying and discussing the major factors influencing distribution and characteristics of recreational use*

There were a number of factors which influenced the distribution and patterns of recreational use. Statistical tests for temporal factors found off-peak and peak periods were the most distinct for determining differences in activity type and level of participation, based on observation survey data. Additionally, data collected during face-to-face interviews indicated that school holidays had a significant effect on group type, with families more likely to visit during these periods. Interview data also revealed differences between characteristics, such as visitor age and origin, associated with the land tenure of the coastal strip adjacent to the NMP. The spatial distribution of recreational participants was influenced by a number of factors, including zoning, coastal geomorphology, access points, road networks and infrastructure (such as boat ramps and accommodation nodes). This knowledge will provide a better understanding of recreational use patterns for future management and planning.

f) *linking the outcome of these objectives to management and monitoring initiatives*

There is currently no strategic framework for monitoring recreational activity within the NMP. This 12-month intensive fieldwork program provided benchmark data on recreational use patterns that can be used to support monitoring and management, and also begin to evaluate the effectiveness of current strategies. There are a number of challenges facing managers at Ningaloo, including the open access environment of the

Marine Park and inconsistent management controls across various land tenures situated along the adjacent coastal strip. The remainder of this chapter will utilise these data to make suggestions for ongoing monitoring and management of recreational activities at Ningaloo, and discuss the wider implications of these findings for marine parks.

9.3 Application to monitoring in marine parks

Marine protected areas are a key management strategy for the conservation of marine biodiversity which is achieved by managing human activities across various spatial and temporal scales. However, they are only effective if monitoring is used to understand the density, distribution and trends of these activities and their interactions with the ecosystem in which they take place (Loomis, 2000; Wilkinson *et al.*, 2003). Monitoring is defined as the systematic, and ongoing, gathering and analysis of data relating to the environment (i.e. water quality, wildlife populations) and its visitors (Newsome *et al.*, 2002). The main purpose of monitoring is to provide warning of abnormal or detrimental conditions and impending concerns which may affect the values of a particular area (Bennetts *et al.*, 2007). It is also important for strategic and operational planning. For example, the adequate provision of facilities, staff allocations, conflict minimisation (Cessford and Muhar, 2003), developing performance indicators (Wardell and Moore, 2005), evaluating management effectiveness (Hockings *et al.*, 2000; Wilkinson *et al.*, 2003), public accountability and legislative requirements (Newsome *et al.*, 2002).

The current study provided a rare opportunity to conduct a longitudinal study of recreational use encompassing an entire marine park using multiple survey types to investigate three components of visitor monitoring (park use, site use and visitor profiling) (Table 9-1). Park and site use could also be defined as visitor counting,

incorporating level of participation along with spatial and temporal variations in use (Wardell and Moore, 2005) or fit within the category of visit attributes (Roggenbuck and Lucas, 1987; Watson *et al.*, 2000) used in Chapter 5 of this thesis. Many of the key variables of visitor profiling were obtained during interviews and, although not explored in this study, visitor outcomes could also be addressed via this survey technique. Although these components are primarily concerned with social values, they can be linked with ecological information, and the connectivity between these systems should be considered when monitoring, as many ecological attributes (such as water quality, health of benthic communities and fish stocks) are closely related to anthropogenic influences.

Table 9-1 Description of the four components of visitor monitoring and the main applications to management of protected areas [adapted from Cope *et al.* (2000), Moscardo and Ormsby (2004) and Newsome *et al.*(2002)].

Component	***Description of key variables***	***Applications***
Park use	Visitor numbers, entry and exit points, mode of transport, future visitation	Resource allocation Public accountability Planning
Site use	Sites visited, temporal patterns, group size, length of stay, frequency of visits, activity participation	Planning Resource allocation Routine management
Visitor profiling	Demographic and socio-economic attributes of individuals, origin, reasons for visiting, attitudes, motivations	Marketing Interpretation Planning
Visitor outcomes	Information on satisfaction, disappointments, suggestions	Routine management Planning

There are many factors to consider when designing a visitor monitoring program. Early literature guiding the implementation of such programs were developed for terrestrial environments (Marion, 1991), although more recent compilations provide generic principles that can be applied in any setting (Hockings, 1998; Hornback and Eagles, 1999; Wardell and Moore, 2005). There have also been recent publications focused on

monitoring and assessment in marine environs (Wilkinson *et al.*, 2003; Schirmer and Casey, 2005). Several consistent themes for the design and implementation of a successful monitoring program include (1) systematic and regular collection of data, (2) simple, innovative data collection techniques (3) collection of data at a relevant scale of analysis for managers, (4) easily accessible and geo-referenced databases for data storage and (5) communication of results to management (and from management identifying their data needs) (Wilkinson *et al.*, 2003; Wardell and Moore, 2005). Most recently, variables have been classified into core and supplementary to assist agencies with prioritizing data collection (Griffin *et al.*, 2008).

Core data needs for a protected area are defined as those that should be collected regularly using a standardised and consistent method so, if necessary, they can be aggregated to a higher (i.e. agency, national) level, while supplementary data provide for specific park-based management requirements (Griffin *et al.*, 2008). Examples of core variables include visitor numbers, frequency of use, demographic profile (i.e. age, origin or occupation), length of stay, visitor satisfaction or perceptions while examples of supplementary variables are spatial patterns of use, visitor characteristics (i.e. repeat visitation or group type), activity participation and commercial tour activity (Griffin *et al.*, in prep). Selecting variables which meet management requirements, as well as practical limitations such as cost and staffing, are important when developing monitoring approaches for protected areas (Monz and Leung, 2006).

Data collected at Ningaloo would ideally focus on both core and supplementary variables which can contribute to specific management strategies developed for the Marine Park. Geo-referenced data should be collected on, in order of priority (1) location of the group or individual undertaking recreation as a latitude/longitude, (2)

platform (i.e. shore or boat), (3) activity type and (4) group size. Vessel type should also be obtained for boating activity. At high use beaches where it is not possible to record separate groups, then a total beach count should be completed. It is also essential that data be obtained on the number of camps, boat trailers, vehicles and boats on the beach not currently used for recreation that are located at standardised geo-referenced sites (i.e. camping areas, boat ramps). These counts are useful indicators of people staying along the coastal strip (camps), level of activity currently occurring from boats (boat trailers) and the shore (vehicles) and, potential recreation effort (boats on beach). Additionally, much of the data for visitor profiling and outcomes are classified as core variables and should be collected via interviews.

Regular aerial flights, supported by coastal surveys should be the preferred survey method for monitoring and obtaining these data on recreational use throughout the lagoon and coastal strip adjacent to the NMP. The high speed of aerial surveys enables rapid collection of standardised data which can provide a synoptic overview of activity. The linear nature of Ningaloo Reef enables the entire area to be observed along a single flight path. Aerial flights also mitigate the challenges of surveying over a large, and open access, environment which could otherwise lead to difficulties in designing a sampling regime that provides comprehensive (and representative) coverage. Investigation of the spatial errors associated with aerial surveys in this study found they were small, and similar to those obtained during coastal surveys, which supports fine-scale analysis to meet management needs if required. This aerial survey method would be adaptable to any study area of this linear configuration located in a coastal environment or confined water space (i.e. river or inlet) where the shoreline can be used as a reference point for a flight path.

