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Integrating social and biophysical data to develop and evaluate marine protected area planning at a local scale: the 1998 Cairns Area Plan of Management as a case study.

Thesis Submitted by

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For the degree of Doctor of Philosophy

In the Department of Tropical Environment Studies

James Cook University of North Queensland

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STATEMENT OF CONTRIBUTION OF OTHERS

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Declaration of Ethics

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement and Guidelines on Research Practice* (1997), the *James Cook University Policy on Experimentation Ethics. Standard Practices and Guidelines* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee.

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ABSTRACT

Use management in marine protected areas is a complex and often changing process, both because of political and legislative requirements and because of the diversity of user groups. It is therefore essential to have accurate and reliable information to guide development of the most appropriate management instruments within a given area.

This thesis explores the challenge for marine protected area managers of making cost-effective use of scientific information in planning for reasonable use of the Great Barrier Reef Marine Park. Using the 1998 Cairns Area Plan of Management as a case study, I develop methods for integrating biophysical and social data in the development and evaluation of marine protected area planning. I also provide an analysis of the interaction between human perceptions and the ecological status of the reef resources.

The main objectives of this study are:

1. to assess the criteria and methods used by government agencies to allocate resource use in the Great Barrier Reef Region (GBR), at both regional and local scales;
2. to identify ways in which existing information on reef resources can be integrated into a format that is easy to access and use;
3. to develop methods to help managers map the location and types of use;
4. develop methods to assess the relationships between information on marine ecosystems and patterns in human use, perceptions and values;
5. to estimate the effectiveness of the 1998 Cairns Area Plan of Management, from the perspective both of its objectives and of its information base.

In order to achieve these objectives, I employ a variety of methods and techniques. First, I conduct an extensive literature review of marine conservation, marine protected areas, the history of the Great Barrier Reef Marine Park and the goals, criteria and

methods used in selection and planning of Marine Protected Areas. I then collate data on planning and management specifically in the Cairns Planning Area. These data are obtained by surveying marine park managers and reviewing existing literature. Results from this survey and review reveal a lack of information on how people perceive the resource they use and what environmental conditions influence their experience and behaviour. Therefore, I conduct a survey of regular reef users in the Cairns Planning Area, with the aim of in collecting such information. Using multivariate and univariate models, I then make comparisons between the human perception of reef resources and scientifically measured indicators of coral reef status. This information is used to assess the ability of humans to perceive and monitor environmental variables. Finally, I demonstrate the use of a decision support system to integrate available biophysical and social information to support use allocation decisions.

As a result of this research I arrive at several conclusions. In the literature review chapters, I identify the need for development of clearly defined, applicable and functional objectives and criteria for marine protected areas such as the Great Barrier Reef Marine Park. Such objectives and criteria would assist with transparent and objective decision making regarding the social and economic values of marine resources during the planning and management of a marine protected area. I present a range of decision support modeling methods that are available to assist managers in the systematic use of data and information sources to select marine protected areas and designate varying levels of protection. I recommend the use of several of these methods to examine information from all sources simultaneously, using a systematic process. This integrated approach is demonstrated using the Cairns Area Plan of Management as a case study.

My survey of regular reef users in the Cairns Planning Area provides information on social conditions, perceptions of reef quality and levels of acceptable use. This type of information should be collected as an integral part of planning and decision making in marine protected areas.

Regular reef users are found to be quite capable of describing the environment that they frequent and detecting change over time. The respondents indicate that the reefs in the Cairns Planning Area are of high quality, with offshore reefs receiving higher ratings than inshore reefs. The perceived quality of coral cover and diversity of fish species are the best indicators of overall reef quality. High quality sites are those with excellent coral cover and high diversity of fish species, while low quality sites have low coral cover and limited underwater topography.

Over fishing, anchoring and cyclones are perceived to cause the most damage to reefs over time. Overcrowding is an issue at most reefs within the Cairns Planning Area, particularly those near a major port. The number of vessels at a reef location is considered to make more of a visual impact than the number of people, and thus may be a better indicator of social impacts.

Using multivariate and univariate models, I compare biological monitoring data with the perceptions of reef quality of regular reef users. Comparisons between the quality variables "coral cover" and "diversity of fish species" suggest higher quality sites have more hard coral, less soft coral and fewer fish species commonly associated with branching corals in back reef locations. In addition, I demonstrate that scientific information could be used to predict areas that could be of high quality for marine park users.

Using decision support software and other statistical techniques, I demonstrate how marine protected area managers could integrate social and biophysical data to develop and evaluate marine protected area planning at a local scale. Comparisons between management settings, information from the survey of regular reef users and data from biological monitoring programs indicate that the Cairns Area Plan of Management maintains current levels of use but does not necessarily reflect diversity in abundance of reef biota at different locations.

This thesis demonstrates the need for formulation of very clear and specific aims and objectives for a marine protected area, prior to the application of different management tools (e.g. settings). When these aims and objectives are clear, input from scientists is necessary to help identify: (a) exactly what needs to be protected and in what manner (b) specific information requirements needed to meet the objectives.

In the case of the Cairns Planning Area, managers could have determined the relative importance of each objective to the overall goal of managing the area. The contribution of various datasets to each objective could then have been determined by scientists. In this way a clear, transparent and flexible decision process for allocating use in the area could have been developed.

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Chapter 1. Introduction

1.1 Background

> "*Coral reefs around the world are being damaged or destroyed at an increasing rate. The estimates in the Status of Coral Reefs of the World: 2002 report that 27% of the world's reefs have been effectively lost, including 16% which were severely damaged during the massive El Nino and La Nina climate changes of 1998. Another 14% are predicted to be destroyed in 2 to 10 years, and a further 18% in 10 to 30 years unless effective management of these valuable resources is implemented soon*." (Global Coral Reef Monitoring Network 2003*,* http://www.gcrmn.org/)

While much of the damage to coral reefs that has occurred in the last decade may be due to climate change, there is evidence that introduction of good local management practices can slow or even reverse adverse changes (Wolanski and De'ath 2005). The *Status of Coral Reefs of the World: 2002* report notes that about half of the 16% of reefs damaged in 1998 are showing encouraging recovery, with the best recovery in well managed or isolated reefs (Wilkinson 2002). It is widely believed that establishment of Marine Protected Areas (MPAs)[1] is important in conserving coral reefs and other important ecosystems (National Center for Ecological Analysis and Synthesis 2001). In 1988, the World Conservation Union (IUCN) recommended that the development of an international system of marine protected areas should be an integral component of marine conservation and management throughout the world.

In Australia, the National Representative System of Marine Protected Areas forms a part of a national strategy for marine conservation and management (ANZECC TFMPA1998b).

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[1] **marine protected area:** any area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or effective means. (ANZECC TFMPA 1998 a, b; IUCN 1994).

This strategy aims to establish a national system of MPAs which contains comprehensive[1], adequate[2] and representative[3] samples of Australia's marine ecosystems.

The Great Barrier Reef Marine Park (GBRMP) off Australia's East Coast is arguably the ‘jewel in the crown’ of Australia’s National Representative System of Marine Protected Areas. It is the world's largest marine protected area, stretching 2,300 km along the north east coast of Australia and 100-300 km offshore, covering a total of 344,400 km^2 (GRBMPA 2005a). It includes some of the richest and most complex ecosystems on earth (GBRMPA 2005a). Because of its international importance, it has been listed as a World Heritage Area (GBRMPA 1981).

The Australian Commonwealth government agency responsible for the conservation and management of the GBRMP is the Great Barrier Reef Marine Park Authority (GBRMPA). The GBRMPA pioneered the multiple use marine protected area concept, which has served as a model for management of marine parks throughout the world (Kenchington 1990, Whitehouse 1993).

The objectives for the management of the GBRMP are aligned with the IUCN objectives for marine protected areas. The goal of the GBRMP is:

> "*to provide for protection, wise use, understanding and enjoyment of the Great Barrier Reef World Heritage Area in perpetuity*" (Kenchington 1990).

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[1] c**omprehensive**: the NRSMPA will include the full range of ecosystems recognised at an appropriate scale within and across each bioregion (ANZECC TFMPA 1998a,b)
[2] **adequate**: the NRSMPA will have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities (ANZECC TFMPA 1998a,b).
[3] **representative**: those marine areas that are selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive (ANZECC TFMPA 1998a,b).

Through legislation and international obligations, the GBRMPA was charged with the responsibility of protecting and maintaining the marine environment while allowing for sustainable use (Chapter 2, Section 2.5.1). However, our understanding of how much use is sustainable and compatible with the protection of the natural resource is limited (Lawrence *et al*. 2002). As a result, the GBRMPA is required to implement a conservative or precautionary approach to managing use of the marine park *(Environment and Biodiversity Conservation Act, C'wlth 1999)*.

Zoning and management plans were developed by the Authority as spatial planning mechanisms to manage use of the GBRMP. Zoning Plans are statutory documents that set out the conditions of use and access in different sections of the GBRMP on a regional spatial scale. Zoning establishes the overall framework for the conservation and regulation of use of a region and is the umbrella under which other management mechanisms are deployed (Lawrence *et al*. 2002).

From 1996, the GBRMPA's approach to zoning began to incorporate strategies to apply the National Representative System of Marine Protected Areas (NRSMPA) strategy within the GBRMP. This process was subsequently became known as the GBRMPA Representative Areas Program. The aim was to zone the entire marine park simultaneously in an integrated plan, using bioregions identified through a scientific process as a basis for selecting suitable representative areas (Bowen and Bowen 2002, GBRMPA 2005a, Fernandes *et al.* 2005). In June 2003, the draft zoning plan for the entire marine park was released for public comment. In May 2004, the Australian National Parliament passed the final revised zoning plan. This plan is now the primary instrument for planning and conservation in the GBRMP at a broad spatial scale (GBRMPA 2004).

Management plans complement zoning plans by addressing issues and areas on a more localised scale. Management plans can be updated more rapidly than zoning plans (because changes are not required to be laid before parliament for consideration) and allow for a more flexible and adaptive management approach to address site-specific issues. In the GBRMP, management plans are statutory documents which may be developed for areas, species or ecological communities that are considered threatened. The objectives of Management Plans are considered in Chapter 2.

Management plans were first developed for the Cairns and the Whitsundays Areas in the marine park, because these are the parts of the GBRMP that experience the greatest pressures from human use. Both plans designate levels of access to specific locations in terms of settings. Locations are designated as low, moderate or intensive use settings depending on the number of vessels allowed at that location. In essence, these plans specify formal estimates of acceptable use at each site (Lawrence *et al.* 2002).

Use management at this localised scale is a complex process because of political and legislative requirements and the diversity of user groups. It is therefore essential to have accurate, reliable and easily updateable information to inform decisions for appropriate levels of use and to guide the development of management instruments for a given area. This thesis focuses on the challenge of using social and biophysical information to plan for reasonable use of the marine park through the use of Area Management Plans, using the 1998 Cairns Area Plan of Management as a case study. The Cairns Area was chosen as the case study because it was (and is) the area of highest use in the GBRMP and thus experienced the most impact from human pressures. When I began work on the thesis, the GBRMPA was seeking public comment on the proposed management plan for the area and I was asked to assist in this process. The information gathered during this thesis fed into the Representative Areas Programme and the rezoning of the Cairns to Cooktown Management Area, but was most relevant to the development of the Cairns Area Plan of Management.

1.2 Research problem and questions

The Cairns Sector of the marine park extends from offshore Mission Beach in the south to just north of Lizard Island and covers approximately 3,600,000 hectares (Figure 1.1). It was declared a section of the Great Barrier Reef Marine Park on 19 November 1981. The first zoning plan for the section was completed by November 1983 and the second such plan was completed by November 1992. The 2003 zoning plan identifies the Cairns Sector as the Cairns to Cooktown Management Area and has maintained the Section Boundary (GBRMPA 2004). The area contains 160 reefs, 54 islands and 32 cays (Ivanovici 1984). Most locations are within close proximity to major ports and the Cairns International Airport and are easily accessed by a rapidly growing tourism industry and increasing resident population.

There is a wide diversity of use of the Cairns Sector, ranging from scientific research to traditional hunting to commercial fishing and tourism. In the late 1990s, there was concern that the growing demand for access to the area would soon surpass the number of available sites (Honchin 1996) and therefore threaten the values of the area. The 1992 zoning plan for the Cairns Sector was not adequate to address the management issues and use conflicts at an appropriate planning scale. The resultant planning deficit was of great concern to managers and reef users. Therefore, even though the overall GBMP zoning plan was in the process of being updated via the RAP, a separate Area Management Plan was developed for the Cairns Planning Area in 1998 (Figure 1.1). The Cairns Planning Area in this management plan was smaller than the Cairns Sector, as it was not considered urgent to develop management instruments for the low use area offshore of Cooktown (GBRMPA Planning Staff, personal communication 1996). It is this 1998 version of the Cairns Area Management Plan that is used as the case study in this thesis. This plan has recently been revised as a result of the recent rezoning of the entire Marine Park. Although the revised plan was not part of my case study, I consider it further in Chapter 8.

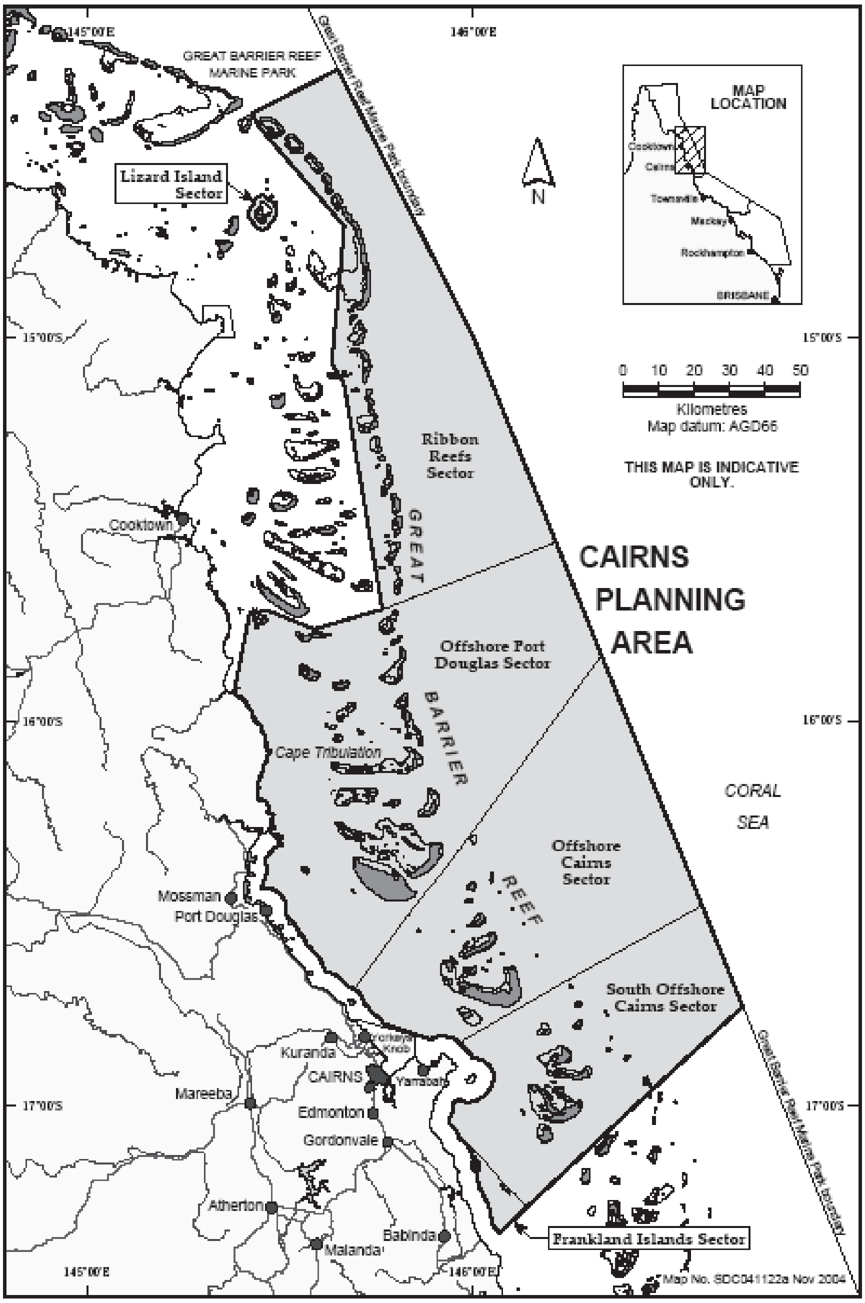

Figure 1.1: The Cairns Planning Area within the Cairns Sector of the Great Barrier Reef Marine Park (GBRMPA 1998)

In order to allow for reasonable use of an area, it is important for managers to consider the types and levels of use and the settings they wish to maintain. Consequently it is important to understand how people perceive the resource they use and what environmental conditions influence their experience and behaviour (Shafer *et al.* 1998). If people using the Cairns Sector of the marine park receive different types and amounts of benefit from different components of the resource (Driver and Brown 1978, Driver *et al.* 1987), then there is justification for designating spatial areas of resource use that best meet their requirements.

Although several researchers have described use patterns in the GBRMP (e.g. Shafer *et al.* 1998, Green *et al.* 1999, Inglis *et al.* 1999), most studies have concentrated on one particular user group at one or a few locations. Also, while there is general acceptance of the importance of social and cultural impacts of marine tourism on the GBRMP, there have been only a few studies that explore the relationship between ecological impacts and social and cultural impacts (Green *et al.* 1999, Shafer and Inglis 2000, Harriott 2002). This thesis integrates biophysical and social data and provides an analysis of the interaction between human perceptions and the ecological status of the reef resources. In addition, it explores the challenge for managers to make cost-effective use of scientific information.

The social data for this thesis were collected at the same time as the GBRMPA was developing the 1998 Cairns Area Plan of Management. My results therefore provided an opportunity to evaluate the planning process, the use of biophysical and social information and the mechanisms by which use of the Area is managed.

In order to achieve my goal of integrating biophysical and social data to evaluate and improve marine protected area planning, my thesis had the following objectives:

1. to assess the criteria and methods used by government agencies to allocate resource use in the Great Barrier Reef Region (GBRR) at regional and local scales;

2. to identify ways in which existing information on reef resources can be integrated into a format that is easy to access and use;

3. to develop methods to help managers map the locations of various types of use;

4. to develop methods to assess the relationships between information on marine ecosystems and patterns in human use, perceptions and values;

5. to apply a decision support system to review the site-based management settings in the 1998 Cairns Area Plan of Management from the perspective of the plan's objectives and information base.

1.3 Structure of the Thesis

In Chapter 2, I present the results of a review of marine conservation, marine protected areas and the historical context of the GBRMP. In Chapter 3, I review the goals, criteria and methods used in MPA selection and planning. In Chapter 4 I conduct a review of information available for planning and management of coral reefs, using the Cairns Sector of the GBRMP as a case study.

In Chapter 5, I report the results of my survey of regular reef users. I conducted this survey because the reviews reported in Chapters 2 to 4 showed that, while there was a considerable amount of information available describing the physical and biological conditions within the area, there was limited information on the social conditions. In order to understand how various user groups perceive, value and experience the natural and social environment in the Cairns Sector, I conducted a survey that aimed to: (1) identify issues of concern in the Cairns Sector; (2) describe attributes of stakeholder groups who regularly use the area; (3) identify physical, biological and social indicators of resource and social conditions in the area, inventory social conditions and perceptions of the resource; and (4) provide data necessary to make comparisons between social perceptions and ecological status of the reef resources.

In Chapter 6, I use multivariate and univariate models to make comparisons between the human perception of reef resources reported in Chapter 5 and scientifically measured indicators of coral reef status. This information is used to assess the ability of humans to perceive and monitor environmental variables. In Chapter 7, I demonstrate the use of a decision support system which integrates available biophysical and social information to support use allocation decisions. In Chapter 8, I summarise the results of the thesis and identify opportunities for further research.

Chapter 2. Conservation, benefits and impacts of marine protected areas

This chapter discusses the importance of marine conservation and the development of marine protected areas. It reviews the types of MPAs that have been developed around the world and describes some of the benefits and impacts of marine protection. In addition, this chapter identifies the need for development of clearly defined, applicable and functional objectives for MPAs.

2.1 Conservation of marine environments

There is wide acceptance that marine ecosystems worldwide are being degraded by increasing human use (Wilkinson 2002). Impacts from activities such as over fishing, pollution, introduction of pests, coastal agriculture and development have affected marine biodiversity in most areas, particularly along heavily populated coasts but also in more remote areas and offshore.

Marine biodiversity can be defined as

> "*the variability among living organisms from all sources, including …. terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems*" (IUCN 1994).

There are many benefits associated with protecting marine biodiversity. The three major categories of benefits identified by Day and Roff (2000) include:

1. Loss of diversity generally weakens entire natural systems and could make marine ecosystems more susceptible to natural and artificial disturbance.

2. Biological diversity represents one of our greatest resources and many of the materials and organisms found in the marine environment could provide new

sources of food, fibre, medicine, energy and scientific and industrial innovations.

3. Humans benefit from natural areas and depend on healthy ecosystems for air, water, food and socio-economic values.

2.2 Marine Protected Areas (MPAs)

Marine protected areas (MPAs) are increasingly being used as a major tool for conserving marine biodiversity, protecting marine habitats and ensuring the sustainability of harvest fisheries (Kelleher *et al.* 1995, Creese and Breen 2003, Lubchenco *et al.* 2003). MPAs can be defined as:

> "*Any area of intertidal or sub tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment.*" (Resolution 17.38 of the IUCN 1988, reaffirmed in Resolution 19.46 1994).

The effectiveness of MPAs in protecting biodiversity varies according to their size, degree of protection, activities that are restricted, compliance, MPA designation and whether the designation restricts polluting activities that occur outside the MPA but which threaten life within the MPA (Day and Roff 2000, Halpern 2000, Creese and Breen 2003). There are two main types of management structure for MPAs. In the "park model", a federal or state conservation agency declares certain areas out of bounds for some or all activities (e.g. designates no take or sanctuary areas) and takes responsibility for policing these restrictions. In the "community based model", local coastal communities assume many of the responsibilities for implementing, monitoring and enforcing the rules protecting their marine areas (Christie *et al.* 2002).

2.2.1 Types of MPA

2.2.1.1 Categories and definitions

There are many categories of marine protected areas available to government and non-governmental agencies throughout the world. As a result of the variety of definitions and objectives, numerous terms have been used to describe various types of MPAs throughout the world. These terms include marine park, marine reserve, fisheries reserve, closed area, marine sanctuary, marine or coastal protected area, nature reserve, ecological reserve, replenishment reserve, coastal preserve, area of conservation concern, sensitive area, biosphere reserve, no-take area, coastal park, national marine park, marine conservation area and marine wilderness area (Agardy *et al.* 2003). However, the World Conservation Union (IUCN) has recommended the use of the following seven protected area management categories (IUCN 1994, 2000), each of which has different primary objectives:

> ***"Ia Strict Nature Reserve: Protected Area managed mainly for science.*** *This is an area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available mainly for scientific research and/or environmental monitoring.*
>
> ***Ib Wilderness Area: Protected Area managed mainly for wilderness protection.*** *This is a large area of unmodified or slightly modified land and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.*
>
> ***II National Park: Protected Area managed mainly for ecosystem conservation and recreation.*** *Natural area of land and/or sea, designated to protect the ecological integrity of one or more ecosystems for this and future generations; exclude exploitation or occupation inimical to the purpose of designation of the area; and provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.*
>
> ***III Natural Monument: Protected Area managed for conservation of specific natural features.*** *This is an area containing one or more specific natural or nature/cultural feature which is of outstanding value because of its inherent rarity, representative or aesthetic qualities or cultural significance.*
>
> ***IV Habitat/Species Management Area: Protected Area managed mainly for conservation through management intervention.*** *This is an area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.*

V ***Protected Landscape/Seascape: Protected Area managed mainly for landscape/seascape conservation and recreation.*** *An area of land, with coasts and seas as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, cultural and/or ecological value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.*

VI Managed Resource Protected Areas: Protected Area managed mainly for the sustainable use of natural ecosystems. *An area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.*"

Implicit in this categorization is the recognition that MPAs which are managed for sustainable use can also make an important contribution to biodiversity conservation goals in a region (Ward and Hegerl 2003). MPAs may incorporate one or more IUCN categories through the use of zones and other management tools and can range in size from large multiple-use marine parks to fisheries closures to small no take reserves. MPAs can also provide various levels of protection, ranging from habitat protection to comprehensive protection of all biodiversity from the effects of human use and disturbance. The various types of MPAs are discussed briefly below.

2.2.1.2 No take marine reserves

A no take marine reserve is a special category of marine protected area which is also known as an ecological reserve or fully protected reserve. Such a reserve provides the highest level of protection out of all the categories of MPA and confers complete protection from all extractive activities. No take reserves are most likely to be established on their own or within MPAs of IUCN Category IA, IB or II (Ward and Hegerl 2003).

No take marine reserves prohibit all fishing, collecting of flora and fauna and removal of substrate, but do allow for non-extractive activities such as sailing, surfing, nature appreciation, swimming, and other activities that do not have any significant impact within the area.

2.2.1.3 Fisheries closures

Fisheries closures represent another type of MPA, primarily established to maintain fish stocks and associated important habitats. This type of MPA ranges from large closures that prohibit the use of specific fishing methods (such as trawling) to small areas designed to protect specific habitats and nursery grounds (Ward and Hegerl 2003).

2.2.1.4 Multiple use marine parks

Multiple use marine protected areas balance sustainable use with conservation of marine biodiversity. They provide conservation management of large areas, managing resource use by means of a variety of spatial and temporal regulations. Most are listed as IUCN Category VI, but some of the zones within these marine parks comply with other IUCN categories (Lawrence *et al*. 2002). For example, within the Great Barrier Reef Marine Park, Preservation Zones and Scientific Research Zones comply with IUCN Category IA. In addition, 33% of the entire Great Barrier Reef Marine Park is made up of no take zones (IUCN Categories Ia and II).

2.2.2 Benefits of MPAs

In areas identified and then selected as requiring protection, the establishment of MPAs can benefit both the natural environment and the people who use it. Several of these benefits are discussed in this section.

2.2.2.1 Conservation of biodiversity and ecological processes

MPAs can protect and manage the marine environment to minimize the effects of human activities on biodiversity. The formation of a marine protected area can prevent further loss of biodiversity (Gray 1997), by protecting endangered or threatened species through specific management plans to protect breeding grounds and essential habitat.

2.2.2.2 Commercial fisheries and aquaculture

MPAs can enhance fisheries of vulnerable species through the protection of important breeding and nursery grounds. Such protection ensures the conservation and continued development of the fish resource and can lead to recovery of depleted stocks (Badalamenti *et al.* 2000). Studies have demonstrated that MPAs have an affect on resident assemblages of organisims (e.g. Edgar and Barrett 1999, Babcock *et al.* 1999, Planes *et al.* 2000, Jamieson and Levings 2001).

In addition, increased protection within a reserve or MPA can have spillover effects that contribute to increased numbers of that species outside the protected area. Such spillover effects may have great benefits to the local fisheries and may offset the loss of fishing areas resulting from the establishment of the MPA (Rowley 1994, Roberts *et al.* 2001).

2.2.2.3 Scientific research

MPAs provide areas that are suitable for scientific study precisely because human activities are limited or controlled there. Areas within MPAs can be zoned specifically for research and can thus provide control sites for studies comparing areas of zero human use to areas of high use.

2.2.2.4 Educational opportunities

MPAs provide educational opportunities through the development of educational programs and resource kits. They provide examples of natural marine areas which can be used to increase public understanding and commitment to marine park management (Salm and Clark 1984). Education can be used to increase environmental awareness and decrease the negative impacts of visitors.

2.2.2.5 Tourism and recreation

MPAs encourage the development of tourism and recreational activities. Zoning is often done specifically to provide for a range of tourism and recreational activities, including low use areas, moderate use areas and intensive use areas. Such zones allow for varying degrees of appreciation of the marine environment. When effectively managed, ecologically sustainable tourism can help meet marine protected area (MPA) objectives by providing for public appreciation, understanding and enjoyment while maintaining marine biodiversity, habitats and processes.

Increased tourism generally brings significant economic benefits to local economies, allowing for the development of regional business and employment opportunities (McIntyre 1998). The financial benefits of tourism to marine protected areas are widely recognised and MPAs are often publicised by tourism operators in their advertising material, illustrating the operators’ belief in the drawing power of protection for conservation (Driml 1994). In many cases, the existence of a protected area status actually increases visitor satisfaction (Davis *et al.* 1995).

According to the Australian Ecologically Sustainable Working Group on Tourism established by the Australian government, attributes of the environment such as good beaches, natural wonders, wildlife, scenic beauty, cleanliness and vastness influence tourists in their decision to travel to Australia (Commonwealth of Australia 1991). An important component of this nature based tourism is the possibility of having an educational experience like seeing and observing animals, plants and landscapes and being provided with information about the biology or ecology of species and regions (Blamey 1995).

Marine related tourism is an important component of nature based tourism and recreation. The natural features and values that lead to an area's being identified and declared as a marine protected area also attract visitors and tourism business. An area's conservation status as an MPA provides potential visitors with an official indication of the natural value of an area and the care taken to protect its condition and quality (Breen 2000). The research and media coverage associated with MPAs and their natural features also create visitor interest.

In more remote areas, marine tourism is considered necessary to the success of MPAs. According to Badalamenti *et al.* (2000), the revenue from tourism activities can be vital for depressed economies, but can also have a negative impact if either the biological or social carrying capacity of the area is exceeded. The effect of MPAs on individual tourists varies depending on their relationship with the area and the activities in which they participate. Badalamenti *et al.* (2000) categorised tourists into two groups, winners (those who benefit from the MPA status) and losers (those who are adversely affected).

"Winners" are mainly new tourists who discover a new environment and generally have no past experiences with which to make comparisons. Many of these tourists participate in mass tourism. If left uncontrolled they have been shown to have negative effects on benthic communities (Harriott *et al.* 1997), particularly seagrass (Martinez *et al.* 1999), coelenterates and bryozoans (Sala *et al.* 1996) and intertidal assemblages (Kay and Liddle 1989).

The "losers" are mainly repeat visitors who often have strong attachments to the unique characteristics of the MPA (Badalamenti *et al.* 2000). They may experience resentment towards the growing number of "winners" and the restrictions imposed by MPAs. They perceive a loss in accessibility, freedom to participate in their activities and the wilderness or remoteness of the location. This group particularly includes recreational fishers and boaters.

Local communities may also feel significantly resentful. Thus Badalamenti *et al.* (2000) and others have recommended that it is important to include local communities in the planning and selection of MPAs (Salm and Clark 1984, Fiske 1992, Wells and White 1995, Bersales 1996, Caldecott 1996, Boshnsack 1997, Badalamenti *et al.* 2000). Locals are generally sensitive to the issues involved and receptive to educational programmes and thus may not require as many restrictions on their activities as do tourists (Alder 1996). Involving local communities at all stages of planning and managing MPAs increases the likelihood of long term success for the protected area.

2.2.3 Impacts of MPAs

Despite the numerous benefits of MPAs, there are a number of issues and conflicts that surround them. These problems mainly relate to the limited amount of information that is available on marine resources and limited knowledge of human-caused impacts. The main conflicts arise from human displacement and the difficulty managers have in determining priority uses for an area.

For example, recreational fishers are probably one of the most affected user groups when MPAs are established, especially in areas where fishing is prohibited (Badalamenti *et al.* 2000). The creation of the MPA can cause a large reduction in the size and accessibility of their fishing ground resulting in resentment from fishers.

However decisions regarding MPAs, particularly with regard to their initial establishment, zoning and formulation of management plans, are often very contentious - and with good reason. Such decisions will often dramatically affect the livelihoods, lifestyles and cultures of many businesses, families and communities that have become specifically adapted to living and working in the environment. In particular, commercial, recreational and subsistence fishers are usually the most directly impacted community groups.

While potential benefits of MPAs for fisheries have been expounded in several recent reviews (e.g. Agardy *et al*. 2003) these benefits have not always been demonstrated in practice, or for all areas. Where benefits do occur, they may not accrue within time scales sufficient to sustain specific individuals and communities, and even when they arrive such benefits may actually go to, for example, other fishers or different stakeholder interests such as tourism, recreation and conservation.

While MPA initiatives often include provisions for review, any review will usually occur too late to compensate for the impacts of MPA establishment on individual fishers and communities. Also, in practice, decisions to revoke MPAs or rezone "no take" areas for fishing are rare. Thus despite the best intentions, or perhaps even the implementation of an adaptive management cycle, the initial application of a MPA strategy is likely to have the greatest impact and will strongly determine the future shape and social implications of the MPA. It is therefore absolutely critical that the initial configuration has objectives that are precisely defined, functional and applicable, is based on the best available information and uses the best available methods and processes.

While progress has been made in recent years in developing appropriate ecological objectives and making use of environmental and ecological data (Breen *et al.* 2004), research on the social impacts and benefits of MPAs is limited and its input into decision making is relatively informal, usually politically motivated and driven and of relatively low priority in decision processes. This paucity of information on social impacts and benefits was the reason for conducting the survey reported in Chapter 5 and 6 of the present thesis.

2.3 The Great Barrier Reef Marine Park

The Great Barrier Reef Marine Park is the world's largest multiple use MPA. As such it is used as a model for multiple use marine park management all over the world. I provide details of the GBRMP because it is the site of my case study, as outlined in Chapter 1.

2.3.1 The Great Barrier Reef Region

The Great Barrier Reef is the largest system of coral reefs in the world, covering 349,000 km^2 of which 345,400 km^2 are contained within the Great Barrier Reef Marine Park boundaries. The GBRMP is over 2,000 kilometres long, extending from Bundaberg in the south to Torres Strait in the north. The park includes approximately 2,900 reefs, 600 islands, 300 cays and 44 wooded islands. The area has high conservation value and is listed as a World Heritage Property.

The Great Barrier Reef Region (GBRR) is a significant economic region with direct and indirect economic activity estimated at over $3.5 billion (Australian Dollars) per year (total value added) and gross product at over $4.1 billion (Australian Dollars) per year (Access Economics 2005). Tourism is the major and most rapidly growing economic activity in the region (GBRMPA 1997, Access Economics 2005). Other commercial activities include fishing, mariculture, shipping, ports and their associated activities. Recreational activities include fishing, boating, diving, snorkelling, coral viewing and island camping. Scientific research is conducted throughout the park, with zones set aside specifically for this purpose. Cane growing, horticulture and grazing are the major land based activities adjacent to the GBRR. Under the *Native Title Act, Commonwealth 1993*, traditional hunting of dugong, turtles and sea birds was permitted in the GBRR. However, scientific evidence suggests that current harvest levels of dugongs are unsustainable and thus require greater regulation (Havemann *et al.* 2005). Traditional Use of Marine Resources Agreements (TUMRA) are being developed to manage traditional use of the marine resources in the context of biodiversity conservation, protection of threatened species and traditional and cultural use (Havemann *et al.* 2005).

2.3.2 Establishment of the Great Barrier Reef Marine Park

During the 1960s and early 1970s, public concern about human and natural threats to the GBRR increased (Kenchington 1990). The environmental risks associated with oil drilling and exploration potentially threatened the conservation of the resource, with nearly 210,000 km^2 of the GBRR being leased for mineral or oil exploration by 1967 (Kenchington 1990). Concern was also expressed over the then rapidly expanding North Queensland commercial fishing industry and the number of foreign fishers who regularly collected reef fish, turtles, giant clams and shells from the area (Kenchington 1990). In addition, Crown of Thorns starfish outbreaks were occurring throughout the reef region, decimating some reefal areas. The final cause for concern was the mining of Ellison Reef.

In light of these issues, it became apparent that the GBRR needed more effective management protection. In 1975 the Commonwealth Government of Australia passed the *Great Barrier Reef Marine Park Act* (the Act). The Act established and enabled the Great Barrier Reef Marine Park Authority (GBRMPA) to regulate use of the park through a system of zoning, management plans and permits. Under the Act, resource use decisions are made in consultation with the state government, federal government, stakeholder and local community groups. This system aims to allow multiple use of the marine park by different groups while avoiding conflicting interests, restrict access to sensitive areas and maintain sustainable use.

Agreements between the Queensland and Commonwealth Governments set up a system of shared management of the marine park (*Emerald Agreement, 1979*). These joint management arrangements were developed mainly in an attempt to overcome jurisdictional problems between the two Governments. In essence, the Authority is responsible for policy and planning for the marine park, while the Queensland Government is responsible for implementing day to day management. In addition, the Queensland government has direct management responsibility for the majority of the islands, cays and inshore areas within the World Heritage Area.

2.3.3 Legal obligations of the Great Barrier Reef Marine Park Authority

2.3.3.1 International agreements

International Conventions relevant to the Great Barrier Reef, include the following:

- *Convention on Wetlands of International Importance Especially as Waterfowl Habitats, 1971 (the Ramsar Convention)*
- *Convention for the Protection of the World Cultural and Natural Heritage 1972 (the World Heritage Convention)*
- *Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973 (CITES)*
- *International Convention for the Prevention of Pollution from Ships, 1973 (the MARPOL Convention)*
- *Convention on the Conservation of Migratory Species of Wild Animals, 1979 (the Bonn Convention)*
- *United Nations Convention on the Law of the Sea, 1982 (the Law of the Sea Convention or UNCLOS)*
- *Marine Pollution – International Convention on Prevention of Pollution of Seas by Ships (MARPOL) 1987 –* implemented through the Navigation Act and Protection of Sea Act. The Great Barrier Reef Marine Park was the first 'Particularly Sensitive Sea Area' designated under the MARPOL Convention.
- *United Nations Framework Convention on Climate Change, 1992 (the FCCC*
- *Convention on Biological Diversity 1992 (the Biodiversity Convention)*

- *Japan – Australia Migratory Bird Agreement (JAMBA) and China – Australia Migratory Bird Agreement (CAMBA) 1988*

Of particular importance to the management of the GBRR is the relevant statutory obligation to manage the region as a World Heritage Property. The Great Barrier Reef was inscribed on the World Heritage List in 1981 (GBRMPA 1981), pursuant to the World Heritage Convention. The GBRR was nominated for world heritage listing in 1981 for both cultural and natural heritage criteria. The nomination for cultural criteria states:

> "*The area of this nomination contains many middens and other archaeological sites of Aboriginal or Torres Strait Islander origin. There are over 30 historic shipwrecks in the area, and on the islands there are ruins and operating lighthouses which are of cultural and historical significance* " (GBRMPA 1981).

The nomination for natural heritage states:

> "*The Great Barrier Reef is by far the largest single collection of coral reefs in the world. Biologically the Great Barrier Reef supports the most diverse ecosystem known to man. Its enormous diversity is thought to reflect the maturity of an ecosystem which has evolved over millions of years on the north east Continental Shelf of Australia.*
>
> *The Great Barrier Reef provides some of the most spectacular scenery on earth and is of exceptional natural beauty. The Great Barrier Reef provides major feeding grounds for large populations of the endangered species Dugong dugon and contains nesting grounds of world significance for the endangered turtle species green turtle (Chelonia mydas) and loggerhead turtle (Caretta caretta)*" (GBRMPA 1981).

2.3.3.2 Commonwealth Australia legislation

The following Commonwealth (Australian federal) legislation and regulations affect the management of the GBRMP:

2.3.3.2.1 Commonwealth legislation specific to the GBRMP

- *Great Barrier Reef Marine Park Act 1975*
- *Great Barrier Reef Marine Park (Environmental Management Charge-Excise) Act 1993*
- *Great Barrier Reef Marine Park (Environmental Management Charge-General) Act 1993*

2.3.3.2.2 *__Regulations in force under the Great Barrier Reef Marine Park Act 1975__*

- *Great Barrier Reef Marine Park Regulations 1983*
- *Great Barrier Reef Region (Prohibition of Mining) Regulations 1999*
- *Great Barrier Reef Marine Park (Aquaculture) Regulations 2000*
- *Great Barrier Reef Marine Park Regulations 2003*

2.3.3.2.3 *__Commonwealth legislation relevant though not specific to the GBRMP:__*

- *Australian Heritage Commission Act 1975*
- *Historic Shipwrecks Act 1976*
- *Environment Protection (Sea Dumping) Act 1981*
- *Protection of the Sea (Prevention of Pollution for Ships) Act 1983*
- *Sea Installations Act 1987*
- *Native Title Act 1993*
- *Environment Protection and Biodiversity Conservation Act 1999*

While 93% of the world heritage property is within GBRMPA's jurisdictional boundaries, the other 7% is contained in Queensland waters and islands and is subject to Queensland law. Although the GBRMPA manages most of the property, it is limited in its ability to managed areas within Queensland government jurisdiction. In addition, GBRMPA does not directly manage commercial fishing within the marine park even though it is the main extractive industry within its waters. Thus no single management authority has complete responsibility for the World Heritage Property, leading to a number of complex jurisdictional issues and a challenging management system for an area of global importance.

2.3.3.3 Queensland State legislation

The formal arrangements for the division between Commonwealth and State jurisdictions were established in a series of agreements between the Commonwealth Government and the Queensland Government from 1979 to 1988. In 1979 the Emerald

Agreement was reached between the Prime Minister and the Queensland Premier (Whitehouse 1993). This agreement dealt mainly with the joint administration of the Capricornia Section. It recognised that the *Great Barrier Reef Marine Park Act 1975* would apply to the low water mark, it formalised the role of the Queensland government in day to day management of the GBRMP and it established a ministerial council to coordinate policy. In the 1980s additional agreements were signed to manage the division of assets and extend the day to day management role of the Queensland Environment Protection Agency (formerly known as Queensland Department of Environment and Heritage) to the rest of the marine park. These agreements set the foundation of QEPA's role in the Marine Park's administration, education and information, monitoring, resource management, surveillance and enforcement.

In addition, the Queensland government has direct management responsibility for the majority of the islands, cays and inshore areas within the Marine Park. However, the definition of Queensland jurisdiction is complicated for two reasons. Firstly, the dynamics of the marine environment can cause the shoreline, islands and cays to change shape and position, or even, in the case of cays, to disappear (Kenchington 1990). Secondly, the State and the Commonwealth have different definitions for the boundary between their direct management areas, which is known as the low water mark. The Commonwealth defines the low water mark as the mean low water mark and the State defines it as the low of Indian Springs (Kenchington 1990).

In order to assist coordination between State and Commonwealth management agencies, the Great Barrier Reef Ministerial Council was formed in 1979 through the Emerald Agreement. The Council is composed of two Commonwealth Ministers and two State ministers. This Council usually consists of the Commonwealth and State ministers for the environment and a further Commonwealth and State minister responsible for a portfolio of relevance to the marine park (e.g. Minister for Industry, Science and Technology).

2.3.3.3.1 <u>Queensland Legislation relevant to the Great Barrier Reef</u>

- *Marine Parks Act 1982*
- *Nature Conservation Act 1992 (Qld)*
- *Native Title (Queensland) Act 1993*
- *Environmental Protection Act 1994 (Qld)*
- *Fisheries Act 1994 (Qld)*
- *Transport Operations (Marine Safety) Act 1994 (Qld)*
- *Coastal Protection and Management Act 1995 (Qld)*
- *Transport Operations (Marine Pollution) Act 1995 (Qld)*
- *Integrated Planning Act 1997 (Qld)*

2.3.4 Planning for use of the Great Barrier Reef Marine Park

In order to meet the legal obligations conferred by all the Acts, Regulations, Agreements and Conventions listed in Section 2.3.3, two types of management planning are conducted by the GBRMPA:

1) Strategic planning and policy development sets guidelines to facilitate management of the marine park through various management instruments and coordinates the State of Queensland's involvement in the process

2) Statutory planning sets limits of use in the marine park and develops the management instruments that regulate activities.