The limitation of aerial surveys is they provide a less complete record of data associated with each observation, with respect to group size and type of activity undertaken from boats, when compared to coastal surveys. Coastal surveys should be used to support and cross-validate data from aerial flights, especially as they are comparable in terms of coverage and indentifying areas of similar recreational densities. Numerous vantage points along the Ningaloo coast enabled observations to be completed from a stable (and stationary) platform. Such a technique could be adapted to coastal areas worldwide, especially those with good road networks to facilitate access to vantage points. The disadvantage of coastal surveys is the length of time required to traverse and make observations along the coast (i.e. 3 days as opposed to 4 hours for a study area such as Ningaloo) and, as a result, they are more costly in terms of staff requirements and fieldwork expenses. However, these costs can be reduced by conducting targeted coastal surveys at specific locations and at selected times of year.

Monitoring at Ningaloo should be conducted throughout the year to ascertain the intra-annual intensity and variability of recreational use. It should also be ongoing to determine inter-annual variability (Watson *et al.*, 2000; Cessford and Muhar, 2003; Wilkinson *et al.*, 2003). Findings from the current study revealed that peak months from April – October were characterised by higher numbers of people and greater spatial extent of activities, especially during the April and July school holidays. This pattern was supported by previous research during these peak periods (Wood, 2003a; Worley Parsons, 2006). However, the observation surveys also found that recreational activity occurred in the traditionally quieter off-peak months from November – March, even though they are characterised by higher temperatures and stronger winds (BOM, 2009). These weather conditions are more suited to people participating in activities such as

kitesurfing, and also corresponds to the northern hemisphere winter, therefore attracting international visitors.

Activity in off-peak months is important to document, especially at highly publicised sites, such as Coral Bay and Turquoise Bay, which experience high intensity and diversity of activities throughout the year. This many also be pertinent for other high use sites identified in this study such as Bundegi and Surf Beach situated along North-West Cape and Lakeside in CRNP. Therefore, regular aerial flights should take place monthly, or at least twice per season (i.e. summer, autumn, winter, spring), to obtain these data. All these high use beaches are situated within sanctuary zones and it is also important to have references sites in other zone types which would be obtained during flights encompassing the entire NMP. Coastal surveys at targeted locations could collect data for months where aerial surveys may not be possible, or for additional days within each month. Beach visitation at popular beaches was highest between 11 am – 2 pm and specific monitoring during these periods would document maximum levels of recreation. Differences in visitor profiles across temporal scales and land tenures were identified in the interviews completed as part of this study, and should also be conducted across these scales to ensure this diversity is captured in ongoing monitoring.

Priority sites for monitoring the level of use in the NMP via counts of boat trailers should be Exmouth Marina, Bundegi, Tantabiddi, Coral Bay and Gnaraloo Bay. These ramps are located away from accommodation locations so people generally leave their trailers at these sites after launching (as opposed to returning it to a campsite). For many beach launch sites (especially on pastoral leases) it is difficult to obtain trailer counts as people transport small vessels on the roof of their car or camper trailer and leave their vessels on the beach. For locations where this occurs, it may be more pertinent to collect

data on the number of boats on the beach (not currently being used for recreation) which will provide an indication of potential recreational effort. Although these counts determine the number of boats, either currently or potential participating in recreation within the NMP, they should be supplemented by direct observation of these activities to determine their spatial extent. Obtaining counts of vehicles is also challenging along many parts of the coast (especially to the south of CRNP) as there are few defined access points and carparks, or people leave their vehicles at their campsite. Selected designated carparks such as Turquoise Bay, Lakeside, Bundegi and the Surf Beach should be counted regularly during coastal surveys. However, it would be easy to incorporate others sites of interest to managers that are located along North-West Cape.

There is currently no systematic framework for monitoring recreational and coastal use at Ningaloo, even though the current management plan provides for the development of such programs to establish benchmarks and assess the effectiveness of strategies such as zoning. Although most previous studies were highly localised and undertaken to meet specific short-term goals (Chapter 2; Table 2-3), DEC has collected data on coastal camping using aerial surveys during April and July since 1995. Vehicle counters, entrance and camping tickets have also been used to calculate the number of visitors to CRNP and Turquoise Bay (DEC, unpublished data). Most recently, a trip logbook (to be completed by DEC staff patrolling throughout the NMP) has been developed to collect data on recreational activities (Hughes and Mau, 2006). Collected variables include the number of vehicles, camps, boat trailers and commercial tour operators within view of specified vantage points, or beaches, as well as counts of vessels and people participating in fishing, spearfishing, collecting, walking/resting or passive in-water activities (such as swimming, kitesurfing or surfing).

A recent review by Northcote and Macbeth (2008) described inadequacies in the level of understanding of visitor use patterns, ability to monitor tourism activities and their associated impacts within the NMP. Recommendations included the implementation of compulsory and systematic data collection, a central storage point for data and also the promotion of stronger inter-agency collaborations. Such mechanisms are recognised worldwide as being important for successful monitoring programs (Wilkinson *et al.*, 2003; Wardell and Moore, 2005). Additional recommendations for existing data collection techniques included more regular aerial surveys, vehicle count information at CRNP to be supplemented by random visitor surveys by entry staff, collection of camping receipts from CRNP and pastoral stations, calculation of number of people involved in recreational fishing, and visitor surveys of different market segments, including residents.

Visitor profiling and outcomes are monitoring components not currently obtained by DEC within the NMP on an ongoing basis, although there have been isolated visitor surveys (Chapter 2; Table 2-3). A suggestion by Northcote and Macbeth (2008) to interview visitors as they enter CRNP may be impractical in peak months without extra staffing, as the heavy flow of traffic already causes queues at this location. This strategy has been employed successfully at the entrance station to Yanchep National Park in Western Australia to provide continuous data on visitor demographics and use patterns, which are provided to management (Wardell and Moore, 2005). Such a technique may be suitable for a few short questions to collect data on core variables such as origin or group size, which would take little time to complete on a per car basis. However, the remoteness of many camping locations at Ningaloo lends itself to face-to-face interviews, as it is difficult to identify a sampling frame from which to select respondents or for researchers to target people by mail or telephone. There is also a high

diversity of visitors, including many from international origins who are difficult to contact after they have left the area.