With regard to strategic planning, there exist a wide range of strategic planning statements and documents, covering many topics across many spatial scales. The strategic planning structure is established by:

- *Great Barrier Reef Marine Park Act, 1975*
- Government and Ministerial Councils policies and agreements
- International treaties and agreements
- Authority policies and decisions
- the Great Barrier Reef World Heritage 25 Year Strategic Plan
- Corporate Plans
- annual and triennial budgets
- three year rolling and annual DDM programs.

Statutory planning in the GBRMP is mainly conducted by the mechanisms of zoning plans, management plans and permitting, as outlined in Chapter 1. The following section considers these approaches in more detail.

2.3.4.1 Zoning plans

Zoning Plans are statutory documents that set out the conditions of use and access in the GBRMP on a regional scale. Zoning establishes the overall framework for the conservation and regulation of use of a region and is the umbrella under which other management mechanisms are deployed (Lawrence *et al*. 2002). Zoning Plans regulate locations of extractive and non-extractive use, but do not regulate levels of use within zones.

For example, the current zoning plan (GBRMPA 2004) set aside 33% of the GBRMP as a network of no take areas. This zoning plan was developed to establish a no take reserve system with a comprehensive, representative and adequate sample of each community type and physical environment. It also included areas of historical and cultural importance and maximised complementarity with people's uses and values.

However it did not prescribe levels of use within the various zones. For example, in the Cairns to Cooktown Management Area, there are areas zoned for extractive use which are under threat from anchor damage. The zoning plan does not address such localized impacts, whereas the Area Management Plans do.

2.3.4.2 Area Management Plans

Management plans are statutory instruments that address issues on a more localised scale than zoning plans and may be developed for areas, species or ecological communities that are considered threatened. Area management plans allow for a more flexible and adaptive management approach to site-specific issues. Management plans have the following objectives:

- to ensure, for particular areas of the Marine Park in which the Authority considers that nature conservation values, cultural and heritage values, or scientific values, are, or may be, threatened, that appropriate proposals are developed to reduce or eliminate the threats
- to ensure management for the recovery and continued protection and conservation of species and ecological communities that are, or may become extinct; or extinct in the wild; or critically endangered; or endangered; or vulnerable; or conservation dependent
- to ensure that activities within areas of the Marine Park are managed on the basis of ecologically sustainable use
- to provide a basis for managing the uses of a particular area of the Marine Park that may conflict with other uses of the area or with the values of the area
- to provide for the management of areas of the Marine Park in conjunction with

community groups in circumstances where those groups have a special interest in the areas concerned

- to enable people using the Marine Park to participate in a range of recreational activities. (*Great Barrier Reef Marine Park Act, Commonwealth, 1975*)

Management plans were developed in the 1990s for the Cairns Area and the Whitsundays Area in the GBRMP and were updated in 2004. Both plans designate levels of access to specific sites in terms of settings. Locations are designated as low, moderate or intensive use settings depending on the number of vessels allowed at that location. In addition, the plans set aside areas for moorings and areas of anchoring.

2.3.4.3 Permitting and environmental management charge

Tourism operators require a license (or permit) in order to operate in the GBRMP. Most operators are entitled to standard licenses, which are described in the state and commonwealth regulations. There are seven categories of standard licenses: standard tour operation (vessel or aircraft less than 70m); long range roving operations (vessels less than 35m, 100 days access per year to the planning area); regional tour operation (vessel or aircraft less than 70m, all year access to the planning area); craftless operations (operations that operate from the beach or from other vessels to go to the reef); hire operation (includes hire craft and equipment and bareboats); support service operation (where a vessel or aircraft is used to service another vessel); and cruise ship operations (vessels more than 70m) (GBRMPA 2005b). The permit system relies on zoning plans and, to a greater extent, on management plans that contain the standard set of conditions and special requirements for each area. In addition, tourism operators are required to pay an Environmental Management Charge and lodge a quarterly return with the GBRMPA. The quarterly log book includes information collected daily on the vessel, numbers of crew, free of charge and transfer passengers and trip destination.

The GBRMPA also encourages wise use of reef resources through emphasis on the use of non-regulatory mechanisms including education, training and self-regulation through codes of practice.

2.4 Summary

This chapter summarises the importance of marine conservation and the development of marine protected areas throughout the world. It reviews the types of MPAs that exist around the world and discusses the benefits and impacts of marine protection. It introduces the Great Barrier Reef Marine Park and World Heritage Property, which is the world's largest and most complex MPA and is often used as a model for multiple use marine park management. The chapter also describes techniques for managing use in the GBRMP, with particular emphasis on local scale Area Management Plans.

This chapter also identifies the need for clearly defined, applicable and functional objectives and criteria to be developed for MPAs. Such objectives and criteria would assist with transparent and objective decision making regarding the social and economic values of marine resources during the planning and management of the MPA. The next chapter reviews marine protected area goals, objectives and selection criteria and the methods available to managers to assist with decision making.

Chapter 3. Goals, criteria and methods used in marine protected area planning

As discussed in Chapter 2, the need for a strategic and systematic approach to biodiversity conservation in marine protected areas (MPAs) is accepted both nationally and internationally. Therefore, the first half of this chapter reviews goals, objectives, criteria and guidelines for marine protected management.

In addition, a range of decision support modeling methods are available which can assist in the systematic use of data and information sources to select marine protected areas. These methods are reviewed in the second half of this chapter. Often, the results from these methods are regarded separately or combined in an *ad hoc* manner. There are, however, advantages in examining information from all sources simultaneously using a systematic process.

3.1 Marine protected area goals, information and decision making

While other conservation strategies may target specific organisms or threats, at least large scale MPAs represent a form of ecosystem management. Such MPAs potentially target many different species, habitats, ecological processes and human activities as a functioning and interrelated system, which includes both social and ecological components and processes.

Ecosystem management has been defined in a variety of ways. However, the central characteristics of ecosystem based management include:

- management for long term sustainability
- clearly defined goals
- recognition of ecological complexity and interconnectiveness

- recognition of the dynamic nature of ecosystems
- careful design of management systems to meet specific local conditions
- recognition of humans as a fundamental part of ecosystems
- recognition that our knowledge is incomplete, that ecosystems change and that management should be adaptive and should learn from management experiments. (Ecological Society of America 1995)

The goals of MPAs are often ecologically and socially complex, vary from location to location, and vary through time in response to environmental and social change. The range of information to assess alternative strategies and ultimately the outcomes of management decisions is also necessarily diverse. Interpretation and assessment of this information can therefore be difficult if not impossible for managers, scientists and stakeholders. The process of information management should not and need not be a process of simplification, but should "*retain the essential elements of the complexity of the real system*" and should "*work with, rather than eliminate or ignore complexity*" (Slocombe 1998).

There is also a need for adequate guidelines, processes and techniques with which to explore alternative decisions. The best available information needs to be used in ways that are understandable, repeatable and accessible to assessment and re-examination by a wide audience. Conservation responsibilities, especially at the ecosystem level, are not restricted to just one program, institution, industry, community or even government. Goals, information and processes must be universal enough to bridge gaps and address overlapping situations, interests and jurisdictions. "*As far as possible, goals and objectives should be as widely applicable as possible for simplicity's sake, for consistency, and as some rough measure of their robustness*" (Slocombe 1998).

At the same time, individual criteria must be flexible enough to address specific issues at a local level. Criteria need to be explicit enough to be objectively and rigorously assessed for review, but be comparable among different areas and situations, while still reflecting basic, fundamental, higher values and ethics (Slocombe 1998).

For MPAs these requirements are critical, especially for multiple use areas that aim to achieve a variety of different outcomes (Agardy 2002). Within multiple use MPAs, and particularly in MPAs as large and diverse as the GBRMP, management must have multiple objectives. A comprehensive, clearly documented and systematic approach to defining goals, objectives and criteria is therefore fundamental in ensuring that all aspects of management are considered.

3.1.1 Goals and criteria for the Australia / New Zealand National Representative System of MPAs

In Australia and New Zealand, goals and criteria for the management of marine protected areas have been developed and adopted by the governments of both countries (ANZECC/TFMPA 1998a, b 1999). These goals and criteria reflect over 30 years of international and national discussion, published research and practical management experience in protected areas (Kenchington 1992, Thackway 1996, Breen *et al.* 2004).

The primary goal of the Australian National Representative System of MPAs (NRSMPA) is to establish and manage a comprehensive, adequate and representative system of MPAs in order to contribute to the long term ecological viability of marine and estuarine systems, maintain ecological processes and systems and protect Australia's biological diversity at all levels (Breen *et al.* 2004).

The NRSMPA has also identified a series of secondary goals, including goals that provide for sustainable use, enjoyment and understanding of the marine environment consistent with maintaining biodiversity values. These goals and the criteria related to them provide the framework on which to base a systematic approach to identifying, selecting and managing marine reserves in Australia.

The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of MPAs to contribute to the long term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biological diversity at all levels.

The **secondary goals** are:

(a) To promote development of MPAs within the framework of integrated ecosystem management

(b) To provide a formal management framework for a broad spectrum of human activities, including recreation, tourism, shipping and the use and extraction of resources

(c) To provide scientific reference sites

(d) To provide for the special needs of rare threatened or depleted species and threatened ecological communities

(e) To provide for the conservation of special groups of organisms - for example, species with complex habitat requirements or mobile or migratory species or species vulnerable to disturbance and which may depend on reservation for their conservation

(f) To protect area of high conservation value including those containing high species diversity, natural refugia for flora and fauna and centres of endemism

(g) To provide for recreational, aesthetic, and cultural needs of Indigenous and non Indigenous people

3.1.1.1 Protection of biodiversity and ecosystem viability.

The primary and secondary goals of the NRSMPA can be categorised under two main headings. The first includes the goals to "establish a comprehensive, adequate and representative system of marine protected areas to protect biodiversity and ecosystem viability". The second includes goals to provide for human use. Most criteria under the primary goal can be organized under three main themes: comprehensiveness, representativeness and adequacy.

3.1.1.1.1 <u>Comprehensiveness</u>

Under ANZECC guidelines, comprehensiveness is interpreted as dealing with "the full range of marine ecosystems and habitats across the marine environment …identified at an appropriate scale and included in the NRSMPA." In order to make progress on the practical development of the NRSMPA, ANZECC TFMPA (1998) recommends that comprehensiveness be assessed specifically at the levels of *bioregion*, *ecosystem* and *habitat.*

At the *bioregional* level, bioregions have been mapped around Australia as part of the Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group 1997). Comprehensiveness at this level requires that the marine protected area system extend across each of the IMCRA bioregions. The prerequisites for assessing comprehensiveness at the *ecosystem* and *habitat* levels include the classification and mapping of discrete *ecosystem* and *habitat* units at an appropriate scale across each entire bioregion.

3.1.1.1.2 Representativeness

Representativeness in the NRSMPA is taken to mean that "*those marine areas that are selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive*" (ANZECC TFMPA 1998a, b). A simple interpretation of this is that while *comprehensively* sampling the range of biotic variation, MPAs should also include a reasonably unbiased and sufficiently large, *representative* proportion of the variation within this range.

With regard to representativeness, one emphasis is on protecting typical species, processes and areas, to counter a perceived bias towards protecting only known, charismatic, rare, threatened, scenic, recreational or convenient elements of biodiversity. On the other hand, vulnerable species should not be ignored solely in the interest of a perhaps more holistic integrated ecosystem management or a 'catch all' strategy to 'insure against ignorance' about biodiversity (Inglis 1992, Jones *et al*. 1992, Jones and Kaly 1996).

To be unbiased, a representative system of MPAs should protect both typical and “special” components of biodiversity. It should also aim to protect a sufficiently large proportion of the community, species, population and genetic diversity within the *comprehensive* range of ecosystems included.

3.1.1.1.3 Adequacy

Adequacy in the NRSMPA has been defined as "the required level of reservation to ensure the ecological viability and integrity of populations, species and communities." Adequacy includes anything that affects the ability of MPAs to protect the biodiversity they aim to conserve. In this context, assessment of adequacy involves the consideration of vulnerability, condition, reserve design and practical MPA management.

The vulnerability of a feature refers to the likelihood that it will survive. In the context of MPA selection and identification, vulnerability can be interpreted in two ways. Where there is a range of options available for protection of a particular habitat, species, or other feature, it may be preferable to include areas that are not particularly threatened in order to increase the probability of survival and the success of the MPA as a whole. This approach may be most applicable when threats originate from outside the MPA and are beyond the immediate control of MPA management.

Where there are only a few examples of a particular feature, there may be more urgent reasons for protecting those areas most threatened. This interpretation may be more applicable when threats originate from within the MPA and under some level of control by MPA management. This priority is now incorporated implicitly in terrestrial reserve selection methods (Cowling 1999, Faith and Walker 1996, Pressey and Taffs 2001) and is based on the premise that reservation of a vulnerable site will eliminate (or at least mitigate) the threatening process.

Condition or 'naturalness' is related to vulnerability in that for many environments the threat has already had some degree of impact. If an area has been affected by pollution, disturbance, pests, disease, habitat loss, or over exploitation, the ecological viability of the area as well as the diversity of organisms present may be affected. As there is usually little or no exact information on what diversity exists or should exist in a given habitat, choosing a more natural site may include a more representative complement of biodiversity.

Ecological viability also includes consideration of reserve design, including size, shape, replication and configuration of reserves within a network. Choices will be influenced by the nature of the biodiversity protected, the natural processes that sustain it, the nature of potential threats, and the ability of management to ensure compliance through education, surveillance and enforcement. The adequacy of a MPA will also be greatly affected by management practicality. Without compliance, any regulation or strategy exists only on paper.

3.1.1.2 Managing and providing for human activities.

The second major group of criteria relates to 'managing and providing for human activities'. This group encompasses goals and criteria that contribute to:

- a formal management framework for a broad spectrum of human activities, including recreation, tourism, shipping and the use and extraction of resources; and
- provision for recreational, aesthetic, and cultural needs of Indigenous and non Indigenous people; and "provide scientific reference sites" (ANZECC TFMPA 1998a, b).

What is most evident here is the wide range of human interests in marine environments and the potential for conflict with conservation values and between competing interests. Careful consideration of human activities is therefore required if MPAs are to be implemented and managed without the domination of management resources by conflict.

Criteria for human activities are scheduled by NRSMPA guidelines into a separate site selection process. However, reserve selection tools can now accommodate human issues in the reserve development process at an early stage without compromising the ecological integrity of the site selection system (Section 3.4).

Assigning higher priority to ecological criteria does not necessarily require a two stage process. The assignment can be achieved by mapping out the distribution of biodiversity surrogates and setting explicit and agreed conservation goals and reserve design requirements prior to reserve selection negotiations. This approach assumes that a number of ecologically viable options is likely to be available. Consideration of both ecological and human requirements at the same time is more likely to arrive at the best possible solution to benefit biodiversity and human use.

In addition, stakeholders often spend many professional and recreational hours observing marine ecosystems and can therefore contribute valuable information on species' distributions, habitats, vulnerability, condition and threats. When used cautiously, such information may lead to more realistic MPA strategies that adapt more ideally to local conditions and particular habitats and organisms (Johannes *et al.* 2000). For example, the information collected from local reef users that is reported in Chapter 5 has been used in the redrafting of the Cairns Area Plan of Management (GBRMPA 2005b).

Making use of information on human activities will also encourage public confidence by providing solutions that realistically attempt to meet objectives for human use, understanding and enjoyment. Davey (1998) lists eleven reasons why plans for MPAs fail, seven of which directly involve stakeholder input:

- they do not address key issues
- they fail to involve stakeholders
- they rely too much on external experts and fail to involve local people
- they are weak on implementation
- they fail to raise political support for protected areas as a worthwhile concern
- they are poorly publicised

- they rely too much on external support and/or funding.

3.1.2 Goals and criteria of the Great Barrier Reef Marine Park

The *Great Barrier Reef Marine Park Act, Commonwealth 1975* specifies that the main objective of the Authority is to

> "*make provision for and in relation to the establishment, control, care and development of a marine park in the Great Barrier Reef Region in accordance with the provisions of its legislation*".

Since this Act was passed in 1975, the GBRMPA has further defined its goal as being:

> "*To provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park*."

Four elements underlie the management philosophy of the Great Barrier Reef Marine Park Authority in achieving this goal:

- Management at the ecosystem level to achieve overall protection of the ecosystem
- Conservation and reasonable use so that while the ecosystem is protected, opportunities are still provided for sustainable use and enjoyment of the Great Barrier Reef
- Public participation and community involvement in the development and implementation of management
- Monitoring and performance evaluation of management (GBRMPA 2003)

Fernandes (1999) developed a list of 200 specific management objectives which the GBRMPA should strive to achieve. The list was compiled from documents and interviews with stakeholders with interest in management of the marine park and is arranged in several levels. Table 3.1 summarises her findings.

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Table 3.1: First two levels of management objectives of the Great Barrier Reef Marine Park as detailed by Fernandes (1999). The sub objectives contribute to achieving the main objectives.

While managers of the Great Barrier Reef Marine Park (GBRMP) aim to achieve these objectives, they have a primary statutary obligation to conserve the park's natural resources. This obligation includes maintenance of the health and variety of ecosystems, habitats, species, populations, genetic pools and physical and ecological processes within the park.

As a multiple use marine park, there are different degrees of protection for different habitats within the boundaries of the GBRMP. Furthermore, there are many management tools (e.g. zoning, education, permits, management plans) that can be used to help achieve ecological and other management objectives.

Habitat protection was recently addressed in the GBRMPA's representative areas program (GBRMPA 2005a). The approach used by the GBRMPA was part of the nationwide program to establish a representative network of marine protected areas (Section 3.2). A network of representative areas that includes highly protected sites of all habitat types is widely regarded as an effective way to enhance protection of biological diversity (Environment Australia 1998). Representative areas are areas that are typical of, or best represent, the natural systems they aim to preserve and protect. The GBRMPA recognised the need to have a comprehensive and adequate network of protected representative areas within the Marine Park and by 2004 rezoned the entire GBRMP using this approach.

3.2 Methods to assess biological diversity in marine protected areas

3.2.1 Surrogates of biological diversity

A comprehensive description of all biological diversity is difficult if not impossible, especially for an area as diverse as the GBRMP. Our knowledge of biodiversity is reasonable for some groups, but poor or non existent for many others.

Most biodiversity estimates rely on a proxy or surrogate variables as general predictors of biodiversity. These surrogates include:

- diversity “hot spots”
- rare or outstanding species and communities
- selected distributions and interpolations of known organisms aggregated at some resolution (e.g. gene, species, community)
- distributions predicted from models relating environment and organism occurrence
- broad scale descriptions of the physical environment

Gladstone and Davis (2003) evaluated the use of different surrogates in the classification of marine habitats. The Representative Areas Project in the GBRMP used a predominantly physical classification of environmental diversity to describe and represent biological diversity (Day *et al.* 2000). By protecting a representative diversity of physical habitats, the project aimed also to protect the diversity in genes, populations, species, and communities produced by variation in the physical environment. As biological diversity is often strongly correlated with physical factors, protection of a range of physical environments should protect a large proportion of biological diversity as well. This “ecosystem” approach should also be effective in preserving the physical systems that drive and support biological diversity and evolution.

An additional advantage of physical descriptions of diversity is that they have a more enduring relevance. Selection of a protected area using the presence of a particular suite of species as the sole criterion is inappropriate in areas where species composition may change markedly from year to year. Selections made on the basis of enduring physical factors like geology, or on recurrent physical processes like tidal regime, should still be relevant after many years.

The other main advantage of basing representative areas on physical data is that physical datasets are often more comprehensive and collected with greater accuracy, in more detail and over wider areas. The distribution of data for many species and communities on the Great Barrier Reef is often very limited in extent and the use of widespread physical data avoids many problems associated with patchy data sets. Protected areas based only on those diversity components for which we have good biological information may be biased and ignore the many genes, populations, species, and communities about which we know little.

On the other hand, the physical approach does involve untested assumptions and possible disadvantages. Physical variables may not always predict biodiversity, as biological communities are capable of markedly altering their physical environment (e.g. reef building by corals and sediment trapping by mangroves). Biological forces like predation, competition and dispersal may also be responsible for structuring patterns of biodiversity. In addition, relationships between physical and biological forces are not necessarily simple and easily predicted. The susceptibility of management decisions to these problems may, however, be tempered by the use of physical data initially to define very broad scale, clearly defined physical environments and then the use of increasing knowledge and detailed models of biological diversity to fine tune the system of representative areas.

3.2.2 Mapping biological diversity.

3.2.2.1 Mapping of physical features.

This approach assumes, on the basis of ecological theory and past observation, that the physical features mapped correlate with variation in ecological processes, habitats and the distributions of organisms. For broad scale patterns in biodiversity, general relationships of this sort are often well documented and may be used to capture undescribed components of biodiversity as well as the physical habitats and processes important in maintaining biodiversity and its continued evolution. A major advantage of this approach is that extensive physical surveys often already exist and can potentially provide rapid, cost effective, approximate predictors of biodiversity. Sources of information include bathymetric models of seabed, geomorphological classifications of coastline, estuaries and topographic features, and surveys of oceanography and sediment types. The increasing availability of technologies in side scan sonar, acoustic mapping, aerial photography and satellite imagery mean that almost continuous coverages of some attributes can be obtained.

3.2.2.2 Biological surveys sampling organism distribution and abundance.

Direct observations on the location, abundance and other characteristics of organisms range from incidental sightings, museum collections and commercial harvest data, to dedicated surveys designed to provide statistical estimates of abundance and variation. Where available, the latter data can provide the most reliable indicators of biodiversity, both for the organisms sampled and for other organisms indirectly associated with the sample biota. For example, species level data were used in conjunction with physical information to help derive bioregional classifications in NSW (Pollard *et al.* 1997).

3.2.2.3 Modeling of distributions from biological data and physical or spatial predictors

Where sparse but reliable data on species and community distributions are available across the entire area of interest, models relating this data to more easily available physical or even spatial attributes can be used to predict patterns of biodiversity.

3.2.2.4 "Delphic" consensus of experts.

This technique in various forms involves providing people possessing relevant expertise with the available information, analyses and objectives and getting them to agree upon a classification.

3.2.2.5 Summary of marine classification and mapping methods used in Australia.

Many ecological mapping projects combine aspects of all of the above approaches. For example, mapping physical features as surrogates for biodiversity indirectly assumes that previous surveys, models and expert opinion support the use of the physical features in representing biotic patterns. Differences generally lie in the degree to which each of the approaches specifically influences the classification.

South Australia has introduced the concept of the 'biounit' as a means of overcoming the lack of systematically surveyed biological information. The planners there initially mapped eight basic "habitat" units, which were defined by physiographic features (including substrate type and geology) using remote sensing techniques. The resultant habitat classification was later supported by sampling and multivariate analysis of benthic flora and fauna.

However, "habitat" defined in this manner failed to represent biological variation occurring within a habitat over distances of 10s to 100s of km. Consequently, the South Australian coast was partitioned into 35 smaller biounits along the coast and across the continental shelf. In the absence of direct biological data, biounits were delineated using biological surrogates (i.e. combinations of several physical datasets that predict where a particular species or community might be found).

Because of the non-availability of biological data for delineating ecological patterns over 10s to 100s of km, the NSW Marine Parks Authority applied a surrogate approach similar to South Australia's 'biounit' concept to delineate marine habitats for the NSW portion of the Tweed-Moreton IMCRA Region (Avery 2000). In the Tweed-Moreton Region, 'physiographic units' (e.g. reef systems) were crudely delineated from secondary data sources such as topographic maps and nautical charts.

Planners in the State of Victoria chose to map marine physical environments directly, using a suite of remote sensing techniques (e.g. LandSat TM imagery, side-scan sonar and submersible video) in a process similar to that used in South Australia (Fern and Hough 1999). However, the Victoria State Government is also in the process of collecting biological data capable of detecting within habitat variation, thereby avoiding the use of biological surrogates.

Tasmania (Edgar *et al.* 1997) initially directed their resources at conducting systematic biological surveys. The data obtained provided quantitative information suitable for identifying broad scale bioregions and assessing representativeness within habitats. An additional benefit of this biological survey approach is that planners now have an extensive baseline data set against which to monitor the effects of widespread ecological change and human impacts. When the biological surveys were completed, direct identification of habitats using remote sensing technology followed. Habitats were classified according to physiographic features (including substrate type and geology i.e. Reef/sand), and the occurrence and density of seagrass.

In the Great Barrier Reef Marine Park, the location of reefs, islands, coast and estuaries was originally mapped by remote sensing. More recent work incorporates a range of physical and biological classifications as layers in a Geographic Information System (GIS) (Kerrigan *et al.* 1999). In particular, point species data from surveys of algae, hard and soft corals, fishes, seagrasses, and invertebrates are used to predict the distribution of reef and inter reef communities. Multivariate regression tree techniques are used to model relationships between the biological point data and spatial position across and along the reef shelf. These relationships are then used to identify 'bioregions' of similar community composition with associated estimates of classification error (Kerrigan *et al.* 1999). Classifications are then refined by panels of experts, in workshops viewing these and other related physical and biological data on a GIS (Kerrigan *et al*. 1999).

The Commonwealth Science Industrial Research Organisation (CSIRO) and the Australian Institute of Marine Science are currently conducting the Great Barrier Reef Seabed Biodiversity Project. These organisations are mapping seafloor habitats and their associated marine life throughout the Great Barrier Reef Marine Park and making this information available to further refine the bioregional classifications (see www.reeffutures.org).

3.3 Methods to assess social benefits from MPAs

In order to plan for the social benefits from MPAs, it is important to understand economic benefits, visitor experiences and the ecological impacts of these experiences. Management objectives must go beyond "protecting the resource" and "providing opportunities for multiple use" (Heberlein 1977) and begin to define the type of experience to be provided, in terms of appropriate economic, ecological and social conditions (Stankey 1980).

Many of the methods used in Australia and around the world have focused on using ecological data in systematic MPA planning processes. There has been much less use of social and economic data, despite the fact that most MPAs have important social and economic objectives which need to be met. Often these objectives prove to be the most influential with respect to the success of the establishment and management of MPAs

(Agardy 2002).

3.3.1 Economic valuation of MPAs

While the main objectives for establishing MPAs relate to areas with important ecological features and high conservation value, MPAs also provide economic value to the wider community. The measurement of economic value takes into account the willingness of the community to pay for the resources, amenity and attractions provided by an MPA and its management and provides an indication of the economic welfare realised by the community because of the MPA (Davis 2001). Thus the total economic value (TEV) of a MPA is made up of its actual user values (derived from the actual use of a resource) and its intrinsic values (a non-use value) (Figure 3.1).

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Figure 3.1: Total economic value of an environmental asset (The World Bank 1994)

The World Bank (1997) found that protected areas provide a range of benefits, but that these vary greatly in nature and magnitude. In high income countries such as Australia, the greatest benefits from protected areas are usually based on their non use (existence) values and on the recreational opportunities they offer (Davis 2001). Many people have a high willingness to pay for these types of benefits (World Bank 1997).

Several valuation studies of natural resources have taken place in Australia (e.g. Hundloe *et al.* 1987, Sloan 1987, Hundloe 1990, Hundloe *et al.* 1990, Walpole 1991, Pitt 1992, Lockwood and Tracey 1993, Driml 1994, Driml and Common 1995, Davis 1997, Hart 1997, KPMG 2000, Davis 2001). While most have focussed on terrestrial areas, these studies demonstrate that natural areas, including protected areas, can be of significant economic value. The techniques used in the above studies can be applied in marine environments as well.

The concept of total economic value (see Fig 3.1) was first applied to coral reefs over 10 years ago (Spurgeon 1992) and since then many papers from several countries have been published reviewing the application of this methodology for marine protected areas (reviewed in Cesar 1996, Spurgeon 2004). There is a growing realisation that as the potential financial value of coral reefs is recognised, management of coral reefs and MPAs will become more business like, with increased private sector participation. However, the ethics of this approach are currently under debate (e.g. Caesar and Chong 2004, Lal 2004, Spurgeon 2004)

3.3.2 Carrying capacity

There has been over 30 years of research on the concept of carrying capacity as it applies to environmental management (Wager 1964). The idea of an environmental carrying capacity evolved from applications in ecology and rangeland management (Odum 1959). In more recent times, this concept has been used as the theoretical basis for establishing limits on the use of natural areas by humans (Shelby and Heberlein 1986, Stankey 1991). The concept assumes that natural resources can tolerate a certain level of development by humans without a noticeable deterioration in the quality of the resource. In park areas, this concept has been expanded to define carrying capacity as the amount and type of use that can appropriately be accommodated within a natural area (Manning *et al.* 1996).

Much of the carrying capacity research in natural environments has focused on the social environment or social carrying capacity. Although varying opinions are expressed about the subject in the literature, there is a general consensus that the definition of social carrying capacity is "*the level of use beyond which experience parameters exceed acceptable levels specified by evaluative standards*" (Graefe *et al.* 1984). Natural resource managers were advised to seek optimum levels of use by examining peoples' perceptions of other users and their perceptions on how the quality of their experience and the quality of the environment was affected by the presence of others (Stankey 1973). The number of people visiting a particular site could then be limited to a figure which would not adversely impact on either the visitors' experience or the environment. This principle is of particular relevance to the present thesis, as it has been applied in the development of the Cairns, Whitsundays and Capricorn Bunker Plans of Management to set limits on number of people allowed at a particular location (GBRMPA 1998).

However, by the early 1980s it was understood that there is no fixed value or single formula for determining the carrying capacity of a natural environment, as no clear relationships can be found between the number of people using a recreational area and their influence on the recreational experience (Becker *et al.* 1984, Graefe *et al.* 1984, Stankey and McCool 1984, Shelby and Heberlein 1984). In addition, social and ecological research in terrestrial environments shows that the idea of setting a single value for carrying capacity is simplistic and unrealistic (Shafer *et al.* 1998). It is wellnigh impossible to set a threshold capacity of human use for a given area, because such a threshold is influenced not only by the number of people, but also by a large range of natural and human conditions. As stated by Oliver (1995), it would be difficult to set an absolute limit to use against a background of large spatial and temporal variation in the abundances and life-histories of the affected species within the natural environment.

Hence, the carrying capacity approach has been modified to include value judgments by managers, who set limits to the number of users based on the nature of the experiences managers want to provide and on the desirability of the consequences of different behaviors within the managed area. This approach is value laden (Shelby and Heberlein 1984) and has rarely been successfully implemented as a management strategy (Shafer *et al.* 1998). It is almost impossible to say how many people are too many.

Recreational carrying capacity has been unsuccessful as a management paradigm for the following reasons (Shelby and Heberlein 1986, Shafer *et al.* 1998):

- The inherent assumption that human needs and desires are as simple for managers to deal with as the food requirements of animals
- The failure to identify specific objectives for the areas' management
- The geographical complexity of recreational areas given complex patterns of human use
- The focus on numbers of users as the management problem, rather than desired natural conditions or attributes
- The failure to understand that human behaviour is as important as the amount of use in influencing the amount of visitor impact
- The fact that use limits tend to introduce new types of management problems,

which managers are not equipped to handle

- Confusion of the technical question of what can be done with the value judgment of what should be done
- The lack of a universally acceptable system of identifying and implementing recreational carrying capacities.

Thus during the late 1970s and early 1980s social scientists focused instead on the concept of a spectrum of opportunities, which recognised that the resource and the social conditions in the different areas would vary (Driver and Brown 1978, Clark and Stankey 1979). These researchers began to investigate the development of indicators and standards of environmental quality (Stankey *et al.* 1985, Graefe *et al.* 1990), chosen to help determine the acceptability of a pre-defined level of change for each relevant indicator (i.e. for each specific variable reflecting the conditions of the environment and users). This approach could then identify when a theoretical limit had been approached and management action was required. The Recreational Opportunity Spectrum (ROS) and the Limits of Acceptable Change (LAC) frameworks were developed to deal with the setting of standards for recreational settings. These frameworks are discussed in the following sections.

3.3.3 Recreation opportunity spectrum (ROS)

With increasing population and the growing importance of leisure in our society there is increasing competition for recreational resources (Broome and Valentine 1995). The Recreation Opportunity Spectrum (ROS) is a conceptual framework developed to provide management agencies with a tool to maintain a diversity of recreational experiences and thus decrease the potential for conflict between different users of same resource (Stankey and Wood 1982, Driver and Brown 1983, Daniels and Kramich

1990).

When the ROS framework was proposed, the concept of a diversity of recreational opportunities was not new. Prior to the early 1970s, researchers had suggested that satisfaction in outdoor experiences was made up of a continuum of recreational opportunities (e.g. Bultena and Klessig 1969). What makes the ROS stand out is the degree to which it has been formalised and translated into management guidelines. The ROS provides a formal approach to inventory, planning and management of outdoor recreation resources, which considers the range of recreational experiences sought (Driver and Brown 1983). The concept aims to understand the spectrum of experiences people want in a wide variety of natural environments (Driver and Brown 1978, Clark and Stankey 1979). The ROS assumes that a ***quality*** recreational experience can best be assured by providing a ***diversity*** of recreational opportunities (Watson 1988). Stankey and Wood (1982) define a recreational opportunity as "*a chance for a person to participate in a specific recreational activity in a specific setting in order to realise a predictable recreational experience*".

The ROS system was developed simultaneously by two groups of researchers: Clark and Stankey (1979) and Brown, Driver and associates (Brown *et al.* 1978, Driver and Brown 1978, Brown *et al.* 1979). It was subsequently adopted by both the Forest Service and the Bureau of Land Management, two major US federal agencies.

Like Carrying Capacity, ROS was developed by both groups as a conceptual framework for planning for recreational opportunities. It explicitly recognizes that experiences are directly related to the setting in which they occur. These settings are a function of environmental, social and managerial conditions that give value to that recreational area (Brown *et al.* 1978, Driver and Brown 1978, Brown *et al.* 1979, Clark and Stankey 1979, Manning 1985). Manning (1985) suggests that the relationship between these three basic factors is linear. Thus, as environmental conditions change, social and managerial conditions change in a corresponding fashion.

Clark and Stankey (1979) develop the ROS framework to include six basic factors to define the recreational opportunity setting. The settings range from “modern” to semi-modern to semi-primitive and primitive and are made up of a combination of factors (e.g. accessibility and mode of transport) (Clark and Stankey 1979).

Brown *et al.* 1978 identify six opportunity classes based on the amount and type of human use, degree of technology and modification of the area. For each opportunity class they describe the associated experience as well as the physical, social and managerial setting. The six classes include: 1) primitive 2) semi primitive – nonmotorised, 3) semi primitive – motorised, 4) rustic, 5) concentrated, 6) modern urbanised. The settings within these classes range from an essentially unmodified natural environment in the first class to high intensity use in the last class.

Following this approach, managers can zone different parks and areas within parks according to their recreation opportunity class. As each recreational area differs in its setting and use, a detailed analysis of demand and resource capabilities of each area needs to conducted prior to management planning for the area. Driver and Brown (1983) suggest that managers and researchers initially follow these five steps for each recreational area to develop an ROS approach:

- Establish clear definitions of each recreational opportunity
- Quantify the demand for recreational use of the area
- Determine the type, amount and quality of opportunities to be provided within an area

- Determine interactions between recreation and other uses under multiple use management
- Measure use of the opportunities provided.

However, despite its apparent applicability, the ROS framework has limitations. For example, the implicit linear relationship between the three basic factors (environmental, social and managerial) as discussed earlier, is not meaningful in most cases. A wide diversity of user attitudes, preferences and motivations contribute to recreational opportunities. The ROS does not address this diversity. Manning (1985) suggested that, at most, the ROS provides a conceptual framework which can help managers set guidelines for recreational use, but that it should not be interpreted too strictly or applied too rigidly. There must be room for individual judgement amongst managers to determine appropriate setting for an area.

3.3.4 Limits of Acceptable Change (LAC)

As discussed above, the ROS system prescribes opportunity classes without taking into account the diversity of human preferences, motivations and attitudes. In the literature, ROS has been superceded by the more flexible Limits of Acceptable Change (LAC) planning system.

LAC was developed in the mid 1980s to address visitor management issues in the US National Wilderness Preservation System (Stankey *et al.* 1985). The system is simply a process for determining what social and resource conditions are appropriate or acceptable and how we obtain those conditions through prescribing a set of management actions. This process represents a large shift from the carrying capacity paradigm which focused instead on “how many is too many”.

According to McCool (1996) the LAC system is built upon 11 principles which emerged from research on visitor impacts and growing public interest in being involved in protected area management. A brief summary of McCool's (1996) discussion about these principles is provided in Table 3.2.

LAC provides a framework for thinking about issues concerning management of recreational use of protected areas. The process recognises the inherent complexity of the issues associated with use management, and without being excessively reductionistic in approach, provides a process to deal with that complexity (McCool 1996).

It is important for managers of protected areas to accept that once use occurs in any environment, the resource and social conditions change. The nature and extent of change in conditions will vary throughout the area due to the amount of use, sensitivity of the environment and other factors. The LAC process explores this intrinsic diversity in conditions and seeks to maintain it through appropriate management action.

PRINCIPLE	CONCEPT
Principle 1: Appropriate management depends upon clear objectives	A recurrent theme discussed in the visitor management literature is the need for explicitly stated objectives.
Principle 2: Diversity in resource and social conditions in protected areas is inevitable and may be desirable	Resource and social conditions in any large protected area are not likely to be uniform.
Principle 3: Management is directed at influencing human induced change	In protected areas, human induced change may lead to conditions that visitors and managers feel are unacceptable or inappropriate. Management of protected areas is oriented towards limiting and managing these changes
Principle 4: Impacts on resource and social conditions are inevitable consequence of human use	Allowing any level of use in a protected area means that some level of impact will occur. Managers must ask "how much impact is acceptable in this area"?
Principle 5: Impacts may be temporally or spatially discontinuous	Impacts from visitor use or management activities may occur offsite and may not be visible until later. (e.g. a decision to limit use in one area may transfer use to other areas).
Principle 6: Many variables influence the use/impact relationship	A variety of variables affects the use/impact relationship, thus attempting to control human induced impacts solely through limits or carrying capacity may fail.
Principle 7: Many management problems are not dependent on the density of use	There is a lack of a precise linear relationship between use and biophysical impacts, thus suggesting that management problems are not density dependent.
Principle 8: Limiting use is only one of many management options	Setting use limits is only one of a number of potential management actions to minimise visitor impacts.
Principle 9: Monitoring is essential to professional management	Monitoring allows managers to maintain a formal recorded of resource and social conditions over time and helps to assess the effectiveness of management actions.
Principle 10: The decision making process should separate technical decisions from value judgments	The decision process should separate questions of "what is" (e.g. existing conditions) from "what should be" (e.g. preferred conditions).
Principle 11: Consensus among affected groups about proposed actions is needed.	Planning is political and must proceed with this acknowledgement. A consensus is needed for managers to implement their strategies.

Table 3.2: Principles upon which the Limit of Acceptable Use Planning System is based. Summarised from McCool (1996).

The LAC planning system contains four major components as summarised by McCool (1996):

1. the specification of acceptable and achievable resource and social conditions
2. an analysis of the relationship between existing conditions and those judged acceptable
3. identification of management actions necessary to achieve acceptable conditions
4. a program of monitoring and evaluation of management effectiveness

Stankey and others (1985) expanded these four components into a nine step process to implement the LAC in a protected area (Figure 3.2). As every protected area differs, it is important to note that both the number and order of steps in this nine step process can be modified to suit the location. In addition, one does not have to proceed through the process in a linear manner. If something arises that requires one of the earlier steps to be revised, the managers can go back and modify that step.

Public involvement is essential to the success of the LAC process. The process revolves around the collection and use of appropriate information. What it then does is provide a systematic approach to guide decision makers in developing explicitly defined information requirements that reflect the objectives of the area to be managed.

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Figure 3.2: The Limits of Acceptable Change Planning System (Stankey *et al.* 1985)

3.4 Integrated Protected Area Planning Frameworks and Tools

While the above tools are used frequently within their own domain or interchangeably to incorporate information from other areas, the results of these analyses are usually regarded separately, combined in an *ad hoc* manner or used as part of a step wise process. However, the number of MPA goals and selection criteria, the difficulty in measuring marine biodiversity and ecosystem processes, the complexity of social requirements and the need for transparent and accountable decision making all favour the use of integrated and systematic rather than *ad hoc* approaches to the identification and selection of MPAs.

Decision support methods can assist this process by allowing information to be rapidly retrieved, analysed and displayed for use by managers. Such methods allow the consequences of alternative decisions to be quickly explored and the specific criteria, priorities and information used in decisions to be reliably recorded. An integrated and systematic approach can make it possible to provide:

- more informed decision making
- greater flexibility through exploration of range of alternative MPA options
- substantial support and evidence for implementing decisions in subsequent negotiations
- precise records of corporate memory, policy and processes
- an informed framework for ongoing management
- a basis for testing assumptions, developing performance indicators, designing research and monitoring and more effective conservation through adaptive management.

There are many advantages to examining information from all sources simultaneously. The tools discussed in this section of the chapter are particularly well suited to integrating information for systematic decision making in a MPA. I introduce these tools here because Chapters 5, 6 and 7 of this thesis focus on using two readily available tools (GIS and multiple criteria models) to demonstrate the integration of a range of social, economic and biological data for developing plans of management in the GBRMP.

3.4.1 Geographic Information Systems.

The amount of information and variety of data sources and formats used in MPA selection and management requires systematic management of data storage, documentation and analysis. An organised system of computer databases will:

- help integrate information and technology from all sources, including scientific surveys, analyses, modeling, literature, expert opinion and community input
- securely store and document high quality information in readily accessible formats
- support and document decision making in a transparent, repeatable and flexible way
- make use of convenient analysis and display capabilities in Geographic Information Systems (GIS), relational databases and decision support and modeling techniques
- allow procedures to evolve as new information, criteria and methods become available
- integrate project outputs with ongoing MPA management and strategies in other regions, agencies and stages of MPA development
- document and test assumptions and limitations in methods, assess the performance of decisions implemented, and prioritise further research where required.

Wherever possible, information collected for MPA selection and management should be converted to and stored in digital format, on reliable centralised data servers. In this way, information from diverse sources - published and unpublished literature, verbal accounts and isolated personal and institutional databases - can be conveniently retrieved for analysis and decision support within one easily accessed medium. Where possible, data should be mapped or linked to spatial references within mapping software such as ARC/INFO and ArcView GIS.

Identifying and selecting MPA options is essentially a problem in defining *where* MPAs should be located, given certain criteria and information. Modern GIS programs provide the ideal basic tool for quickly and accurately displaying and exploring potential solutions to this essentially spatial problem. The ability of GIS to display maps in an interactive environment and produce easily understood information for both management and public use is invaluable. However these capabilities can be greatly extended by linking the GIS with database and dedicated decision support software.

GIS software allows the planner to integrate a wide variety of spatially referenced data and analyses, including:

- remotely sensed data - e.g. satellite and aerial photographs, sonar (single beam, seismic, side scan, multi-beam swath and airborne) and laser altimetry
- systematic surveys of biological populations and communities - e.g. dugongs, grey nurse sharks, coral reef monitoring data
- socio-economic surveys with a spatial reference
- geological, geomorphological, oceanographic and climate data
- results of spatial analyses and models - e.g. distance measures, buffers and influence of neighbouring areas, variograms, autocorrelation, point process
- statistical analysis - e.g. multivariate statistics (Chapters 5, 6 and 7)
- Other spatial analyses e.g. cplan, simulated annealing, MARXAN
- data sets from many formats, disciplines, institutions and regions using space as a common field in a relational database
- spatial management tools - e.g. zoning, permit restrictions and plans of management (Chapter 8)
- Delphic and other group decision making and data exploration techniques - e.g. group (Delphic) meetings of managers, scientists and stakeholders.