There are only nine roads by which accommodation sites along the Ningaloo coast can be accessed by vehicle. This current study, and work by Remote Research (2002), found a strong correlation between access roads and accommodation. Vehicle counters may therefore be used as an indicator of camping along some parts of the coast. However, large cross-boundary movements by people accessing the Marine Park on day trips (from Coral Bay and Exmouth) may confound these results, although previous studies in North America found that day trip and overnight users are not profoundly different in their behaviours (Cole, 2001). Furthermore, aggregating visitor numbers from such data collection techniques may not be reliable with double counts of vehicles and ongoing calibration required to ensure accuracy (Wardell and Moore, 2005).

Aerial surveys of coastal camping undertaken by DEC commence at a standardised time of 8.30 am at the end of the first week of school holidays (which are known for increased visitation). The original 2 flights per year (during April and July school holidays) have recently been expanded to include October and December school holidays. The standardisation of flight times in this morning period provides maximum opportunities for observing activities during these periods of lighter or offshore winds and was also applied in the current study. Aerial flights are also able to incorporate the DEC trip logbook (Hughes and Mau, 2006), which was designed to be integrated with other facets of park management, thereby improving the cost-effectiveness of monitoring. However, DEC aerial surveys aggregate data to broad spatial areas and this should be discontinued to provide site specific information for management (as during the current study), rather than an overall summary based on land tenure.

The DEC trip logbook has the potential to provide data for monitoring strategies, such as zoning or assessing the level and patterns of recreational use, outlined in the NMP management plan. However, monitoring programs cannot be successful without the support of managers and co-operation of staff. Current operational practices should be adapted to ensure these data are collected regularly to have sufficient robustness to detect trends and changes in use patterns. This includes increasing the number of aerial surveys to indicate synoptic patterns, while being supported by coastal surveys at high use or other sites of interest to management. It is also imperative that staff resources and expertise be developed in the areas of data storage, analysis, interpretation and transfer of these findings to management.

9.4 Contribution to management of marine parks

There are a multitude of strategies for managing tourism and recreation in protected areas (Newsome *et al.*, 2002). Common classifications fall under the broad headings of site and visitor management (Hammitt and Cole, 1998) or direct and indirect management (Lucas, 1990b). Site management is the manipulation of infrastructure and the natural environment to minimise visitor impacts while visitor management focuses on regulating use through restrictions in numbers, length of stay, zoning, fees or education (Buckley, 1998; Hammitt *et al.*, 2001; Eagles *et al.*, 2002; Newsome *et al.*, 2002). Indirect actions allow visitors to enjoy their experiences under the influence of education and controls for sustainable use (Newsome *et al.*, 2002) while direct actions are aligned with visitor management, and are more intrusive and regulated (MacLennan, 2000). The choice of management strategy will be affected by legislative or policy restrictions, resource implications as well as efficiency, cost and preferences of stakeholders (Eagles *et al.*, 2002; Newsome *et al.*, 2002).

These management strategies have been implemented worldwide. However, difficulty arises when evaluating the effectiveness of these strategies, especially with increasing demands for reporting and accountability (Hockings *et al.*, 2000). Methods for evaluating management effectiveness are developing rapidly; with >40 techniques identified in a recent review (Leverington *et al.*, 2008), including some developed for marine protected areas (Alder *et al.*, 2002; Pomeroy *et al.*, 2004; Staub and Hatziolos, 2004). Although the necessity of moving beyond solely biological indicators for evaluation purposes has been identified, data on social indicators are lacking in many situations (Muthiga, 2009). Water sports, marine nature-based tourism, coastal use and recreational fishing were identified as social values aligned with recreational use in the NMP (CALM and MPRA, 2005). Maintaining these values can be achieved through generic management strategies such as monitoring (discussed in the previous section, zoning, enforcement, research and direct management intervention which are applied across Western Australian marine parks, and supported by data from the current study.

Zoning is a tool implemented in marine parks worldwide to protect biodiversity while managing for multiple activities, including the separation of conflicting uses (Day, 2002). Ningaloo is a multiple-use marine park and zoning is a key management strategy implemented at its inception in 1987. The main restrictions of this zoning relate to prohibiting extractive activities, such as commercial and recreational line fishing or netting, in sanctuary zones. This study identified a high level of compliance with sanctuary zone boundaries by people involved in extractive activities from boats and the shore. This displacement of extractive activities outside sanctuary zones may assist with achieving ecological management objectives such as maintaining diversity and biomass of fish stocks, as suggested by Westera *et al.* (2003). However, these trends are complex, and are likely to be influenced by factors such as the size of the sanctuary

zone, the date of its inception, differences in marine habitats and behaviour of targeted fish species (Babcock *et al.*, 2008).

Conversely, while sanctuary zones appear to displace extractive activities to other zone types, this study found they also attracted high densities of people participating in non-extractive activities, which may still damage the environment (Harriott, 2004; Hawkins *et al.*, 2005; Courbis, 2007). The highest densities of people participating in activities such as snorkelling, swimming, diving and wildlife interactions from boats or the shore was obtained in sanctuary zones; specifically Bundegi, Lighthouse Bay, Lakeside, Turquoise Bay and Coral Bay. They were also popular for shore activities such as relaxing on the beach. This attraction may be due to the placement of sanctuary zones in locations considered unique for their biodiversity, which are often well publicised.

Another commonality between these high use sanctuary zones is they are all accessible by sealed roads or located near accommodation or service centres. This study found remote sanctuary zones, such as in the southern extent of the Marine Park (around Cape Farquhar on Gnaraloo Station or south of Point Cloates on Ningaloo Station), received extremely low levels of use. General use or recreation zones located adjacent to these sanctuary areas were documented with similarly low levels. This highlights the potential for sites to be protected without zoning due to their isolation, i.e. far from boat launching areas, accessible by 4WD only or exposed to dangerous wave conditions. This phenomenon has been documented in previous studies of recreational fishing (Bohnsack, 1998; Dayton *et al.*, 2000) and wildlife interactions (Bejder *et al.*, 2006).

The effect of zoning and remoteness on the distribution of recreational activities identifies a clear need for a holistic approach to managing (and monitoring) these

activities throughout the NMP. This will ensure that studies such as by Babcock *et al.* (2008) can incorporate the effects of these activities on biological processes. Section 9.3 made recommendations for a monitoring program that would encompass the entire NMP and assist in achieving several specific management strategies; primarily relating assessing the level and distribution of recreation. Other strategies to which monitoring can contribute include establishing a baseline for marine nature-based tourism occurring adjacent to existing tourism nodes, such as Coral Bay, or those proposed in the regional planning strategy (WAPC, 2004), such as Gnaraloo Bay on Gnaraloo Station.

Research into recreational fishing and its ecological effects, to ensure sustainable fishing practices, is also a key management strategy that is the responsibility of DoF and DEC. The current study collected fine-scale observational data on the location of people undertaking recreational fishing. Data on recreational catch and catch per unit effort were also obtained during interviews with people participating in fishing in the NMP, although this has been reported in other forums (Smallwood *et al.*, 2009). The DoF completed a 12-month survey of recreational fishing in 1998/99 (Sumner *et al.*, 2002), that was repeated in 2007/08 (DoF, in prep.), which will provide data on changes in recreational catch and effort at broad spatial resolution (i.e. 5 x 5 nautical mile blocks) using fishing locations self-reported by anglers. Some specific management strategies already in place in the NMP include licensing of commercial tourism operators, which includes mandatory logbooks for charter fishing and wildlife interaction activities, and joint surveillance operations by the DoF and DEC. The implementation of electronic vessel monitoring systems on charter or commercial vessels in recent years in Western Australia and elsewhere will also support the collection of spatial data on their distribution (Deng *et al.*, 2005; Bejder *et al.*, 2006; Mills *et al.*, 2007).

Access to recreation sites along the Ningaloo coast was highly dependent on private vehicles and the vast road and track network, of which ~60% consists of sandy tracks. There was significant clustering of activity along this network and also from beach access points, with people travelling a median of <0.1 km by foot to reach a shore recreation location. Travel to the NMP may be further restricted by the road network, as many coastal sections were not accessible by 2WD vehicles, especially on pastoral leases. Previous research found visitors supported the retention of 4WD only access along parts of the coast to preserve the amenity and experience of these remote locations (Polley, 2002). The maintenance of secluded areas for remote experiences is an additional key management strategy identified in the current plan (CALM and MPRA, 2005), Locations identified in this study where little recreational use occurred were generally isolated from access points, are 4WD access only or are areas to which access is restricted to authorised personnel only, such as the stretch of coast on Gnaraloo Station, around Cape Farquhar. The quantification of distance travelled by visitors for shore recreation also means these data can be used to determine the effect of new coastal access points and track rationalisation on these activities.

This study provided fine-scale data on recreation to support specific management strategies developed for Ningaloo. However, an assessment of the effectiveness of management objectives is difficult to achieve, with a lack of specific reporting or targets provided for these social values. Zoning was found to affect the distribution of activities, and this has been linked with biological research (Babcock *et al.*, 2008), indicating that zoning may be achieving management objectives such as maintaining values important to recreational fishing (i.e. diversity of fish species). This study can be used as a benchmark for determining the patterns of recreation that can be used as a basis for developing ongoing monitoring which may be linked with biological research

to ensure that these activities are managed consistently with the ecological and social values of the NMP.

9.5 Future research

Vehicles, in numbers exceeding designated carpark bays, are now occurring at sites such as Turquoise Bay and Coral Bay. Likewise, there are designated overflow areas for camping on sporting fields and lawn areas in Coral Bay and Exmouth which have been established to cope with peak periods. Although this indicates that these areas are reaching capacity in terms of facilities, the perceptions of overcrowding by visitors are currently unknown. These capacity concerns would benefit from additional research into crowding which would contribute to planning through the allocation of more resources at existing sites, development of additional sites or use of pre-visit information to direct people to alternative sites. Alternatively, options may also include restricting access to sites once full or shifting towards public transport alternatives (Connell and Page, 2008).

Lighthouse Bay, Turquoise Bay and Coral Bay were also identified has having the highest diversity of activities (which were maintained year round), indicating potential conflict between users. User conflict was discussed briefly within the context of this study, with zoning and infrastructure found to affect the distribution of some activities, such as recreational fishing. However, this aspect of recreational use would also benefit from additional research into perception, satisfaction and experience. These are considered core data needs (Griffin *et al.*, 2008) and could be integrated within the monitoring program or specialised studies into overcrowding or carrying capacity

There is also potential for future research using agent-based modelling programs such as RBSim, which would allow simulation and prediction of movement patterns of visitors (Itami *et al.*, 2000). As discussed in the travel analysis, this is currently only applicable to linear networks (i.e. roads or tracks) but could be used to predict changes to the distribution and density of recreational activities due to the implementation of management initiatives, future coastal developments or access points. However, some additional data would be required on the travel movements of visitors and their preferences in order to undertake analysis using this particular program.

Ningaloo Reef has been proposed for listing as a world heritage site along with the Great Barrier Reef and Shark Bay (located ~600 km to the south of Ningaloo) which were listed in 1981 and 1991, respectively (World Heritage Consultative Committee, 2005). This would further enhance the international reputation of Ningaloo as a place with unique natural features and biodiversity. Although world heritage sites worldwide have built support for protected areas with respect to raising awareness, enhancing funding and improving management, there are stakeholders who view this as negative, with concerns over social impacts and competition for recreational amenity (Buckley, 2004; Nicholas *et al.*, 2009).

Future research should aim to provide linkages between social and ecological elements of the NMP, using geo-referenced frameworks. The potential for such linkages has been demonstrated in North America (Leung *et al.*, 2002), and they will be required to achieve many of the current management strategies for Ningaloo, such as managing recreation in a manner that is consistent with geomorphology and biological communities. The data from this study has provided fine-scale geo-referenced data on recreation that can be considered in the wider context of environmental or ecological

attributes. Furthermore, this process is already underway, with these data contributing to the development of an integrated ecosystem and socio-economic model for Ningaloo, which is being developed as part of the CSIRO Ningaloo Collaborative Cluster. This will not only improve the capacity of this model, but is also useful for identifying spatial co-variation between factors which may require management intervention, such as boating activity, seagrass and manatees in Florida (Sidman *et al.*, 2002) or water quality and tourism pressure in Queensland (Hadwen *et al.*, 2003). There are also opportunities for these data to be incorporated into systematic conservation planning, using programs such as MARXAN, which have been applied successfully around the world (Possingham *et al.*, 2000; Leslie, 2005; Klein *et al.*, 2008).

9.6 Conclusions

This study offers significant scientific contributions to protected area management within the context of coastal and marine environments. These environs are exposed to increasing levels of use by a diverse range of visitors undertaking many different recreational activities. Fine-scale information, obtained using a multi-faceted approach to data collection, can be applied to coastal marine parks worldwide to provide baseline data and support future monitoring. This enables a greater understanding of spatial and temporal patterns which can be proactively managed and used to assess management effectiveness. This study has also demonstrated that relevant human use data can be applied to management, not only within the context of Ningaloo, but to marine parks globally. This can support decision making to ensure that areas are sustainably managed for biodiversity conservation as well as providing recreation and tourism opportunities for future generations.