3.4.2 Decision support

'Decision support' means providing and organising information to assist in decision making. In its broadest sense, decision support can range from the provision of advice, answers to simple queries, or reviews to development of computer assisted models analysing multiple criteria, data sources and alternative decision options. At any stage, decision support is meant only to facilitate normal human decision making processes, but it can be very useful where large amounts of information and potentially complex problems are involved. Identifying MPA options from a potentially large range of possibilities, criteria and information sources is the management area likely to benefit most from decision support.

3.4.2.1 Hierarchical Multiple Criteria models.

Conceptual decision support trees can be used to estimate the relative performance of MPA options in meeting an overall goal. MPA options are evaluated against the most specific criteria in a given decision tree. Datasets are weighted at each level according to assigned priorities and assessed against the overall system goal as a function of these weights and values.

As the relative values for each MPA option can be derived from both quantitative and qualitative data, the method permits information from widely different sources to be integrated within a single analysis. Identifying specific weightings within each level of the tree can either be used to guide the decision process or to document the actual priorities used in choosing MPA options.

Such systems allow quick and graphical display of the bases on which management decisions may be made and the outcomes of using different priorities, data sources and criteria. Such displays may be particularly valuable in achieving consensus during

MPA identification and selection where differences in opinion are likely among both experts and community stakeholders.

Multiple criteria decision support systems are regularly used in marketing and management (Edwards 1977) and in environmental impact assessment, fisheries (Mardle and Pascoe 1999) and the selection of reserve networks (Edwards 1977, Bakus 1982, Fernandes 1996).

3.4.2.2 Complementarity, irreplaceability and reserve selection algorithms.

Where there are constraints on how much of the marine environment can be included in MPAs, it seems wise to choose areas that best meet conservation criteria. For situations involving a few areas and values this can be done by inspection. With increasing numbers of planning sites and values, the problem rapidly becomes more complex.

A number of related computer assisted techniques have provided assistance in many reserve selection applications since 1983 (Kirkpatrick 1983). Importantly, these techniques take into account the 'complementarity' of different areas in jointly achieving targets. In including a planning unit for a particular habitat or species, contributions may incidentally be made towards goals for other habitats, species and criteria. Including planning units then continually alters the potential value of remaining areas in meeting overall goals.

These changing values are difficult to quantify within a static measure but have been approximated as 'irreplaceability', which is defined as:

> *"(1) the likelihood that an area will be required as part of a conservation system that achieves the set of targets; and (2) the extent to which the options for achieving the set of targets are reduced if the area is unavailable for conservation*" (Pressey *et al.* 1994).

Goal seeking algorithms are used to search for solutions that attempt to meet or optimise conservation criteria, while minimising or meeting some cost (usually area). Such algorithms include integer linear programming methods (Cocks and Baird 1989), iterative heuristic algorithms (Nicholls and Margules 1993), and simulated annealing.

Integer linear program methods have the advantage of producing a single optimal solution, but where the number of possible reserves is large the problem is difficult to solve in a reasonable time.

Heuristic algorithms work by iteratively applying sets of rules in a stepwise manner to select planning units sequentially for inclusion in reserves. At each iteration an additional planning unit is selected, according to how it complements previously selected units in meeting overall targets. Decision rules within each iteration are used to resolve ties between planning units and prioritise criteria. An example of this process might be: Rule 1. Select the unit that includes the rarest habitat not already included. Rule 2. If there is more than one unit that satisfies Rule 1, choose the unit that includes most unrepresented species. Rule 3. If there is more than one … then … and so on until a unit is selected, when the first rule is reapplied. Heuristic algorithms are not very likely to find optimal solutions, but they can rapidly find approximate solutions for relatively complex problems.

Simulated annealing seeks to minimise an objective function by making random changes to the reserve system. The method begins from a random starting point and at each step compares the new solution with the previous one. During initial iterations almost any changes are accepted, but the algorithm becomes progressively more choosy until only changes that improve the solution are accepted. The method will generally perform better than heuristic algorthims, but at the cost of a slower running time. It does however have the advantage of being able to produce a number of solutions (albeit suboptimal ones), thus providing a range of options for selection and negotiation processes.

Measures like irreplaceability and goal seeking selection methods are more likely to find more efficient solutions (i.e. to represent more conservation values in less area) than simple scoring or *ad hoc* approaches. In addition, these approaches may identify a potentially greater variety of near optimal, alternative solutions. This flexibility may enable potential MPAs to be placed in a more effective network (e.g. to "connect" spawning and nursery grounds) and to achieve better compromises between conflicting conservation and stakeholder requirements. The benefits of these methods for both conservation values and human activities strongly recommend them for both identification and selection of MPAs.

Specific choice of method will depend on the complexity of the problem, the time required for analysis and the importance of a guaranteed optimal solution (ANZECC TFMPA 1998a, b, NSW Marine Parks Authority 2000). Ensuring that solutions are optimal may be of reduced importance if there is uncertainty in data inputs and priorities and the methods are to be used only as support for more precise conventional decision making. If the methods are to be used interactively to explore alternatives, then computational speed will be important.

Since implementing such methods can be a complex task, the availability of specialised advice and software will also influence the specific methods used. However modern programming techniques now provide relatively simple user interfaces linked to GIS display and selection capabilities and several NSW and Australian federal agencies and scientists have been developing and applying these techniques for some time.

For computational reasons, the methods described require that explicit targets be set for conservation and other goals. However these targets can be used either prescriptively or simply as a means to explore the consequences of alternative scenarios.

3.4.3 Adaptive management

For complex ecosystems, which include diverse social impacts and interactions, the level of knowledge available to managers at appropriate scales is often very low. Adaptive management processes provide a means to correct mistakes and continue learning of what strategies are effective and what improvements can be made. It is essential to include evaluation and assessments of management effectiveness at the beginning of the planning cycle. The evaluation results can then feed into ongoing management strategies.

Direct information on performance is something that can only be obtained by direct measurement of that performance. Smaller scale laboratory, field and other management experiments, while often having more refined elements of control and replication, are not fully transferable to other localities, situations, scales and times. While such experiments may provide good evidence of general patterns and trends, working hypotheses for broader applications, or starting points for ongoing management, the only real tests of an individual MPA's effectiveness are measurements made on that MPA system. Essentially, we should use existing MPAs to obtain information about effective design criteria, including minimum sizes, and the extent of no-take areas (Agardy 2000, Agardy *et al.* 2003).

The fundamental first steps to achieving an adaptive management system are well thought out, comprehensive objectives that can be explicitly and directly linked to specific criteria for both initial and ongoing assessment.

By using an adaptive management approach to evaluating existing MPAs, we can determine:

- the extent to which the objectives of management have been met,
- a more transparent and systematic link between management objectives, management actions and gaps in information,
- what works and what doesn't work based on scientific evidence
- how MPAs actually work socially and ecologically by assessing the dynamics of the system and the interaction with management efforts (Day *et al.* 2003).

All too often, day to day management matters often displace longer term strategic monitoring and evaluation programmes (Jones 2000). Therefore, it is essential to have a strategic approach for developing monitoring priorities and to recognize that the evaluation techniques used need to be continuously adapted and improved (Day *et al.* 2003).

3.5 Summary

This chapter reviews goals, objectives, criteria and guidelines for marine protected management, with particular emphasis on the GBRMP. In addition, I present a range of decision support modeling methods available to MPA managers to assist in the systematic use of data and information sources to select marine protected areas designate varying levels of protection. I recommend that these methods are used to examine information from all sources simultaneously, using a systematic process. This integrated approach is demonstrated in Chapters 5, 6 and 7, using the Cairns Area Plan of Management as a case study.

Chapter 4. Information for marine protected area planning in the Great Barrier Reef Marine Park

While comprehensive guidelines for MPA management and a wide variety of decision support tools to assist in the systematic application of these guidelines are available, both guidelines and tools have been under-utilised in planning for the Great Barrier Reef Marine Park. In addition, the GBRMPA had some of the most extensive information resources and data collection programs available for any MPA on the planet. However, these resources were not readily available to managers at the time of this study and thus their direct use in marine park planning, permitting and day to day management was limited.

This chapter first audits the use of ecological, social and economic information in Marine Park management at the time of this thesis, through a survey of marine park managers. I then make recommendations for future planning processes, identify information gaps and suggest additional information sources that could be adapted or developed to assist in decision making. In particular, I concentrate on the integration of different data sets and decision support tools using geographic information systems (GIS) and the development of spatially explicit data sets to represent community input to marine park planning processes.

4.1 Introduction

The shift towards a more strategic, systematic and spatial approach to managing impacts has required and will continue to require investment in quality *research, monitoring* and *consultation* (GBRMPA 1997). This approach aims to allow the development of credible information systems on which management decisions can be based. Just as significant is a need to understand the users, their motivations, expectations, and perceptions of the Marine Park. This information is essential to the effective setting of appropriate levels of use and the identification of the best management instrument for the Marine Park.

However, the ability to assimilate information into the decision making process is often limited. Decision making in any conservation management agency should be an information-intensive task (Loh and Rykeil 1992) based on clearly defined goals, objectives and criteria. As public concern about resource conservation and environmental quality increases, managers must continue to make decisions based on fact and not on anecdotal evidence or hearsay.

The information base at the GBRMPA was largely ineffective prior to the development of the Representative Areas Program in 1998 (GBRMPA planning staff, pers comm. 1998). Information was either not available, not collected at an appropriate scale, or not accessible because of varying format and location or in some instances the sheer, overwhelming abundance of the data.

Although there was a theoretical commitment to setting limits of use, such limits could not be achieved without an appropriate information base, available to all agencies and individuals involved in strategic and statutory decision making for the marine park. At the Fenner Conference in 1997 Senator Ian MacDonald stated:

> "*It is important that the effects of use can be measured, and as necessary mitigated, in order to prevent irreversible damage to natural heritage or to the productive capacity of ecosystems.*
>
> *Effective management of multiple use therefore requires a sound information base. Judgments have to be made on the basis of the best available information. We need sound information about the environment and the way it reacts to the pressure we put on it if we are to be sure that we are doing our very best to protect it.*" (MacDonald 1997).

During the mid 1990s, a large proportion of the information describing the reef resources in the GBR was not making its way into the decision making framework at GBRMPA. In a review of the GBRMPA, the Auditor General (Australian National Audit Office 1998) stated that

> "*The authority does not have adequate data to determine whether it is achieving its primary objective of protecting, conserving and allowing for reasonable use of the Great Barrier Reef Marine Park*".

Managers need to understand the biophysical and social system at a scale appropriate for managing the resource. Managing multiple uses therefore requires a sound information base that is easily accessible to the actual staff members responsible for making recommendations and decisions regarding the allocation of use.

In light of the perceived lack of this information base, in 1995 I conducted face to face interviews with key planning staff at the QEPA and GBRMPA.

4.2 Interviews with managers on information use in marine park planning

The aim of these interviews was to identify what information was readily available and what further information was required for making decisions about resource use. Specifically the survey aimed to: 1) identify what data were required to support decisions about resource use; and 2) determine the managers' perception of the availability of this information.

Twenty two staff members at the GBRMPA and QEPA were identified by the Chairman of the GBRMPA as having input into the planning process for the allocation of resource use in the Cairns Sector of the GBRMP (pers comm, GBRMPA Chairman 1995). Face to face interviews were conducted with all 22 staff members, using an open-ended survey approach (Appendix 2). While standard questions were asked during the interview, staff members were encouraged to elaborate on their information requirements and levels of expertise.

For each question, staff members were asked to identify their area of expertise (e.g. strategic planning, zoning plans, management plans, site specific plans, mooring and anchoring plans and permit assessments) and answer the question accordingly. The survey was divided into four sections. The respondents' level of experience at the GBRMPA was discussed through a series of questions at the beginning of the survey. The questions in the second section helped the respondent recall the types of decisions they made in their area of expertise, the relative success of these decisions and the duration of the decision making process.

The third section of the survey identified the respondents' perception of the availability of data available to assist in decisions concerning use of the resource. The fourth section of the survey asked questions about the data they used and would like to use in the future such as preferred scale of information.

4.2.1 Results of the survey of managers

The level of experience of the 22 respondents ranged from three to 18 years with 77% having over six years of experience at the GBRMPA. Individuals had worked in their current position from three months to just under five years. The main areas of expertise (NB: most respondents had more than one area of expertise) included permit assessments (55%), zoning plans (45%), management area plans (45%), site specific plans (45%), mooring and anchoring plans (41%), strategic planning (32%), and other related areas (mainly scientific research) (23%). Table 4.1 lists the types of decisions, duration and scale of information for decisions made by the respondents in each area of expertise.

Area of Expertise	Type of Decision	Time required for decision	Spatial scale of information required
Permit assessment	• assess permit applications to conduct tourist, traditional hunting and research programs in the GBRMP • make recommendation to accept or reject permit application • decide what fees to charge	Should be quick Varies from 1 hour to 2 years	1:1000 (e.g. a site within a reef)
Zoning plans	• develop public consultation program • develop plan framework • develop policy on use management for an area • control fishing and collecting use • make recommendations for zoning plan • decide mailout and public consultation protocol • communication strategy • issues and options • identify priorities • determine what management tools to use	Several years	1:100,000 to 1:250,000 (e.g. entire GBRMP)
Area Plan of Management	• identify concern and define what elements are causing that concern and develop strategies to deal with it • develop Plan objectives • develop Terms of Reference • determine what management tools to use • determine which options are available • decide what information to use • decide which locations to protect • develop use policy for area • decide levels and types of access	Can take several years - open ended process	1:5000 to 1:10,000 (e.g. a section of the marine park)
Site Specific Plans	• develop use policy for site • determine site restrictions, site surveys	1 to 6 months	1:2500 to 1:5000 (e.g. a reef or group of reefs)
Mooring and Anchoring Plans	• develop mooring and anchoring protocols • determine site restrictions • conduct site surveys	Long term (e.g. anchor damage takes 5-10 years to assess)	1:2500 to 1:5000
Strategic plans	• conduct strategic assessments of GBR resources and use of resources	Long term, over 3 years	1:100,000 to 1:250,000

Table 4.1: Summary of comments made by the 22 managers regarding the types of decisions they make, how long the decision took and the scale of information required to support these decisions in each area of management expertise.

For all areas of expertise the data requirements were similar and varied by the spatial scale of the information required (Table 4.1). Managers identified three main types of information required for decision making: information about the natural environment, the social environment and the management environment. Table 4.2 details the data requirements for each of these domains.

Natural Environment	Social Environment	Management Environment
• biological survey information • reef type • reef classifications • habitats • rare, threatened or endangered, and significant species	• Aboriginal and Torres Strait Islander information • conservation values • existing use patterns • conflicts in existing use • perception of reef resource • projected growth in demand for future use • anticipated use of adjacent areas • distance from population centres • database of submissions	• zoning, site plan, and management plan requirements, legislative requirements, precedence from past decisions, • administration information • MPA policy • existing use data • input from public meetings • database of submissions • personal knowledge of staff

Table 4.2: Summary of information requirements for decision making regarding use allocation.

While the managers agreed on the types of information they would like to use to support decision making (Table 4.2), there was a great deal of disagreement on the accessibility of this information. For example, some planners felt that biological monitoring data was seldom used as it was difficult to access and interpret, while others were able to incorporate it in their decision process concerning site use. There was consensus about the lack of social data to support use decisions and the difficulty in accessing what social data there were. For example, the introduction in 1993 of the Environmental Management Charge (a reef tax for all tourism operators) provided an opportunity to develop a database on visitor use, as the resulting Data Returns Database could have provided an excellent tool to monitor and identify commercial tourism use at all scales in the GBRMP. However, even by 1997 this database was perceived as completely user "unfriendly", being difficult to query and having limited connections to other corporate databases (Valentine *et al.* 1997).

All of the survey respondents believed that decisions based on environmental grounds were the "easiest to defend" and were therefore the "most successful". More than 50% of respondents also commented that decisions based on biophysical questions with measurable impacts, public safety issues, the setting of clear policy and guidelines and decisions that were not threatening to existing use of the marine park were the easiest to make.

Therefore, the respondents wanted to be able to: a) access all relevant information in a useable and easy to interpret format, b) share information between the relevant state and federal agencies, c) obtain detailed site information about the values and use of reef areas, d) look at the relationships in the data (ie: between biological and social values), and e) identify where conflicts could occur between reef user groups and conservation issues.

In order to assist managers in achieving these aims, I developed a relational database linked to a geographic information system (GIS), using ArcView 3.2a. This relational database displays accessible and relevant natural, social and managerial information in an easy to interpret graphical format and was made available to both the state and federal agency to assist with future use allocation planning. The rest of this chapter details the information I included in the GIS and used for analyses in Chapters Six and Seven. I have separated the rest of this chapter into sections addressing several datasets describing the natural environment, social environment and management environment.

4.3 The Natural Environment of the Cairns Sector of the Marine Park

A healthy coral reef ecosystem is required by most of the users of the Cairns Sector. For example, tourism operators who present the marine park to a wide variety of domestic and international visitors require a resilient, functioning and productive environment with high coral cover and species diversity in order to sell their product (GBRMPA 1998). Recreational use, traditional activities, commercial fishing and collecting also require these features to varying degrees.

A great deal of scientific information had been collected in the Cairns Sector of the marine park describing various ecological and physical features of the area. Although many datasets were reviewed for this thesis, only a limited number were readily accessible, free of charge, in an appropriate format and collected over an appropriate geographical scale.

4.3.1 General ecological description of area

For the purpose of managing use in the marine park, planners at the GBRMPA required information describing the following ecological variables:

- corals and associated biota
- marine wildlife and their habitats (including dugongs, turtles and whales)
- seabirds (GBRMPA 1998).

Physical variables that are known to affect use of the area include:

- distance of the reef from the nearest port
- shelf position of reef (inner shelf, mid shelf, outer shelf)

Much of this information was spread among many institutions, departments, and individual researchers and held in a variety of formats. There was a widespread sense of ownership of the data and often additional resources were required to code data in such a way that they could be used with other datasets.

Therefore, although a great many data existed describing the GBRMP or the Cairns Planning Area, it was a lengthy and sometimes difficult process first to obtain and then to format those data to a useful state. The thesis provides an ideal means of making these data available to be used in the actual management of the marine park and thus provides a basis for well informed decisions in the future.

In order to find data describing the ecological variables mentioned above, I approached a number of key research and management institutions associated with the Marine Park: the Great Barrier Reef Marine Park Authority, Australian Institute of Marine Science, Queensland Department of Environment, Department of Primary Industries – Fisheries, Royal Australian Navy, Queensland Museum, James Cook University and the Cooperative Reef Research Centre. The following agencies or individuals provided ecological or physical data for this project:

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Agency / Individual	Type of Data	Spatial Extent
Australian Institute of Marine Science	biological monitoring data	entire marine park
James Cook University and Sea Research: Drs. Bruce Mapstone, Tony Ayling and Professor Howard Choat	biological monitoring data	Cairns Sector
Great Barrier Reef Marine Park Authority	pontoon biological monitoring data	seven locations (Agincourt Reefs Nos. 2d, 3 and 4; Low Isles; Norman Reef; Hastings Reef; Arlington Reef)
Great Barrier Reef Marine Park Authority	physical data; GIS base maps (e.g. Queensland coast, reefs, islands, cays, rivers, cities, dugong protected areas, bird nesting sites)	entire marine park
James Cook University: Professor Helene Marsh	dugong, turtle and cetacean sitings and population density estimates	entire marine park
Queensland Department of Primary Industries	fish spawning sites (coral trout only)	Cairns Sector

Table 4.3: List of data and agencies who provided information for this thesis

Once obtained, these datasets were incorporated into a Microsoft Access database with a common reference field identifying the location of the study or sighting. This information was then linked to the GIS using the spatial field as a reference.

4.3.2 Corals and Associated Biota

Corals, fish and other animals are dominant visual features of the underwater landscape in the GBRMP (Shafer *et al.* 1998), but little is known about peoples' ability to perceive different types of these organisms in this environment. In addition, there is no information on people's preferences for sites with different levels of natural conditions, such as different types of coral and fish assemblages, different sizes and varying levels of species diversity.

There is, however, a great deal of scientific information describing the corals and fish species found within the GBRMPA. Most studies have focussed on a small geographical scale (within a few km); few have assessed coral and associated biota over large geographical scales. In the Cairns Sector, the two major research programs that have been conducted to describe reef resources are the long term monitoring program (particularly the broadscale monitoring task) conducted by AIMS and the monitoring research conducted by Mapstone, Ayling and Choat (1995) for the Marine Park Authority.

4.3.2.1 Australian Institute of Marine Science (AIMS)

The Australian Institute of Marine Science has collected data on a wide spectrum of reefs in the marine park since 1985. Using the manta tow technique, AIMS researchers have described many of the patterns in reef processes associated with COTs outbreaks. The information has helped to develop understanding of the effects of the Crown of Thorns Starfish and the extent of their activities in the marine park. The objectives of the AIMS research program have been to:

- Identify the source of COTs outbreaks
- Detect outbreaks
- Determine the effects of outbreaks on corals
- Determine the effects of large scale disturbances (e.g. cyclones)
- Monitor the recovery of corals
- Monitor the general cover of live and dead corals.

In 1992, AIMS initiated a long term monitoring program to assess long term changes on the Great Barrier Reef. This research incorporated previous monitoring programs, is ongoing and is jointly supported by the Australian Institute of Marine Science, the Reef CRC and the GBRMPA. The objectives of this program are (a) to monitor the status and changes in the distribution and abundance of reef biota on a large scale and (b) to provide environmental managers with a context for assessing the impacts of human activities within the GBRMP and with a basis for managing the GBR for ecologically sustainable use. There are four tasks within the monitoring program: broadscale surveys (manta tow surveys); water quality measurements; video surveys of benthic organisms and fish surveys.

Methods

Video and fish surveys have been conducted annually on the NE reef flank on 34 reefs throughout the marine park since 1992. These reefs were chosen to represent geographical variation in coral composition, fish communities and water quality (Done 1982, Williams 1982, and Furnas 1991). Three or more reefs from each of the inshore, mid-shelf and outer shelf regions were selected in the Cooktown to Lizard Island Sector, the Cairns Sector, the Townsville Sector, Whitsunday Sector, the Swains Sector and the Capricorn Bunker Sector. In the Cairns Sector this amounted to a total of 16 reefs sampled on the NE reef flank. The limited number of reefs sampled in the Cairns Sector and the lack of spatial replication within a given reef (e.g. no samples taken from back reef or front reef habitats) made it difficult to make comparisons with other datasets or extrapolations from this dataset. Thus this dataset was not used for comparisons in my research.

Broadscale manta tow surveys have also been conducted annually by AIMS on other reefs throughout the marine park since 1985. On average, 98 reefs per year were sampled throughout the marine park and 39 of those were located in the Cairns Sector. In these surveys, the perimeter of the entire reef was surveyed using the manta tow technique (Moran and De'ath 1992). During each two minute manta tow, the following variables were recorded: number of COTS, presence of feeding scars, extent of COTS activity, percent cover of live coral, dead coral and sand and rubble. The clarity of the water was also estimated on the first tow at each reef. In addition, after the tows were completed on a given reef, researchers recorded an aesthetic value for the front reef, flanks and back reef habitats.

Although the limitations of this sampling method have been discussed by Fernandes *et al.* (1990), it provided a very useful dataset for elucidating broad scale patterns of coral and substrate cover throughout the Cairns Sector over an 11 year period.

Data storage, quality control and accessibility

The long term monitoring database is held at AIMS, stored as an Oracle^{TM} database. This database has been consistently collected, entered and edited (Sweatman 1997). It is readily accessible and should be used to provide information on broadscale patterns of COTS and coral cover to any management program relating to the marine park. The database can be easily linked to the GBRMPA corporate database through a common reef identification number.

Unfortunately, it is impossible to disaggregate the AIMS data into different habitats within a given reef. Although a series of two minute tows were conducted around each reef, it is impossible to tell where each tow was located within the reef. Thus the data provided by the AIMS database can only be summarised at a whole reef level, with no information available on back reef, front reef and flank habitats. Information on these habitats within a reef, particularly the more sheltered back reef habitat, is important to managers in developing site plans, mooring and anchoring plans and area plans of management. Thus, in 1996 I edited the AIMS database for the Cairns Sector, using the original survey maps and field data to include an additional field that describes the tow's position within the reef's different habitats.

4.3.2.2 Mapstone, Ayling and Choat (1995)

Mapstone *et al.* (1995) published the results of their research on the Cairns Sector of the marine park in a series of reports for the GBRMPA. Their research aimed to describe large scale patterns of distribution and abundance of coral reef organisms. It was hoped that this research would assist with planning for use of the marine park and result in the development of management strategies that took into consideration patterns in the distribution and abundances of various reef biota. In addition, the research was used to provide insight into the design of future sampling and monitoring studies of coral reef environments.

Methods

The data provided by Mapstone, Ayling and Choat were collected throughout the Cairns Sector in 1991 and at the Frankland Islands in 1998. Data were provided for 45 sites in the section including four inshore fringing reefs, 20 middle shelf reefs and 21 outer shelf reefs. Each reef was sampled at three sites within back and front reef habitats. Belt and line transects were sampled within each site for fish and sessile benthos. All sampling was conducted by divers using SCUBA. The researchers provided the data as mean numbers of mobile species and mean percent cover of sessile species per site.

The organisms these researchers investigated included:

- *Acanthaster planci, Linkia laevigata* and *Tridacna* spp.

- Sessile benthic biota and non living substrata
- Fish with medium to great mobility over short periods
- Fish with restricted home ranges and limited mobility over short periods.

Data storage, quality control and accessibility

The information from this project is held by the researchers at James Cook University, stored in dBase III^{+} tables. The database has undergone extensive editing and datachecking using programs developed by the researchers. Quality control of the data entry was ensured by double entry of the data by two different operators. Several comparisons were made between the two datasets to cross check and correct for errors until the files matched and all data were within logical boundaries. In addition, following the crosschecking and correction cycle, 100 records from the dataset were randomly selected and checked against the raw data sheets.

These data are accessible upon request, with limitations on their use enforced by the researchers. For example, for this thesis, the following conditions existed:

1. That the data were treated as confidential and not passed on to anyone else
2. That the data were used only to supplement those which had been collated for this PhD thesis
3. That the data were not published or publicised in any form in any forum
4. That the data were not presented in the thesis other than as they served to 'ground truth' the other data.

Given these limitations, the data could be downloaded in a variety of formats, including SAS 6.11/6.12 tables, dBase III tables and text files. The information could be linked to the GBRMPA corporate dataset via the reef identification field.

Field maps of the study sites existed, but no positions had been entered into the database or mapped in a GIS. Thus it was difficult to identify the exact location of the transects.

4.3.3 Marine animals and their habitats (including dugong, turtles and whales)

Large marine animals such as the dugong, turtles, dolphins and whales are found within the Cairns Sector of the marine park and are highly valued by the Indigenous, local, national and international communities (Marsh 1996). However, little is known about how the presence of these animals affects the experiences of visitors to the Cairns Sector of the Marine Park. In addition, there is no information to indicate whether people prefer to visit locations where these "charismatic megafauna" are commonly found.

There is, however, some scientific information describing the presence and abundance of these organisms within the GBRMPA. This information has been collected as a result of Australia's international obligations to protect these animals and their habitats. Most studies have focussed on a large geographical scale, in order to detect trends in population density over a long period of time.

4.3.3.1 Dugong

Dugongs (*Dugong dugon*) are found in coastal and island areas from east Africa to Vanuatu, between latitudes 26^{O}north and south of the equator (Marsh *et al*. 1999). Dugongs are the only member of the family Dugongidae. They are listed as vulnerable to extinction on a global scale by the IUCN (World Conservation Union). Dugongs are also listed under CITES, the Bonn Convention, the *Queensland Nature Conservation (Wildlife) Regulation 1994* and the *Environment Protection and Biodiversity Conservation Act 1999*. As explained in Chapter 2 Section 2.3.3, one of the main reasons cited for nominating the Great Barrier Reef for World Heritage listing in 1981 was the fact that the GBR provided major feeding grounds for dugongs (GBRMPA 1981).

The Great Barrier Reef Region is an important feeding area for dugong, which feed primarily on seagrass. They generally prefer species from the genera *Halophila* and *Halodule*, which are small and delicate, have high nutritional value and are easily digested (Marsh *et al.* 1996).

Dugongs are considered to be under threat from human influences. In the GBRMP, pollution and damage to seagrass beds are the main threats to dugongs. Other threats include accidental drowning in fishing gear and over harvesting of dugong by traditional hunters (Havemann *et al.* 2005).

Following a significant decline in the numbers of dugongs in the southern regions of the marine park (Marsh *et al.* 1994, 2005), the Great Barrier Reef Ministerial Council established a series of Dugong Protection Areas along the Queensland coast (Marsh 2000). The Council hoped that this action would stop the decline in dugong numbers. The protected areas prohibit net fishing and hence accidental capture of dugongs at important habitats. There are no dugong protection or control areas in the Cairns Planning Area, as this area supports relatively few dugongs. However, dugongs are known to exist in inshore waters which contain seagrass beds, particularly in the Port Douglas to Cape Tribulation inshore waters (GBRMPA 1998)

4.3.3.2 Turtles:

Six species of turtles are found in the Great Barrier Reef Region: loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricate*), leatherback turtle (*Demochelys coriacea*), olive ridley turtle (*Lepidochelys olivacae*) and flatback turtle (*Natator (Chelonia) depressus*). All marine turtles in

Australia are listed as threatened in *Queensland's Nature Conservation (Wildlife) Regulation 1994* and under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999.*

Most marine turtles are listed as endangered by the 2000 IUCN (World Conservation Union) Red List of Threatened Animals and are listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In addition, marine turtles are a conservation priority under the Bonn Convention.

Turtles are currently under threat from human influences. According to Environment Australia (1997), pollution and damage to important habitats including seagrass beds, coral reefs, mangrove forests and nesting sites are among the main threats to turtles. Other threats include over harvesting of turtles and eggs. The Recovery Plan for Marine Turtles in Australia (Environment Australia 2003) lists additional human related mortality factors for marine turtles on the Great Barrier Reef, including boat strikes, coastal development and loss of habitat, declining water quality, defence exercises, disease, feral animals, fishing activity, hunting and collecting, marine dredging and construction.

The Great Barrier Reef Region is an important feeding area for all marine turtles, both local populations and populations that nest in other areas. As a result, turtles are commonly seen in all areas of the Marine Park. Green and Hawksbill turtles are the most commonly seen species, while the leatherback and Olive Ridley are quite rare (Marsh, *et al.* 1994). One of the main reasons cited for nominating the Great Barrier Reef for World Heritage listing in 1981 was the fact that the GBR contained nesting grounds of international significance for the green and loggerhead turtles (GBRMPA 1981).

The diet of marine turtles varies between species. Adult green turtles feed mainly on seaweed and seagrass. Hawksbill turtles feed on primarily sponges but also eat seagrass, algae, soft coral and shellfish. Flatback turtles feed on sea cucumbers, soft corals and jelly fish. Leatherback turtles feed on jellyfish and soft bodied invertebrates in the open ocean. Loggerhead turtles feed on shellfish, sea urchins, crabs and jelly fish. Olive Ridley turtles feed on shellfish and small crabs.

Turtles often migrate long distances between feeding grounds and nesting sites. There are only a few large nesting rookeries left in the world and several of these are in the GBRR. However, none of these large nesting areas is located in the Cairns Sector.

4.3.3.3 Cetaceans

Twenty species of whales and dolphins have been recorded in the Great Barrier Reef Marine Park (Marsh *et al.* 1994). Little is known about most of these species, which is reflected in their IUCN listing as “DD – Data Deficient”.

The humpback whale (*Megaptera novaeangliae*), which is commonly seen during its seasonal migration to tropical breeding grounds, is listed as vulnerable in the *Queensland Nature Conservation (Wildlife) Regulation 1994*. The dark shouldered form of minke whale (*Balaenoptera acutorostrata sensu lato*) is listed as secure in the Australian Cetacean Action Plan and the dwarf minke whale is listed as “no category assigned due to insufficient information”. Sperm whales (*Physeter catodon*) have also been sighted by tourism operators in the northern regions of the GBRMP (Dunstan, pers. comm). The sperm whale is listed as vulnerable in the IUCN 2000 Red List of Threatened Animals.

Two species of dolphins commonly seen in the GBRMP are the Indo Pacific humpback dolphin (*Sousa chinensis*) and the recently described Australian snubfin dolphin

(*Orcaella heinsohni*). The Indo Pacific humpback dolphin and the Irrawaddy dolphin (*Orcaella brevirostris*), from which the Australian snubfin dolphin has only recently been differentiated (Beasley *et al*. 2005), are listed as rare under the *Queensland Nature Conservation (Wildlife) Regulation 1994*. In addition, the IUCN Action Plan for Conservation of Cetaceans (Reeves and Leatherwood 1994) expressed concern over the vulnerability of all coastal species of dolphins, including those mentioned above and the bottlenose dolphin (*Tursiops aduncus*).

Cetaceans are currently under threat from human influences. Damage to important habitat, boat strikes, disturbance from whale watching, noise, accidental drowning from fishing gear and shark nets are all impacts of widespread national and international concern.

4.3.3.4 Marsh, Breen and Preen (1994)

In 1986, 1987, 1992 and 1994, Marsh and others conducted aerial censuses of dugong, turtles and cetaceans in the inshore regions of the Great Barrier Reef Marine Park south of Cape Bedford (Marsh *et al.* 1994). The primary aim of the overall survey was to provide estimates of dugong populations, and as such it was designed around known dugong distributions in the area.

Methods

The survey methods and analyses are described in detail in Marsh and Sinclair (1989), Marsh and Saalfeld (1989) and Marsh *et al.* (1994). The inshore waters of the Cairns Sector were surveyed between 13 November and 12 December 1992, on days when weather conditions were below a Beaufort Sea State of 3 and glare from the sun was at a minimum. Transects were flown in an east to west direction perpendicular to the coast. The transects were positioned 5’ latitude apart and flown at 137m above sea level at speed of 185km per hour. The transect width was 400m, with 200m either side of the aircraft. Dugong, turtles and cetaceans were counted along the transect. Species specific correction factors were used to correct for perception bias and standardise for availability bias prior to calculating population estimates.

Data storage, quality control and accessibility

Data from all aerial surveys are held at James Cook University and the GBRMPA, stored in a Microsoft Access 97 database. This database has been consistently collected, entered and edited. It is readily accessible upon permission from the principal researcher and should be used to provide information on broadscale patterns of dugong, turtle and cetacean distribution to all management programs relating to the Marine Park. The database can be easily linked to the GBRMPA corporate database through a common reef identification number. The information is also available in a GIS format.

4.3.4 Seabirds

Birds create a part of the "above water" landscape and are commonly found on islands and cays within the Cairns Sector. There is no information on how seabirds influence peoples' preferences for visiting different islands and cays in the section. There is also little scientific information available on the diversity and abundance of birds in the area.

The Herald Petrel (*Pterodroma heraldica*) and the Yellow Chat (Dawson) *(Epthianura crocea macgregori*) are listed as critically endangered under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. They are found at only a few isolated locations within the Great Barrier Reef, but not within the Cairns Sector.

However, it is known that Michaelmas Cay is the most important seabird bird roosting and nesting location in the Cairns Sector and the second most important nesting site in the GBRWHA (GBRMPA 1998). The cay supports populations of Common Noddys (*Anous stolidus*), Sooty Terns (*Sterna fuscata*) and Lesser Crested Terns (*Sterna bengalensis*). Over the past decade there have been declines in seabird numbers at Michaelmas Cay. For example, the Sooty Tern has declined by 25%, the Common Noddy by 45% and the Crested Tern has also declined (Heatwole *et al.* 1996). Other islands and cays in the Cairns Sector that support nesting seabirds include SeaBird Islet, West Hope Island, Woody Island, Mackay, Undine, Vlasoff, Upolu Cays and Sudbury Cays (GBRMPA 1998).

There has been ongoing concern that tourism and recreation, defence exercises, fishing, shark control programmes, aquaculture and traditional collection of eggs impact upon breeding seabirds in the Great Barrier Reef Marine Park. An Action Plan for Australian Birds 2000 (Garnett and Crowley 2000) was developed to give an overview of the conservation status of all birds found in Australia, identify threats and recommend actions to minimise these threats. The GBRMPA has developed guidelines for managing visitors to seabird breeding islands, brochures, information leaflets and best environmental practices for observing seabirds and has also set limits in the Cairns Area Plan of Management on speed of vessels and aircraft and approach distances to significant seabirds sites in the Cairns Planning Area.

4.4 Physical Variables

It is commonly stated by tourism operators and local resource users that physical conditions play a major role in their preference for different reef sites (GBRMPA EMC Database, GBRMPA planning staff, pers. comm. 1997). Variables such as exposure to prevailing winds, shelf position of reef, underwater topography, and water clarity influence the quality of reef sites. Different interest groups may have different requirements for the physical environment. However, there is little information on the role of physical conditions on marine experiences. Shafer *et al.* (1998) explored the influence of weather conditions on tourist experiences in the marine park. They found that rough weather conditions had a high potential for a negative influence on visitor enjoyment. Tourists were found to prefer days with lower wind speed and higher temperatures.

Weather conditions cannot be managed, as they are constantly changing and beyond human control. Site selection by tourism operators, recreational users and other interest groups is influenced by exposure, bathymetry and shelf position (GBRMPA EMC Database, GBRMPA planning staff, pers. comm. 1997). Thus knowledge of these more permanent physical conditions could help in the management of the natural resource. However, there was no available information on the influence of these variables on site selection or visitor preference. As a result, this information was collected in this thesis (Chapter Five).

4.5 Social Conditions in the Cairns Sector of the Marine Park

There is a wide diversity of use of the Cairns Sector, including scientific research, traditional hunting, commercial and recreational fishing and tourism. In 1997, there were approximately 800 registered tourist vessels permitted to use the area, with the capacity to carry over 2.5 million tourists per annum. Forty-five reefs in the area were used for site specific activities. The Cairns Sector of the GBRMP has the Marine Park’s highest level of marine tourism use, with operators permitted to visit most locations within its boundaries.

In addition, Blamey and Hundloe (1993) found that people residing adjacent to the Cairns Sector had among the highest number of private motor boats registered in the entire GBRMP. At the same time, there were over 200 commercial fishers operating in the area. The inner reef shipping channel also runs through the Cairns Sector, with several large ships passing through its waters each day. Aboriginal people and Torres Strait Islanders live in coastal communities adjacent to the section and there are several areas of cultural significance within the marine and state parks (Britnell 1996). The area is regularly used for traditional hunting and fishing. In short, the Cairns Sector has some of the most intensively used reefs and waters in the entire Marine Park.

In the late 1990s, concern was expressed that the large number of people using the area, the close proximity of vessels to reef sites and the types of activities being undertaken were diminishing the reef experience for many visitors (GBRMPA planning staff, pers. comm. 1998). All of these factors are part of the social conditions that influence both users and the marine environment they are visiting (Manning *et al.* 1996). A study by Shafer *et al.* (1998) for the Reef CRC Research Centre looked at the influence of these conditions on tourist visitation. These workers found that the conditions which had the most positive influence on visitors' reef experience were related to natural features of the site (e.g. corals, fish and settings) and the services offered by the staff. Conditions that had a neutral and negative influence on the visitors were related to the number of people or man made structures and the weather and water conditions on the day of travel. Chapter Five in this thesis describes a survey I conducted to determine the effects of social, biological and physical conditions on the reef experience of regular users of the resource. It provides a detailed analysis of the effects of these conditions on the choice of reef sites for a range of user groups, including commercial fishers, tourism operators and recreational boaters.

4.5.1 Patterns of Human Use in the Cairns Sector of the GBRMP

4.5.1.1 Cultural and Heritage Use:

Within the Cairns Sector of the Marine Park there are many sites of cultural and heritage significance to Indigenous peoples. The reef resources also provide important hunting and fishing grounds for local communities.

In 1996, the Authority commissioned Damien Britnell and the Mossman Gorge Community to undertake a study of the issues concerning Aboriginal communities in the Cairns Sector. Britnell (1996) found that the coastal communities adjoining the Cairns Sector were concerned about the level of protection of culturally important sites. The communities believed that cultural sites should not be used for commercial tourism and in some cases, not be accessed at all. They also expressed concern that Indigenous people were being squeezed out of traditional hunting grounds by commercial operators, through the presence of vessels and excessive traffic through these areas.

Britnell (1996) identified several areas of major Aboriginal interest in the area, which includes significant cultural sites as well as the most commonly used or preferred resource use areas. Other areas were identified that did not suffer diminished or limited cultural significance, but were merely areas on which community groups were unwilling to see any further access restrictions placed.

Therefore the GBRMPA, on the advice of local Indigenous groups and through other consultancies (Smyth 1990, 1991), identified specific locations of cultural and heritage significance in the Cairns Sector. These are: Petherbridge Islets, Beor Reef, Draper Patch, Cairns Reef, Bee Reef, Malcolm Patch, Gill Patches, Rosser Reef, parts of Lizard Island, Cowie Point, Bailey Point, Pearl Reef, East Hope Island Reef, West Hope Island Reef, Ruby Reef, Endeavour Reef, Pickersgill Reef, Evening Reef, Rudder Reef, Tongue Reef, Snapper Island Reef, Batt Reef, Low Islets, Hastings Reef, Michaelmas Reef, Arlington Reef, Green Island Reef, Moore Reef, Scott Reef, Frankland Islands and several fringing reefs along the coastline. The locations of all these areas are shown in Appendix 1.

The Decopolis Island and Three Island lighthouses are both recognised by the Authority as having European heritage values. These lighthouses have been important navigational aids to shipping along the inner Great Barrier Reef shipping route since the late nineteeth century. The Low Island lighthouse and light station were built in 1878 and provide an example of long term human habitation of a marine park cay (GBRMPA 1998).

4.5.1.2 Tourism Use

A great deal of information is available describing tourism use of the marine park. This information is contained in several corporate databases within the GBRMPA, including the EMC - Data Returns Database and the permits database. These databases were reviewed in a technical report for the Reef CRC by Valentine *et al.* (1997). Following this review, the Data Returns Database was upgraded in the late 1990s and many of the errors identified were removed from the system.

4.5.1.2.1 Data Returns Database

As a part of the Environmental Management Charge that was implemented in the Marine Park in 1993, tourism vessels are required to lodge a quarterly return with the Authority. The quarterly log book submitted by these vessels includes information collected daily on numbers of crew, free of charge passengers and transfer passengers and trip destination. This information has been entered into an Oracle Database developed by the GBRMPA for storage and easy retrieval of the data.

Owing to the quarterly reporting requirements and the data entry process, there is a six month lag time between a visit to the site by an operator and information availability in the database. Information that can be retrieved from this source includes data on visitor numbers on a given date or over a certain period, information on number of visitors to a given location and the number of operators and/or vessels accessing an area or location.

For example, from the database, 16 locations were identified as key tourism locations. These are Agincourt 2d, Agincourt 4, Agincourt 3, Norman Reef, Arlington Reef, Moore Reef, Green Island, Low Island, Michaelmas Cay, Opal Reef, Hastings Reef, Tongue Reef - 3rd Sister, Mackay Reef, Cod Hole, Ribbon No 5., Lizard Island. The locations of all these areas are shown in Appendix 1. All of these sites are within 1 - 2 hours of either Port Douglas or Cairns and are used by site specific and roving operators.

Data storage, quality control and accessibility

In the late 1990s, the Data Returns Database was full of errors, ranging from misreporting by the operator to errors in data entry. Despite the usefulness and importance of the database there were not enough checking mechanisms during data entry. Thus careful interpretation and checking of results was required.

4.5.1.2.2 Permit Database

The Permit Database was set up for the GBRMPA in 1993 as an administrative database to keep track of all types of permits currently active in the marine park. Information contained in this database includes type of permit, name of company or individual, name of vessel, size and registration number of vessel, mooring location and size specifications, location of activity, permitted activity and permitted number of people.