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Appendices

Appendix 1 Monthly (2007) fieldwork schedule for aerial and land-based coastal observation surveys in the NMP showing weekend/public holidays and school holidays.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mon	1									1 - Y - EX		
Tues	2				1					2 - Y - CB		
Wed	3 - EX - Y				2 - EX - Y			1 - Aerial		3 - CB - Y		
Thurs	4 - Aerial	1 - EX - Y	1		3 - EX - Y			2 - Y - CB		4 - EX - Y	1	
Fri	5 - Y - CB	2	2 - Aerial		4 - Aerial	1		3 - CB - Y		5 - Aerial	2 - Y - EX	
Sat	6 - CB - Y	3	3 - EX - Y		5 - Y - EX	2 - Y - EX		4 - Y - EX	1	6 - Aerial	3 - EX - Y	1 - EX - Y
Sun	7 - Y - EX	4 - EX - Y	4 - Y - EX	1	6	3 - Aerial	1 - EX - Y	5	2 - Aerial	7 - EX - Y	4 - EX - Y	2 - Aerial
Mon	8	5	5 - Y - CB	2 - Y - EX	7 - Y - CB	4 - Aerial	2	6 - Y - CB	3 - EX - Y	8 - Y - CB	5	3 - Y - CB
Tues	9 - Y - CB	6 - EX - Y	7 - CB - RB	3 - Y - CB	8 - CB - RB	5 - Y - CB	3 - Aerial	7 - CB - RB	4 - Y - CB	9 - CB - RB	6 - Y - CB	4 - CB - RB
Wed	10 - CB - RB	7 - Y - CB	7 - RB - CB	4 - CB - RB	9 - RB - CB	6 - CB - RB	4	8 - RB - CB	5 - CB - RB	10 - RB - CB	7 - CB - RB	5 - RB - CB
Thurs	11 - RB - CB	8 - CB - RB	8 - CB - Y	5 - RB - CB	10 - CB - Y	7 - RB - CB	5	9 - CB - Y	6 - RB - CB	11 - CB - Y	8 - RB - CB	6 - CB - Y
Fri	12 - CB - Y	9 - RB - CB	9	6 - CB - Y	11	8 - CB - Y	6 - EX - Y	10	7 - CB - Y	12	9 - CB - Y	7
Sat	13 - Y - EX	10 - CB - Y	10 - Y - EX	7 - Aerial	12	9	7 - Y - EX	11 - Aerial	8 - EX - Y	13	10	8 - EX - Y
Sun	14	11 - EX - Y	11 - Y - CB	8 - Aerial	13 - EX - Y	10 - EX - Y	8	12 - Y - EX	9	14	11	9 - Y - EX
Mon	15 - EX - Y	12	12 - CB - Y	9 - EX - Y	14	11	9 - Aerial	13	10 - Aerial	15	12 - Aerial	10 - Aerial
Tues	16	13	13 - EX - Y	10 - Y - CB	15	12	10 - Y - CB	14	11 - Y - CB	16	13	11 - Y - CB
Wed	17	14 - Aerial	14 - Y - EX	11 - CB - Y	16 - Y - EX	13 - EX - Y	11 - CB - RB	15	12 - CB - Y	17	14	12 - CB - Y
Thurs	18	15 - Y - CB	15	12 - EX - Y	17	14 - Aerial	12 - RB - CB	16 - EX - Y	13 - Y - EX	18 - Y - EX	15 - Y - EX	13 - Y - EX
Fri	19	16 - CB - RB	16	13 - Y - EX	18 - Aerial	15	13 - CB - Y	17	14	19 - Aerial	16	14
Sat	20 - Y - CB	17 - RB - CB	17	14	18 - Y - EX	16 - EX - Y	14	18 - Aerial	15 - EX - Y	20	17 - Y - EX	15
Sun	21 - CB - RB	18 - CB - Y	18	15	20	17 - Y - CB	15 - Aerial	19 - EX - Y	16 - Y - EX	21 - Y - CB	18 - Y - CB	16
Mon	22 - RB - CB	18 - Y - EX	19	16 - Aerial	21	18 - CB - RB	16 - EX - Y	20 - Y - EX	17	22 - CB - RB	19 - CB - RB	17
Tues	23 - CB - Y	20	20 - Y - CB	17 - Y - CB	22	19 - RB - CB	17 - Y - EX	21	18	23 - RB - CB	20 - RB - CB	18
Wed	24 - EX - Y	21	21 - CB - RB	18 - CB - RB	23	20 - CB - Y	18 - Aerial	22	19	24 - CB - Y	21 - CB - Y	19 - Y - CB
Thurs	25	22 - Y - CB	22 - RB - CB	19 - RB - CB	24 - Y - CB	21	19 - Y - CB	23 - Y - CB	20 - Aerial	25 - EX - Y	22 - EX - Y	20 - CB - RB
Fri	26 - Aerial	23 - CG - Y	23 - CB - Y	20 - CB - Y	25 - CB - Y	22 - EX - Y	20 - CB - Y	24 - CB - RB	21 - Y - CB	26	23	21 - RB - CB
Sat	27 - Y - EX	24 - Y - EX	24 - Aerial	21	26	23 -Y - CB	21 - Y - EX	25 - RB - CB	22 - CB - RB	27 - EX - Y	24 - Aerial	22 - CB - Y
Sun	28	25 - Aerial	25	22 -Y - EX	27 - Aerial	24 - CB - Y	22	26 - CB - Y	23 - RB - CB	28 - Aerial	25 - Y - CB	23
Mon	29	26	26 - EX - Y	23 - Aerial	28 - Y - CB	25 - Y - EX	23 - Y - CB	27 - EX - Y	24 - CB - Y	29	26 - CB - Y	24 - EX - Y
Tues	30	27	27	24	29 - CB - RB	26	24 - CB - RB	28	25 - EX - Y	30	27	25
Wed	31	28	28	25 - EX - Y	30 - RB - CB	27	25 - RB - CB	29	26	31	28	26
Thurs			29	26	31 - CB - Y	28	26 - CB - Y	30	27		29	27 - Y - EX
Fri			30	27		29	27	31	28		30	28
Sat			31	28		30	28		29			29
Sun				29			29		30			30
Mon				30			30					31
Tues							31					

EX – Y = Exmouth – Yardie Creek, Y = CB = Yardie Creek – Coral Bay, CB – RB Coral Bay –Red Bluff, Aerial = Aerial flight

= school holidays = weekends/public holidays

Appendix 2 List of shore and boat-based recreational activities observed at the Ningaloo Marine Park throughout 2007 [adapted from Horneman *et al*. (2002), Moscardo and Green (1999), Finkler and Higham (2004), Porter and Bright (2004)].

General category	***Recreational activity***	***General category***	***Recreational activity***
Beach Games	Ball games	Off Road Driving	4WD, private
	Beach cricket		Quadbiking, commercial
	Beach volleyball		Quadbiking, private
	Bocce, bowling	Relaxing	Beach (sun) shelter
	Crochet, crosswords		Domestic duties
	Football, soccer, rugby		Drawing, reading
	Frisbee		Picnic
	Geo-caching		Relaxing, sitting, sleeping
	Golf		Standing/socialising
	Jetty jumping		Sunbaking
	Kite flying	Research	Research
	Mini golf	Sailing sports	Kitesurfing
	Playing (in shallows)		Rigging (kitesurfer/windsurfer)
	Sandcastle building		Sailing
	Skimboarding		Windsurfing
	Volleyball	Sandboarding	Sandboarding
Bike riding	Bike riding	Sightseeing/spectating	Photography
Boating	Boat launching		Sightseeing, private
	Boat retrieving		Sightseeing, commercial
	Loading charter passengers		Spectating
	Motoring		Supervising
	Outboard maintenance		Videography
	Unloading charter passengers	Snorkelling	Snorkelling, boat
Collecting/netting	Collecting, unspecified		Snorkelling, private
	Collecting, bait		Snorkelling, commercial
	Collecting, octopus		Snorkelling, shore
	Collecting, shells/beachcombing	Spearfishing	Spearfishing
	Crayfishing	Surfing	Boogie boarding
	Crabbing		Surfing
	Netting, haul or cast		Towing in surfers
Diving	Diving, commercial boat	Swimming	Swimming
	Diving, private boat	Towing sports	Kneeboarding
	Diving, shore		Skurfing, tubing
Education	Interpretative centre		Wakeboarding
	School group		Waterskiing
	Yardie Creek, commercial	Unknown	Unknown
Exercise	Yoga, jogging, pilates	Walking	Wading
Fishing	Fishing, boat		Walking, beach
	Fishing, commercial tour		Walking, bush
	Trolling		Walking, dogs
	Squidding, boat		Walking, reef
	Fishing, fly	Wildlife interaction	Manta rays, commercial
	Fishing, shore		Whale sharks, commercial
	Squidding, shore		Eco-tour
Horseriding	Horseriding		Fish feeding
Jetskiing	Jetskiing	Wildlife viewing	Coral viewing
Kayaking	Kayaking, private		Turtle watching
	Kayaking, commercial		Turtle watching, commercial
	Waveski, private		Wildlife watching
Management	Maintenance (DEC)		Wildlife, shark aggregation
	Management (DEC)		Whale watching, private
Motoring	Motoring		Whale watching, commercial

Appendix 3 List of coastal vantage points (and their facilities) at each location used for observations and/or standard counts throughout the NMP (where T=Public Toilet, S=Shop, F=Fuel).

Tenure	*Location Name*	*Latitude S*	*Longitude E*	*Vantage point*	*Access*	*Camping*	*Carpark*	*Boat launching*	*Moorings*	*Facilities*
Ex	Exmouth Marina	-21.9558	114.1392	Y	2WD	N	Y	Y		T
	Yacht Club	-21.9486	114.1389	Y	2WD	N	Y	Y		
	Town Beach	-21.9425	114.1409	Y	2WD	N	Y	N		T
	Truscott Crescent Carpark	-21.9399	114.1391	N	2WD	N	Y	N		
NWC	Bundegi Lookout (LO)	-21.8606	114.1525	Y	2WD	N	N	N		
	Bundegi North Sanctuary Zone	-21.8550	114.1561	Y	4WD	N	Y	N		
	Bundegi Beach	-21.8261	114.1778	Y	2WD	N	Y	Y	Y	T
	Pier Right	-21.8177	114.1874	Y	2WD	N	Y	N		
	Pier Left	-21.8135	114.1889	Y	2WD	N	Y	N		
	Mildura Wreck Track Access 6	-21.8003	114.1697	N	4WD	N	Y	N		
	Mildura Wreck Track Access 5	-21.7967	114.1667	N	4WD	N	Y	N		
	Mildura Wreck Track Access 4	-21.7931	114.1689	N	4WD	N	Y	N		
	Mildura Wreck Track Access 3	-21.7919	114.1686	N	4WD	N	Y	N		
	Mildura Wreck Track Access 2	-21.7894	114.1681	N	4WD	N	Y	N		
	Mildura Wreck Track Access 1	-21.7883	114.1664	N	4WD	N	Y	N		
	Mildura Wreck Carpark	-21.7861	114.1647	N	2WD	N	Y	N		
	Mildura Wreck Beach	-21.7856	114.1650	Y	2WD	N	N	N		
	Occys Carpark	-21.7919	114.1540	Y	2WD	N	Y	N		
	Mildura Road Carpark	-21.7975	114.1459	Y	2WD	N	Y	N		
	Surf Beach	-21.8017	114.1397	Y	2WD	N	Y	N		T
	Mantas Carpark	-21.8061	114.1292	Y	2WD	N	Y	N		
	Mantas South Carpark	-21.8072	114.1244	Y	2WD	N	Y	N		
	Hunters Point Carpark	-21.8028	114.1089	Y	2WD	N	Y	N		
	Hunters Road Carpark	-21.8042	114.1072	N	2WD	N	Y	N		T
	Jurabi Turtle Centre	-21.8067	114.1022	N	2WD	N	Y	N		T
	Mauritaus	-21.8098	114.0956	Y	2WD	N	Y	N		
	Jacobsz	-21.8117	114.0881	Y	2WD	N	Y	N		
	Jacobsz South	-21.8169	114.0797	Y	4WD	N	Y	N		
	Jansz	-21.8278	114.0722	Y	2WD	N	Y	Y		

Tenure	*Location Name*	*Latitude S*	*Longitude E*	*Vantage point*	*Access*	*Camping*	*Carpark*	*Boat launching*	*Moorings*	*Facilities*
NWC cont.	Wobiri	-21.8294	114.0681	Y	2WD	N	Y	N		T
	Five Mile	-21.8392	114.0478	Y	2WD	N	Y	N		
	Trisel	-21.8469	114.0378	Y	2WD	N	Y	N		
	Brooke Access	-21.8472	114.0339	Y	2WD	N	Y	N		
	Bauden	-21.8483	114.0314	Y	2WD	N	Y	N		
	Graveyards North Carpark	-21.8558	114.0219	N	4WD	N	Y	N		
	Graveyards South Carpark	-21.8572	114.0211	Y	4WD	N	Y	N		
	Sand Dune/Drift Sand	-21.8917	113.9908	Y	4WD	N	Y	Y		
	Beacon	-21.8986	113.9872	N	4WD	N	Y	N		
	Tantabiddi	-21.9122	113.9781	Y	2WD	N	Y	Y		T
CRNP	Mangroves	-21.9656	113.9431	Y	2WD	N	Y	N		T
	Low Point Carpark	-21.9828	113.9364	N	4WD	N	Y	N		
	Neds Day Use	-22.0003	113.9328	Y	2WD	N	Y	N		
	Neds Camp	-22.0062	113.9275	N	2WD	Y	N	Y		T
	Mesa Camp	-22.0061	113.9275	N	2WD	Y	Y	Y	Y	T
	Mesa Day Use	-22.0064	113.9272	Y	2WD	N	Y	N		
	Milyering Visitor Centre	-22.0278	113.9239	N	2WD	N	Y	N		T,S
	T-Bone North	-22.0225	113.9214	Y	2WD	Y	Y	N		T
	T-Bone South	-22.0247	113.9203	Y	2WD	N	Y	N		
	Kori Bay	-22.0300	113.9175	Y	2WD	N	Y	N		
	Lakeside	-22.0339	113.9144	Y	2WD	Y	Y	Y		T
	Varanus Beach	-22.0447	113.9100	Y	2WD	N	Y	N		
	Trealla Beach	-22.0500	113.9083	Y	2WD	N	Y	N		
	Tulki Beach	-22.0753	113.8983	Y	2WD	Y	Y	Y		T
	Turquoise Bay	-22.0982	113.8879	Y	2WD	N	Y	N		T
	Turquoise Drift	-22.0993	113.8858	Y	2WD	N	Y	N		T
	Oyster Stacks	-22.1319	113.8781	Y	2WD	N	Y	N		
	North Mandu	-22.1421	113.8728	Y	2WD	Y	Y	N		T
	South Mandu	-22.1458	113.8706	Y	2WD	N	Y	N		
	Bloodwood Creek	-22.1689	113.8619	Y	2WD	N	Y	N		
	Kurrajong	-22.1798	113.8592	Y	2WD	Y	Y	N		T