This information has been entered into an Oracle Database developed by the GBRMPA for storage and easy retrieval of the data.

It is possible to query the database to obtain information on the permitted number of passengers to a given location, permitted number of vessels accessing a location, permitted number of passengers per vessel and number of days any given operator is permitted to access a location over a specified time period (daily, weekly, monthly, etc).

Data storage, quality control and accessibility

As with the Data Returns Database, the limitations of the Permit database are mainly due to errors in data entry. Despite the usefulness and importance of this database, there were not enough checking mechanisms during data entry. Thus careful interpretation and checking of results are required.

In the 1990s, the permitted amount of tourism use in the marine park was far greater than the actual use of the area. In 1991, tourist operators were permitted to take over 4 million passengers to the entire marine park. By 1995, they were allowed to take over 10 million passengers, but according to log book returns, they actually took approximately 900,000 passengers. In 1997, the permitted number of passengers had increased to 11.7 million while the actual number taken increased to just over 1.2 million. The concern over this latent capacity has led to the development of a new permit system.

In the Cairns Sector, the discrepancy between permitted and actual use was less than in other sections of the park, e.g. the Central Section. Trends in the permitted capacity of the tourism industry in the Cairns Sector suggest that the industry is very diverse, with varying sectors of the industry having different demands for use of the marine park.

4.5.1.3 Recreational Use

Recreational use of the Cairns Sector tends to be concentrated in inshore areas and inner reef areas near the main population centres such as Innisfail, Cairns, Port Douglas, Bloomfield and Cooktown (see Appendix 1). There is concern that growth in use may erode the value of the area and limit access to popular locations for recreational use.

Recreational activities in the area include yachting, boating, fishing, diving and snorkelling. In 1993, Blamey and Hundloe (1993) found that there were approximately 8,460 private motor boats registered in the Cairns Sector which made over 75,000 recreational fishing trips per year.

The Authority, on the advice of local community groups and marine park surveillance information has identified specific locations of concentrated recreational use in the Cairns Sector. These locations are Boulder Reef, Egret Reef, Cairns Reef, Reef No. 15043, Osterland Reef, Emily Reef Reef No. 15070, Rosser Reef, Cowlishaw Reef, Dawson Reef, Coastal areas from Weary Bay to Cape Bedford, Lizard Island, East Hope Island, West Hope Island, Pickersgill Reef, Evening Reef, Rudder Reef, Tongue Reef, Snapper Island Reef, Batt Reef, Michaelmas Reef, Oyster Reef, Vlasoff Reef, Arlington Reef, Upolu Cay Reef, Green Island Reef, Thetford Reef, Moore Reef, Elford Reef, Briggs Reef, Sudbury Reef, Scott Reef, Frankland Islands, King Reef and the Barnard Islands. The locations of all these areas are shown in Appendix 1.

4.5.1.4 Commercial Fishing Use:

Commercial fishing use of the area is well established and includes inshore net fishing, reef line fishing, trawling, collecting, aquarium trade collecting and mariculture. With the rising tourism and recreational use of the area, access to fishing grounds and secure anchorages near fishing grounds are the main issues concern for commercial fishers in the area.

When staff at the GBRMPA identified areas of importance to the commercial fishing industry following consultation with the community groups, workshops with the local industry groups and information from the surveillance of the area. These areas are Boulder Reef, Egret Reef, Cairns Reef 15043, Osterland Reef, Emily Reef 15070, Rosser Reef, Cowlishaw Reef, Dawson Reef, Lizard Island, East Hope Island, West Hope Island, Endeavour Reef, Morning Reef, Opal Reef, Pearl Reef, Ruby Reef, St. Crispins Reef, Undine Reef, Ribbon Reef No. 1, Ribbon Reef No. 2, Ribbon Reef No. 3, Ribbon Reef No. 4, Ribbon Reef No. 5, Ribbon Reef No. 6, Ribbon Reef No. 7, Ribbon Reef No. 8, Harrier Reef Cay, Ribbon Reef No. 9, Ribbon Reef No. 10, No Name Reef, Pickersgill Reef, Evening Reef, Rudder Reef, Tongue Reef, Snapper Island Reef, Batt Reef, Breaking Patches, Jorgies Patches, Michaelmas Reef, Oyster Reef, Pixie Reef, Pretty Patches, Vlasoff Reef, Arlington Reef, Saxon Reef, Upolu Cay Reef, Green Island Reef, Thetford Reef, Moore Reef, Elford Reef, Briggs Reef, Sudbury Reef, Scott Reef, High Island, Frankland Islands, King Reef and the Barnard Islands. The locations of all these areas are shown in Appendix 1.

4.5.1.5 Research Use

Scientific research and monitoring of the Marine Park provide critical information and understanding of coral reef ecosystems. This information is used to aid in the protection and conservation of the area.

There are three research stations in the Cairns Sector of the marine park, located at Green Island, Lizard Island and Low Island. Many research programs are conducted from these locations.

Permits are not required in some zones if the research is “limited impact research” and the researcher is associated with an educational or research institute accredited by the GBRMPA(www.gbrmpa.gov.au/corp_site/permits/applications/research_permits/index.html). All other researchers are required to submit to a permit assessment and an ethics review in order to conduct their research program. All research permits are entered into the Permits Database, from which it is possible to identify those areas that are used for research programs in the Cairns Sector. These areas are Lizard Island, Agincourt Reefs, Low Islets and Green Island. The locations of all these areas are shown in Appendix 1.

4.6 Summary

As a result of political and legislative requirements, the diversity of human uses and the associated impacts, the decision making process at the GBRMPA is complex and fluctuates over time. There is a wide range of management options available to deal with this complexity. The management options used need to be based on a transparent decision process, which uses systematic and integrated methods based on reliable information. Therefore it is essential for all decision makers within the organisation to have access to and an understanding of the information available to them. At the organisational level there need to be clearly defined policies and criteria for information requirements which reflect the objectives of the area to be managed.

This chapter reviews the social, economic and biophysical information that was available to help planners in the Cairns Sector make effective decisions on use allocation during the development of the Cairns Area Plan of Management. The chapter surveys the information requirements for marine park managers to make decisions about the spatial allocation of resource use in the Cairns Sector of the GBRMP and then describes the natural and social information available to those managers.

The Cairns Sector has some of the most intensively used reefs and waters in the entire marine park. There was concern that the large number of people using the area, the close proximity of vessels at reef sites and the types of activities were diminishing the reef experience for many visitors (GBRMPA planning staff, pers. comm. 1998).

As there was no information available to planners about the social conditions that influence both the users and the marine environment they were visiting, I developed a survey to determine the effects of social, biological and physical conditions on the reef experience of regular users of the Cairns Sector. Chapter Five provides a detailed description of the survey and analysis of the effects of these conditions on the choice of reef sites for a range of user groups (e.g. commercial fishers, tourism operators and recreational boaters).

Chapter 5. Perception of Reef Resources in the Cairns Sector of the Great Barrier Reef Marine Park

This chapter describes a survey I conducted to determine the effects of social, biological and physical conditions on the reef experience of regular users of reef resources. It provides a detailed analysis of the effects of these conditions on the choice of reef sites for a range of user groups. If multiple use opportunities are to be effectively managed, it is important to understand how regular reef users are influenced by changes to the environment and how they experience, perceive and value the natural and social environments. The survey reported in this chapter was conducted concurrently with the development of the Cairns Area Plan of Management and information gathered was used to evaluate the 1998 Plan (Chapter 7). The methods and some of the data reported in this chapter were also used in development of the Representative Areas Program (RAP).

5.1 Introduction

Although the Cairns Sector of the Great Barrier Reef Marine Park contains only 1% of the Park's reefs, over 90% of the human use of the Park is concentrated within its boundaries (GBRMPA 1998). Within the section, use tends to be focused around population centres and major ports, which means that there are areas of low and infrequent use throughout the Section. A wide diversity of uses exists, with different uses placing different pressures on the reef resources. Types of use range from scientific research to Indigenous hunting to commercial fishing and tourism.

In the mid 1990s, feedback from various stakeholder groups had led managers to believe that overall use of the Cairns Sector was approaching a level beyond which unacceptable change in the biophysical and social resources of the park would occur. Although there was a large amount of ecological and environmental information describing reef resources in the GBRMP (Chapter 4), there was only limited information describing human perceptions of that environment. The present study attempted to address that information gap.

5.1.1 Theoretical framework

Since the 1970s, the dominant paradigm for studying human use of a resource has been the behavioural approach. This approach assumes that an activity is undertaken by an individual in order to achieve certain physical and psychological goals (Driver and Tocher 1970). The behavioural approach is based on expectancy theory, in which values are a phenomenon of the human mind and not the physical world. For example, people are motivated to participate in a behaviour in order to attain a goal that has internal value and meaning. Information or beliefs about values and outcomes determine an individual's attitudes, intentions and behaviours (Ajzen 1991).

Most of the research based on this theory has focussed on identifying the underlying motives for behaviour and the meaning of the recreational experience. Several studies have collected information to determine the physical, psychological and social needs that provide motivation for recreational activities (Driver and Brown 1975, Tinsley *et al.* 1977, Kelly 1978). These studies set the foundations for many of the recreation management frameworks discussed in Chapter 3, Section 3.3.

Perhaps the greatest problem with this sort of research lies in its applicability to the management of natural resources. In the management of natural resources, managers or planners have to deal not only with people's motivations and behaviours, but also with the biophysical environment. The complexities of developing management settings to cater for several behaviours where different experiences are desired within one recreational area are not dealt with using expectancy based research. Expectancy theory fails to connect between the world of the mind and the world of matter.

The ecological perception model described by Pierskalla and Lee (1998) provides a more holistic approach to structure recreation management research. This model is based on ecological perception theory, which has been developed since the 1950s (e.g. Gibson 1950, Shaw *et al.* 1974, Michaels and Carello 1981). Ecological perception theory does not try to understand the motives of behaviour, but aims to understand the continual process of seeking and detecting information from the environment, developing perception and participating in activities.

Pierskalla and Lee (1998) suggest that the recreation experience can be viewed as a process of learning where to seek information, seeking information and perceiving information. In summary, their model proposes that the environment is central to the ecological perception model, because the environment is what provides the information to the observer. Special patterns in the environment (e.g. ecological community structure, changes to species composition, cover of coral, fish diversity, etc) provide information and it is the role of the perceiver to detect or discover this information by engaging in perceptual activities.

In this concept, the information discovered by the perceiver is realised as 'affordances' in the human environment. An affordance is defined as something invariant, objective, real, physical and psychical that is offered, provided or furnished by the environment and made available to the observer (Gibson 1966). Some examples of affordances in a reef environment include locomotion (e.g. dive trails), shelter (e.g. back reef habitats), manipulation (e.g. commercial fishing products) and psychical concepts such as excitement, relaxation and stress (Gibson 1979, Pierskalla and Lee 1998). In addition, the environment in which recreation takes place will influence the type of activity in which people participate and the type of information perceived will depend on individual levels of perception and skills related to the activity undertaken. Figure 5.1 illustrates the ecological affordance model of leisure affordances as described above.

Figure 5.1: Perceptual Event in the Human Environment - An ecological affordance model of leisure affordances (from Pierskalla and Lee 1998).

The ecological affordance model dictates that researchers should focus on the significance of the mode of activity, information flows and feedback between the environment and the perceiver rather than the cause of activity selection (i.e. motivation). This is the approach that I used to develop the survey described in this chapter. Instead of focussing on the motivations of reef users, I followed the theoretical approach of the ecological affordance model and combined and contrasted social and biophysical variables.

Environmental perception, particularly perception of resource quality, is influenced by an individual's knowledge of the environment (Fenton and Reser 1988). Repeated experience in an environment develops finer-tuned perceptual skills, which allow humans to detect certain additional information. The activity in which one participates can either enhance or limit one's ability to perceive information (Pierskalla and Lee

1998). For example, commercial fishermen rarely enter the water to view coral communities and thus have limited ability to perceive the underwater landscape. On the other hand, experienced SCUBA divers, who visit the reef specifically to view the underwater landscape, may be especially sensitive to features or changes in that environment (Rouphael 1997).

5.1.2 Aims of the survey

I designed a survey to obtain information from regular reef users on how they perceived the reef resources in the Cairns Sector of the GBRMP. The survey aimed to achieve the following objectives:

- Description of the attributes of stakeholder groups who regularly use the area
- Production of an inventory of environmental perceptions of the resources in the area
- Identification of physical and biological indicators of resource conditions in the area
- Production an inventory of social conditions in the area
- Provision of the data necessary to make comparisons between human perceptions and the ecological status of the resource (Chapter 6).

5.2 Survey methods

5.2.1 Study Area

The study was conducted in the Cairns Sector of the Great Barrier Reef Marine Park (see Chapter 1, Section1.2 and Figure 1.1). The area contains over 160 reefs and covers approximately 3,600,000 hectares (GBRMPA 1998). Most locations are within close proximity to major ports and the Cairns International Airport and are therefore easily accessed by a rapidly growing tourism industry and increasing resident population.

5.2.2 Participants

The target subjects for this survey were interested locals and commercial operators using the Cairns Sector of the GBRMP. The survey was conducted from August to December 1995, in conjunction with the Public Consultation stage of the Cairns Plan of Management. The survey was administered with the assistance of the GBRMPA and the QEPA (Queensland Environment Protection Agency) in Cairns, who allowed me to hand out surveys at their public meetings and promoted the survey to their regional advisory groups.

Members of the regional advisory committees, people who attended public meetings about the Cairns Area Plan of Management, held a commercial tourism or fishing license or a research permit, attended boat shows and SCUBA dive festivals, used marinas or visited fishing tackle shops, resided or operated between the towns of Cooktown and Mission Beach were given a copy of the survey and requested to return it as described below. These groups included recreational boaters and fishers, commercial fishers, tourism industry workers, sailors, scientific researchers, and resource managers. The ethics approval for the survey that was granted by the James Cook University Ethics Committee did not permit the survey to be distributed to Indigenous groups and the GBRMPA also considered that this survey was not an appropriate means of gathering information from Indigenous communities, so such groups were not surveyed.

In order to provide as many of the regular reef users in the Cairns Sector as possible with the opportunity to respond to the survey, surveys were distributed using a combination of several methods. Self-administered surveys were conducted at 20 public meetings run by the management authorities. Respondents were given a 10 minute description of the survey and were then given time to fill it in on site or the option of completing it at home and mailing it back. Surveys were also handed out at two boat shows in the region, at two conferences, a dive festival, an interest group meetings, at all dive and fishing tackle shops in the region and at all marinas in the area. Surveys were also mailed to all tourism and research permit holders and commercial fishermen in the Cairns Sector. An incentive of a draw for a free meal for two was given to all respondents who returned their surveys. In most cases, the survey was returned by mail in a prepaid envelope.

Two mailed reminders (Babbie 1989) were sent to all participants except for those participants who received surveys at the boat shows. Participants at the boat shows were not required to give their return address because of the limited amount of time available for contact.

5.2.3 Survey design

The survey (Appendix 3) was divided into three sections. Section 1 aimed to describe natural conditions of frequented reef and island sites and to identify which biological, physical and aesthetic indicators were important to reef visitors when making choices about the quality of reef sites. Respondents were asked to rate the quality of the three reef sites they visited most frequently according to 17 different biophysical and social variables. The variables used in this section were chosen during a number of workshops with managers and reef advisory committees, including Reef 2001, the Cairns Reef Resources Marine Advisory Committee, Mission Beach Marine Advisory Committee. Respondents were then asked to assess the overall quality of these sites. Sites were rated on a scale of 1 - 7 representing a range of quality from very poor (1) to outstanding (7) for each of the variables. Respondents were also given the option of answering “does not matter” for each variable.

The second section of the survey aimed to determine whether respondents were able to detect environmental damage from a variety of impacts. They were asked to rate the frequency of damage affecting the quality of their three chosen reef sites from 11 different human and natural impacts. The frequency of damage at each site was rated on a scale of 1 (never observed) to 7 (constantly observed) for each of the 11 different impacts. If the respondent did not know or did not want to answer these questions, s/he was given the option of ticking the “no opinion” box.

Section 3 aimed to describe the social conditions of frequented reef sites, identify levels of unacceptable use and determine crowding norms using the "numerical approach", based on a set of standard questions proposed by Donnelly *et al.* (1992). Despite current debate on its limitations, a shortened version of the numerical approach to measuring crowding norms was chosen instead of the visual approach (Manning *et al.* 1999) in order to reduce respondent burden and shorten the survey. These crowding questions were modified to suit the social conditions encountered while visiting coral reefs.

Throughout the survey, respondents' perceptions of their level of experience and depth of knowledge of the reef resources within the marine park were ascertained. Additional comments were also collected on the last page and provided insight into several of the main issues and concerns about use in the Cairns Sector.

The original version of the survey was pilot tested on 20 students and 20 advisory committee members to ascertain the length of time it took to complete, ease of understanding of the questions, and ability to identify on a map the locations frequented.

On the basis of this pilot test, the survey was shortened, the descriptions of how to circle locations on maps and describe activities in those locations were clarified and some variables were removed.

5.2.4 Limitations

A readily available contact list that included the diversity of reef users in the GBRMP did not exist. Therefore several distribution methods were employed to help ensure a good representation of users were included in the study. However, since these methods were effectively a convenience sample, there are limitations on the validity of any interpretation of the results of this study. The probability of all types of reef users' receiving and responding to such a survey is unknown and thus this sample may not be representative of the full range of users. In particular, Indigenous traditional users were not sampled at all.

A further difficulty is that each respondent was asked to assess the three sites that they accessed most frequently, thus these sites are not independent. Several reef locations were dominated by one or two user groups. As a consequence, the probability of spatial confounding of use type is high and the results of my analyses need careful interpretation.

5.2.5 Analyses

A correspondence analysis was used to illustrate patterns of reef use among the different interest groups, based on the main activity of the respondents and the reefs that they most frequently visited.

The sections of the survey concerning natural conditions of reef sites (e.g. reef quality and impacts from human use) were analysed using a principal component factor analysis with orthogonal varimax rotation. Missing values were replaced with the mean value for that variable. Sites that were not assessed for either reef quality or impacts were not included in the analyses, thus removing approximately 70 datapoints. Factor analysis was used to identify a reduced number of dimensions that explained the variance among the 17 variables influencing the quality of a reef site and the 11 impact variables. Factors were interpreted as part of the solution only if they had an eigenvalue of at least 1 and explained at least 5% of the variance. Variables were interpreted as belonging in a factor if they had a loading of at least 0.30 and did not load similarly on any other factors. A reliability analysis (Cronbach's Alpha) was then conducted to test internal consistency, based on the average inter-item correlation. The variable "overall quality" was not included in the analysis (see below). All analyses in this section were done using SPSS statistical software (www.spss.com). In addition, for each dimension, the mean factor score for each reef was mapped using PC ArcInfo. By mapping the scores it was possible to identify perceived patterns of reef quality and impacts.

The section of the survey concerning reef quality was further analysed using regression trees in order to determine how overall reef quality depended on the 17 other biophysical and social variables. All analyses in this section used S-Plus statistical software with specific applications developed by De'ath and Fabricus (2000). Regression trees were used to explain the variation of overall quality by repeatedly splitting the data into more homogeneous groups, using combinations of the 18 biophysical and social variables (De'ath and Fabricus 2000). Splits were selected by maximising the homogeneity of the two resulting groups and minimising the sum of squares within groups. Models were ascertained by cross-validation. For each tree, a series of 50 ten-fold cross-validations were run and the most frequently occurring tree size was chosen using the 1-SE rule as outlined in De'ath and Fabricus (2000). As reefs were the sampling units, they were not included in the models as explanatory variables, but were used to form the subsets for cross-validation. Results from these analyses are presented graphically to aid interpretation.

Pearson Chi-Square analyses were used to test whether reefs (pooled to different shelf position e.g. inner, outer or middle reef) received the same proportion of ratings (e.g. very poor to outstanding) for each of the quality variables, damage variables and social condition variables. Cells with values of less than five were pooled.

5.2.6 Comparison between levels of tourism use and perception of crowding

To allow for reasonable levels of use in the Cairns Sector, it is important to understand the relationship between actual levels of use, perceived levels of use and crowding. With such an understanding, it might be possible to identify a benchmark for socially acceptable levels of use and thus assist the Authority in developing appropriate strategies to manage use.

Information on actual levels of tourism use was provided by the GBRMP through the Environmental Management Charge database (Chapter 4). As explained in Chapter 4, since 1993 tourism vessels have been required to lodge a quarterly return to the Authority, including information collected on daily numbers of crew, numbers of passengers and trip destination of vessels operating in the GBRMP. For comparison with the survey of regular reef users, I used information on the total number of visitors to each reef during the financial year 1995 - 1996 (i.e. 1 July 1995 to 31 June 1996). This period corresponded with the administration of the survey of regular reef users (July 1995 - October 1995).

5.2.6.1 Analysis

Bivariate correlations using Spearman's-rho were used to compare the survey respondents' perceptions of crowding with the actual levels of tourism use for the financial year 1995/1996 (GBRMPA EMC Database, GBRMPA planning staff, pers comm. 1996). Data from all of the survey responses were averaged for each reef before the analysis. Outliers and extreme values, as identified by boxplots of the averaged data, were removed before the calculation of correlation coefficients. Data from reefs where there were missing EMC data or missing responses for perception of crowding were excluded from the analyses.

5.3 Results

5.3.1 Responses

In total, of the 2000 surveys distributed, 463 were returned. Five of the returned surveys were not completed and thus not used in the analyses. This represented an overall return rate of 23%, which is considered reasonable for mailback surveys from reef users of the GBRMP (GBRMPA planning staff, pers. comm. 1995).

The different methods of administration had varying success rates. Figure 5.2 illustrates the response rates for the each of the techniques. Distributing surveys at public meetings was the most successful method of obtaining high return rates.