Tenure	*Location Name*	*Latitude S*	*Longitude E*	*Vantage point*	*Access*	*Camping*	*Carpark*	*Boat launching*	*Moorings*	*Facilities*
CRNP cont.	Pilgramunna	-22.1939	113.8558	Y	2WD	Y	Y	Y		T
	Sandy Bay (CRNP)	-22.2317	113.8428	Y	2WD	N	Y	N		T
	Osprey Bay	-22.2375	113.8394	Y	2WD	Y	Y	Y		T
	Bungarra	-22.2466	113.8404	N	2WD	Y	Y	N		T
	Yardie Creek	-22.3206	113.8133	Y	2WD	Y	Y	Y		T
	1k Camp	-22.3319	113.8064	Y	4WD	Y	Y	N		T
	Boat Harbour	-22.3639	113.7861	Y	4WD	Y	Y	Y		T
DoD	North Winderabandi Zone	-22.3811	113.7769	Y	4WD	N	N	N		
	Kangaroo Flats/Sandy Point	-22.3881	113.7656	Y	4WD	Y	N	Y		
	Doddies	-22.4033	113.7547	Y	4WD	Y	N	Y	Y	
	Cliffs (DoD)	-22.4028	113.7558	Y	4WD	N	N	N		
	Coastal Track (017)	-22.4628	113.7408	Y	4WD	N	N	N		
	Coastal Track (018)	-22.4722	113.7378	Y	4WD	N	N	N		
	Coastal Track (038)	-22.4722	113.7378	Y	4WD	N	N	N		
	Coastal Track (019)	-22.4850	113.7475	Y	4WD	N	N	N		
NS	Ningaloo Access Gate	-22.4936	113.7258	Y	4WD	Y	Y	N		
	Winderabandi Point	-22.4956	113.7069	Y	4WD	Y	N	Y		
	Locked Gates	-22.5147	113.7156	Y	4WD	Y	N	Y		
	Unlocked Gates	-22.5207	113.7118	Y	4WD	Y	N	Y		
	Lefroy Bay North	-22.5147	113.7156	Y	4WD	Y	N	Y		
	Vantage Point 9	-22.5439	113.6856	Y	4WD	N	N	N		
	Lefroy Bay South	-22.5519	113.6647	Y	4WD	Y	N	Y		
	Norwegian Bay	-22.6008	113.6739	Y	4WD	N	N	N		
	Short Stay Camping	-22.6675	113.6876	Y	2WD	Y	Y	N		
	Shearing Shed	-22.6764	113.6859	N	2WD	N	Y	Y		
	Hilton Shack	-22.6955	113.6729	Y	2WD	Y	N	N		
	Ningaloo Homestead	-22.6972	113.6744	Y	2WD	N	N	N		
	Lighthouse	-22.7019	113.6825	Y	4WD	N	N	N		
	Jane Bay/4 Mile	-22.7153	113.7092	Y	4WD	Y	N	N		
	Vantage Point 8	-22.8150	113.7806	Y	4WD	N	N	N		
	Vantage Point 7	-22.8681	113.7964	Y	4WD	N	N	N		

Tenure	*Location Name*	*Latitude S*	*Longitude E*	*Vantage point*	*Access*	*Camping*	*Carpark*	*Boat launching*	*Moorings*	*Facilities*
CS	Cloates Southern Sanctuary Boundary	-22.9108	113.8167	Y	4WD	N	Y	N		
	Vantage Point 6	-22.9411	113.8239	Y	4WD	N	N	N		
	Brudoodjoo (9 Mile) - Gate 5	-22.9764	113.8214	Y	4WD	Y	Y	Y		
	Sand Bar - Gate 4	-23.0108	113.8297	Y	4WD	N	N	N		
	Gate 3	-23.0258	113.8300	Y	4WD	N	N	N		
	Cardiac Hill/Dog Rock – Gate 2	-23.0469	113.8264	Y	4WD	N	N	N		
	Lagoon - Gate 1	-23.0578	113.8208	Y	4WD	N	Y	N		
	Oyster Bridge - Gate 1	-23.0714	113.8161	Y	4WD	N	Y	N		
	Mauds Landing	-23.1147	113.7764	Y	2WD	N	Y	N		
	Coral Bay	-23.1428	113.7672	Y	2WD	N	N	N	Y	T,S,F
	Coral Bay BLF	-23.1554	113.7664	Y	2WD	N	N	Y		
	Moncks Head	-23.1580	113.7654	Y	4WD	N	Y	N	Y	
	Five Fingers North	-23.1786	113.7647	Y	4WD	N	N	N		
	Five Fingers South/Turtle Rock	-23.1803	113.7656	Y	4WD	N	N	N		
	Navigation Marks	-23.1961	113.7744	Y	4WD	N	N	N		
WS	14 Mile North/Ronchis Rock	-23.2561	113.7828	Y	4WD	N	N	N		
	14 Mile South	-23.2814	113.7903	N	4WD	Y	Y	Y		
	Pelican Point North Sanct Sign	-23.2939	113.7947	Y	4WD	N	N	N		
	Sandy Point Campsite (WS)	-23.3125	113.7944	N	4WD	Y	N	Y		
	Sandy Point Lookout (LO)	-23.3106	113.7942	Y	4WD	N	N	N		
	Pelican Point	-23.3714	113.7869	Y	4WD	Y	N	N		
	Maggies North	-23.3842	113.7774	Y	4WD	N	N	N		
	Pelican Sanctuary Marker	-23.4097	113.7819	Y	4WD	N	N	N		
	Maggies	-23.4164	113.7839	Y	4WD	Y	Y	Y		
	Maggies South	-23.4214	113.7817	Y	4WD	Y	N	N		
	Elles Campsite	-23.4334	113.7828	Y	4WD	Y	N	N		
	Elles Lookout (LO)	-23.4386	113.7811	Y	4WD	N	N	N		
	Stevens North	-23.4539	113.7817	Y	4WD	Y	Y	N		
	Stevens South	-23.4589	113.7808	Y	4WD	Y	N	N		
	Wedding Hill/Whale Watching	-23.4642	113.7814	Y	4WD	N	N	N		
	Warroora Homestead	-23.4853	113.7808	N	2WD	Y	N	N		T

Tenure	*Location Name*	*Latitude S*	*Longitude E*	*Vantage point*	*Access*	*Camping*	*Carpark*	*Boat launching*	*Moorings*	*Facilities*
WS cont.	Warroora Beach	-23.4852	113.7756	N	4WD	Y	Y	Y		
	Gate Campsite	-23.5133	113.7644	N	4WD	Y	N	N		
	Camp 36 Lookout (LO)	-23.5208	113.7592	Y	4WD	Y	N	N		
	Blowout/Bulbari Overflow	-23.5267	113.7558	Y	4WD	Y	N	N		
	Nicks Camp	-23.5356	113.7442	Y	4WD	Y	N	N		
	Lagoon Campsite	-23.5414	113.7394	Y	4WD	Y	Y	Y		
	Lagoon Lookout (LO)	-23.5422	113.7336	Y	4WD	N	N	N		
	Vantage Point 5	-23.5592	113.7142	Y	4WD	N	N	N		
	Camp 49	-23.5444	113.7289	Y	4WD	Y	N	N		
	South Boundary	-23.5588	113.7164	Y	4WD	Y	N	Y		
GN	Farquhar Lookout (LO)	-23.5825	113.6908	Y	4WD	N	N	N		
	Farquhar Shack	-23.6228	113.6328	Y	4WD	Y	N	N		
	Vantage Point 4	-23.6594	113.6064	Y	4WD	N	N	N		
	Vantage Point 3	-23.6906	113.5953	Y	4WD	N	N	N		
	Gnaraloo Bay	-23.7661	113.5428	N	2WD	N	Y	Y	Y	
	Gnaraloo Homestead	-23.8217	113.5258	N	2WD	N	Y	Y		T
	3 Mile	-23.8742	113.4967	Y	2WD	Y	Y	Y	Y	T,S
	Tombstones	-23.8833	113.4839	N	2WD	N	Y	N		
	Vantage Point 2	-23.8950	113.4733	Y	4WD	N	N	N		
	Turtles Lookout (LO)	-23.9404	113.4691	Y	4WD	N	N	N		
Q	Vantage Point 1	-23.9686	113.4700	Y	4WD	N	N	N		
	Red Bluff	-24.0336	113.4458	Y	2WD	Y	Y	Y		T,S

Appendix 4 Questionnaire form used for face-to-face interviews with people participating in recreational activity on the beach at Ningaloo throughout 2007.

Human Usage - Intercept Survey Form

MURDOCH UNIVERSITY PERTH, WESTERN AUSTRALIA

1. Observations

Date				Time				Interviewer		
								Rec. activity		
Latitude	S			Longitude		E		Platform		Boat / Shore
Total no. in each age category	Sex	<17	18-24	25-34	35-44	45-54	55-64	>65	Total	Interviewee
	M									*Age:*
	F									*Age:*
Group type	☐ individual ☐ couple ☐ family ☐ friends ☐ comm. tour ☐ club/org ☐ other									

2. Current activity & trip information

Hi, I am from the School of Environmental Science at Murdoch University. We are doing a survey on the recreational activities undertaken by visitors to the Ningaloo Marine Park which will take 5-10mins. You are under no obligation, but may I ask you a few questions regarding your activities? Yes / No

What time did you arrive at the beach today?		What time do you expect to leave?	
What is the main activity that brought you here today?			
How long have you spent doing this activity today?		If fishing, what time did you start?	
How many people in your group are <activity>?	All / M: F: Child:		
Where did you access the beach?		Where did you stay last night?	
How many days ago did you arrive here?		How many more nights will you stay here?	
Will you (or have you) stayed elsewhere in the NMP?	Yes / No	How many nights will you spend elsewhere?	
What main road did you use to access your accommodation?	☐ Yardie Creek rd ☐ Quobba access rd ☐ Ningaloo access rd	☐ Yardie Creek crossing ☐ Coral bay-Ningaloo access track	☐ Exmouth-Minilya rd ☐ Warroora access track ☐ Fly (Learmonth)
What is the postcode of your place of residence?		If 6707 or 6701, how long have you lived here?	
Have you been interviewed by us before?	Yes / No		
☐ resident (day trip) ☐ resident (extended stay) ☐ visitor (day trip) ☐ visitor (extended stay)			

3. Recreational activity patterns

On this *day / extended* trip, what recreational activities have **you** undertaken:

Activity	Y	N	On how many days?	Activity	Y	N	On how many days?
Fishing (shore)				W/surfing			
Fishing (boat)				K/surfing			
SCUBA diving (private)				Comm. tour (.....)			
SCUBA diving (comm.)				Sunbaking			
Snorkelling (shore)				Beach walking			
Snorkelling (boat)				Bush walking			
Swimming				Other ...			
Kayaking				Other ...			
Surfing				Other ...			

Has anyone in the group collected shells, octopus or crayfish during the trip?				Shell / Octopus / Cray / None	
Do you have a 4WD on this trip?		Yes / No			
What is the furthest you have travelled from your <stay last night> for a shore-based activity?		Driving time/distance & dir: Location:			
Do you have a boat on this trip?		Yes / No -- ➢ If yes, then ask the following questions			
What length is your boat? (ft or m)		What size motor/s does it have? (Hp)		What size fuel tank? (L)	
On this trip, where have you launched your boat? *(if more than one, rank from one)*					
What is the furthest you have travelled from your <primary launch location> for a boat-based activity?		Motoring time/distance & dir: Location:			

4. Usage patterns

Is this your first trip to the NMP?	Yes / No -- ➢ what year was your first trip?				
	-- ➢ how many times have you visited in the last 12 months (excluding this trip)?				
	-- ➢ when was your most recent trip? *Month:* *Year:*				
	-- ➢ do you always stay in the same location when you visit the NMP? Yes / No				
What is the main reason for choosing to stay at <stay last night>? *n/r*	☐ no stay limit ☐ toilet facilities	☐ not National Park ☐ no fees	☐ boat fishing allowed ☐ other	☐ scenic	
Do you intend to visit the NMP again?	Yes / No	What is your next destination after the NMP?			
What is your occupation?		If unemployed/retired, your last occupation?			

5. Fishing Activity ***----if currently shore fishing or returning from boat fishing---***

What species are you trying to catch?			
How often have you fished at this spot on this trip?		Number of rods/handlines in the group?	
Have you gone fishing at night on this trip?	Yes / No	How many times on this trip?	
Where is the closest sanctuary zone?	Correct / Incorrect / Don't know		
Has this affected where you fish?	Yes / No	Why?	
Have you kept anything today?	Yes / No	Have you released anything today?	Yes / No

Indicate numbers kept/released and total lengths (mm) on reverse side of form