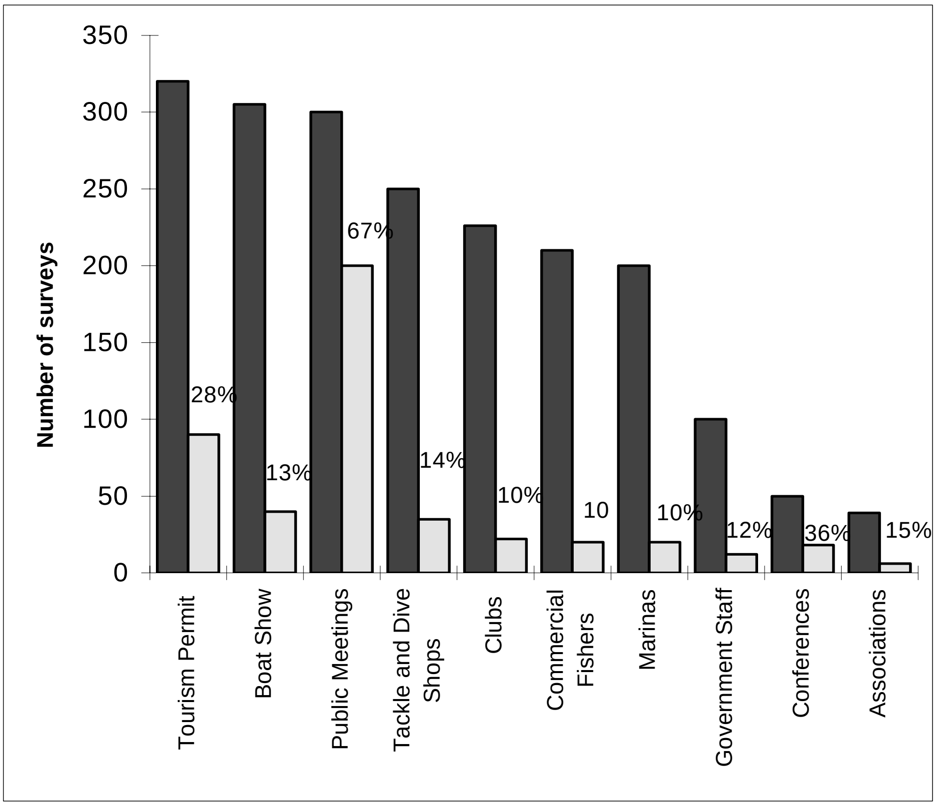

Figure 5.2: Response rates for different methods of survey administration. Black bars indicate the number of surveys handed out at a given venue and light grey bars indicate the number of surveys returned (percentage of returns is given).

5.3.2 Attributes of Stakeholders:

Most of the respondents were regular reef users. Seventy four percent of the respondents visited the marine park at least once a month and 54% had over 10 years of experience in the reef region. Seventy-three percent of respondents had visited more than 10 reefs in the marine park and 78% usually visited a new reef site every 6 months or so.

Cairns was the most popular port of departure amongst the survey participants (47%), followed by Port Douglas (18%) and Lizard Island (5%). Most respondents (80%) travelled between 10 and 100km from their port of departure to visit their reef sites. Vessels used to reach reef sites tended to be less than 12m long (52%), had a cruising speed of under 15 knots (52%) and usually carried up to 10 passengers (76%). Over half of the respondents owned the vessel they used to visit the reef (53%). Fifty-two percent were the people who made the decision about which sites would be visited during a particular trip. Most respondents (58%) considered they had more than 10 reef sites available to choose from in the Cairns Sector for their type of reef use.

Eighty-two percent of the respondents were male and 48% were between 35 and 50 years old. Although few of the respondents had any formal training in reef ecology, most (55%) rated their knowledge of ecological processes in the GBRMP from good to excellent. Respondents were asked to describe the main activity in which they participated while visiting the reef. The percent of responses that described each of the main activities is shown in Table 5.1.

Main Activity	**Number of respondents**	**Percent of respondents**
recreational fishing	117	31%
SCUBA diving	67	18%
snorkelling	42	11%
scientific research	38	10%
commercial fishing	35	9%
sailing	29	8%
other	22	6%
game fishing	15	4%
collecting	7	2%
spear fishing	5	1%
glass bottom boat tours	5	1%
reef walking	1	<1%

Table 5.1: Number and percent of responses for each main activity (only 383 of the 463 respondents answered this question).

Forty-three percent of the respondents were involved in some form of commercial industry capitalizing on the reef resources. Of that group, 65% were involved in the tourism industry, 22% were commercial fishermen and a further 13% were involved in other forms of commercial activity such as photography, commercial diving and environmental consultancies.

Respondents were also asked to indicate their three most frequently visited reef and island sites in the Cairns Sector. They described 1143 sites distributed over 120 reefs. Half of the sites (52%) were located on midshelf reefs while the other half were distributed amongst inner (22%) and outer shelf (26%) reefs and islands.

Results of the correspondence analysis between the main activity of the respondents and the location of the reef sites (Figure 5.3) showed that commercial fishers, recreational fishers and commercial collectors described many of the same reef sites, primarily inshore reefs and reefs located off Innisfail and Cooktown. These areas tend to be less crowded than the offshore reef areas directly off Cairns and Port Douglas. The areas most frequently accessed by commercial fishers and collectors were away from the high use tourism locations, while still relatively close to Cairns International Airport.

Those respondents who mainly participated in snorkelling, underwater photography, game fishing and scuba diving commented on sites off Cairns, Port Douglas and on many of the Ribbon Reefs. Log Book data required by the Environment Management Charge (see Chapter 4, Section 4.5) (GBRMPA 1998) also indicated that these locations were the most heavily used tourism sites in the area. Respondents involved in scientific research mainly commented on sites around the Lizard Island Research Station, the major research station in the Section. People who primarily accessed the Cairns Sector to participate in recreational yachting tended to comment on islands and cays scattered throughout the entire Cairns Sector.

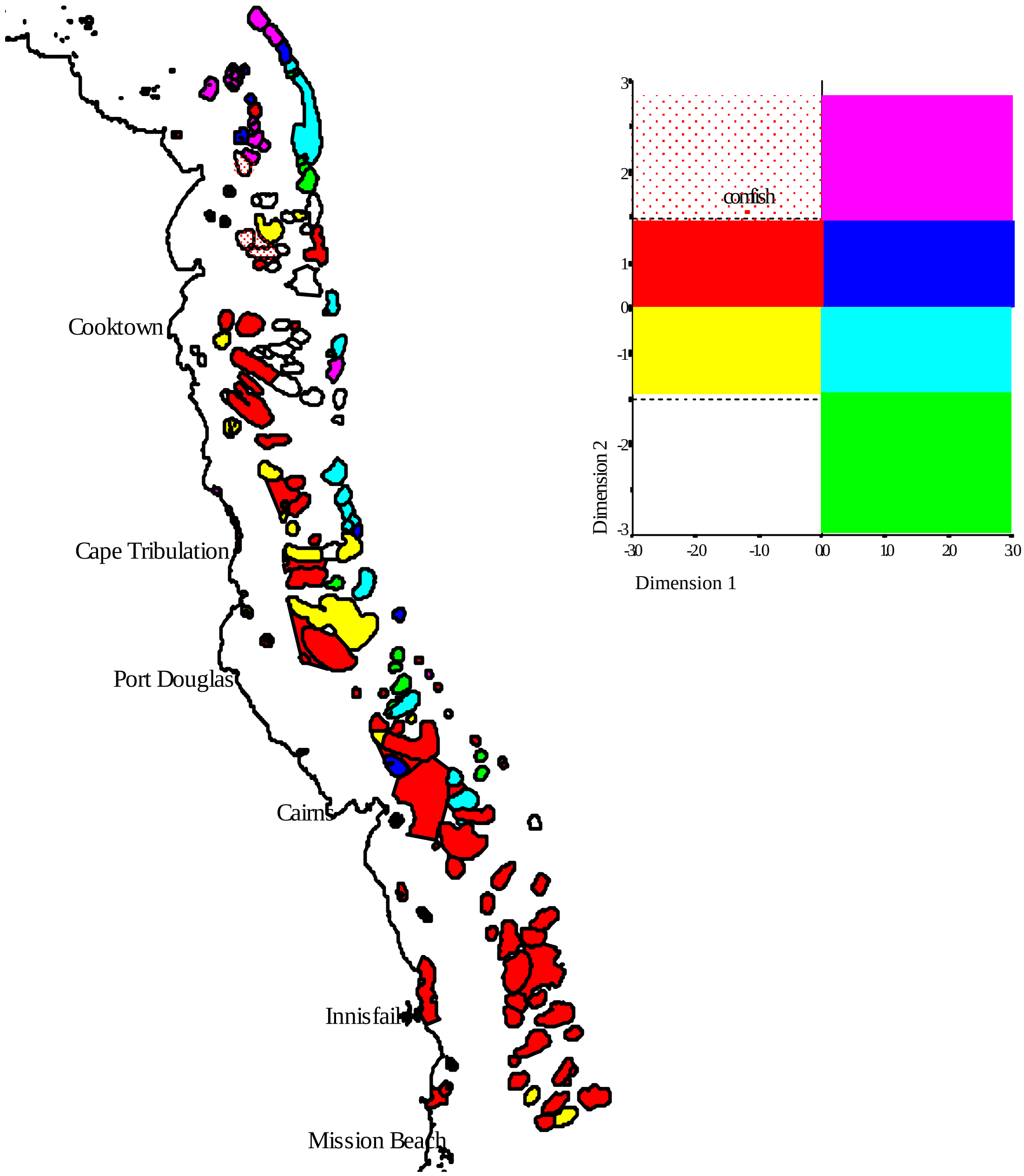

Figure 5.3 : Correspondence analysis of the main activity of survey respondents categorized by reef. Colours of reefs and interreefal areas on the map of the Cairns Sector correspond with colours in each quadrant of the plot of the first two dimensions of the correspondence analysis. For example, recreational fishers and commercial collectors described the same reefs, these areas are coloured in red on the map and in the correspondence analysis plot.

Names of main activities are coded for display purposes as follows: collect = commercial collecting; comfish = commercial fishing; game = game fishing; recfish = recreational fishing; research = scientific research; sail = sailing; scuba = SCUBA diving; snork = snorkeling.

5.3.3 Environmental Perception and Indicators of Reef Quality

The survey contained two sections addressing environmental perceptions of reef quality. Respondents were asked to assess the quality of 17 biophysical variables at their three most frequently visited reef sites. They were then asked to assess any damaging changes that may have affected the site quality over time. The results for this section of the thesis are presented in two sections, dealing first with perceptions of overall site quality and then with perceptions of damaging changes to these same locations.

5.3.3.1 Perceptions of Reef Quality:

Most respondents from all interest groups rated their sites highly for all of the 17 quality variables. The aesthetic variable “scenic beauty”, had the highest mean score (5.45 - above average to excellent) with most respondents indicating that their sites rated outstanding for this variable.

Respondents were also given the opportunity to indicate whether or not these 17 biophysical and social variables affected the quality of their reef site. It is interesting to note that over 20% of the respondents considered that ease of navigation, the presence of sharks and rays and wilderness did not influence their assessment of the quality of their reef sites (Table 5.2).

Condition Variable	**% “does not matter” responses**
Ease of navigation	28.1
Presence of sharks and rays	22.2
Wilderness area	20.2
Underwater topography	19.3
Presence of marine animals	18.5
Presence of sea turtles	16.3
Clams and other invertebrates	15.9
Shelter from northerly winds	15.9
Mild currents	15.1
Scenic beauty	14.8
Convenience to other reef sites	14.8
Water clarity	12.3
Convenience from port	11.6
Shelter from southeasterly winds	9.5
Coral	9.0
Diversity of fish life	8.6
Number of large fish	8.1
Overall quality of the sites	5.1

Table 5.2: Percent of responses indicating that a particular condition variable "does not matter" to the quality of a reef site.

In contrast, over 90% of respondents considered that shelter from SE winds, coral, diversity of fish life, number of large fish and overall site quality were important. Most of this 90% was made up of recreational fishers, SCUBA divers, snorkellers and game fishers (Table 5.3). Commercial fishers and scientific researchers considered that most of the variables did not matter to their choice of reef site (Table 5.3).

Condition Variable	Percent of “does not matter” responses						
	Recreational fishing	Commercial fishing	Game fishing	SCUBA diving	Snorkelling	Scientific research	Private boating
Water clarity	17	25.3	11.4	0.5	4.6	16.7	2.7
Shelter from southeasterly winds	6.9	17.1	0	5.9	11.9	22.2	8.0
Scenic beauty	12.8	41.1	20.5	1.1	6.4	36.1	0.0
Coral	8.1	21.5	11.4	0.5	1.8	20.4	1.3
Underwater topography	29.3	26.6	18.2	5.3	9.2	22.2	16.0
Wilderness area	25.1	44.9	13.6	1.1	11.9	31.5	8.0
Number of large fish	3.9	20.3	6.8	0.0	1.8	31.5	4.0
Convenience to other reef sites	10.1	19.0	15.9	5.3	23.9	28.7	6.7
Convenience to port	2.4	35.4	20.5	3.2	6.4	30.6	.0
Shelter from northerly winds	12.2	33.5	0.0	9.6	16.5	29.6	9.3
No. of clams & other invertebrates	44.2	48.1	31.8	1.1	6.4	46.3	9.3
Ease of navigation	10.4	39.9	11.4	11.2	22.0	30.6	10.7
Presence of marine animals	20.6	27.2	38.6	1.6	7.3	48.1	4.0
Diversity of fish life	6.0	25.3	6.8	0.0	2.8	20.4	1.3
Mild currents	12.5	37.3	20.5	6.4	10.1	23.1	8.0
Presence of sea turtles	19.1	27.2	27.3	1.6	7.3	38.0	1.3
Presence of sharks and rays	22.5	35.2	21.2	3.2	8.5	29.6	8.0
Overall quality of the sites	4.5	18.4	0.0	0.0	1.8	6.5	0.0

Table 5.3: Percent of responses indicating that a particular condition variable "does not matter" to the quality of a reef site for respondents who participate in the top seven activities as indicated in Table 5.1.

In general, the respondents who participated in appreciative activities (such as SCUBA diving, snorkelling and private boating) were more likely to assess each of the quality variables than those who participated in extractive activities (e.g. recreational fishing and commercial fishing) (Table 5.3).

An assessment of cross shelf patterns indicated that inshore reefs tended to receive poorer ratings than mid and outer shelf reefs for most of the quality variables. For example, the frequency distribution of quality scores was different in reefs at different shelf positions (Pearson Chi-Square = 39.9, df = 8, p = 0.000). Reef sites that received a higher overall quality score were mainly at offshore and midshelf locations. The only variables that were not affected by shelf position were wilderness, presence of marine mammals and presence of sea turtles. However the distribution of wilderness scores was different for reefs of different latitudes in the Cairns Sector (Pearson Chi-Square = 46.8, df = 12, p = 0.000). Reefs located north of the city of Port Douglas received higher wilderness scores than reefs to the south.

5.3.3.2 Indicators of reef quality

Respondents were asked to rate their most frequently visited reef sites with respect to the perceived quality of 17 variables. Factor analysis allowed me to test several potential indicators of reef quality. This analysis has a functional value in that it allowed me to reduce the 17 quality variables to four groups: ecological landscape, megafauna, convenience and shelter. Fifty two percent of the variance using principal component factor analysis with orthogonal varimax rotation was explained by these four groups (Table 5.4).

Quality VARIABLE	**Mean SCORE**	**Factor Loading**	**% OF total variance**	**Domain Mean**	**Alpha**
Ecological Landscape			21.903	5.03	.84
Coral cover Underwater topography Scenic beauty Wilderness Diversity of fish species Water clarity Clams and other invertebrates	5.17 5.21 5.45 4.71 5.20 5.00 4.50	0.802 0.786 0.658 0.674 0.574 0.442 0.484			
Megafauna			11.549	4.15	.64
Marine mammals Turtles Big fish Sharks and rays	3.64 4.06 4.66 4.22	0.717 0.569 0.533 0.508			
Convenience			9.175	5.22	.50
Convenience to port Convenience to other reefs Ease of navigation	5.10 5.19 5.37	0.757 0.740 0.609			
Shelter			8.898	4.27	.55
Shelter from south easterlies Shelter from northerlies Mild currents	4.81 3.58 4.41	0.534 0.579 0.471			

Table 5.4: Factor analysis of perceived reef quality based on the level of influence of each variable on perceived quality of the respondents' most frequently used reef sites in the Cairns Sector of the Great Barrier Reef Marine Park. Mean scores for each variable were calculated over 1143 responses to questions using a seven point scale to rate each variable, where 1 = very poor, 4 = average and 7 = outstanding. Factor Domains were Ecological Landscape, Megafauna, Convenience and Shelter. Domain Mean values were calculated across variables in each domain. (n = 1143 responses).

The ecological landscape factor domain, which was best represented by the variables “coral cover” and “underwater topography', but also included “water clarity, “scenic beauty”, “wilderness”, “clams and other invertebrates” and “diversity of fish species”, explained more of the variance than the other three factors. The reefs off Cooktown had higher factor scores for ecological landscape than the reefs off Cairns and Innisfail (Figure 5.4). Reefs coloured in red had the highest factor scores, while reefs coloured in blue had the lowest (Figures 5.5 – 5.8).

A higher factor score does not necessarily mean a higher 1 – 7 rating, but in general, the higher scores did correspond to higher ratings (above average to outstanding) for the groups of variables in each of the factor domains.

The megafauna dimension explained 12% of the overall variance. The most important variable in explaining this portion of the overall variance was “presence of marine mammals” but “sharks”, “big fish”, and “turtles” also contributed. The Ribbon Reefs, several reefs off Cooktown and Port Douglas and a few interreefal sites off Cairns received the highest factor scores for this dimension (Figure 5.5).

Convenience (including “convenience to port”, “convenience to other reef sites”, and “ease of navigation”) explained 9% of the overall variance. The reefs in the offshore Cairns and Port Douglas area rated the highest for the convenience dimension (Figure 5.7). Shelter (“shelter from SE” and “N winds” and “mild currents”) also explained 9% of the variance. Several inshore and midshelf reefs throughout the Cairns Sector of the marine park rated highly for this dimension (Figure 5.7).

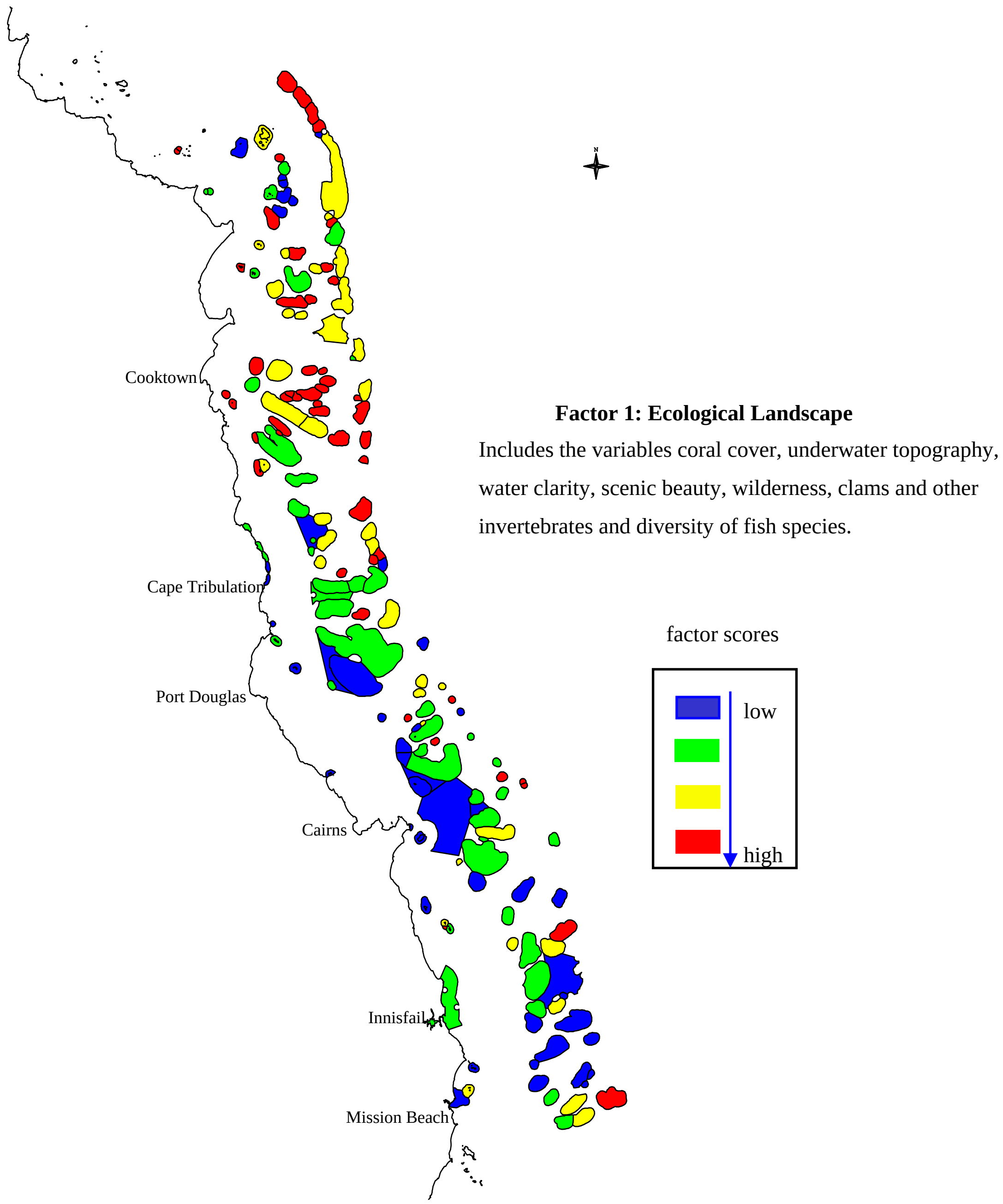

Figure 5.4: Map of the mean factor scores for the ecological landscape dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 17 quality variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey (above average to outstanding) for the groups of variables in the ecological landscape dimension.

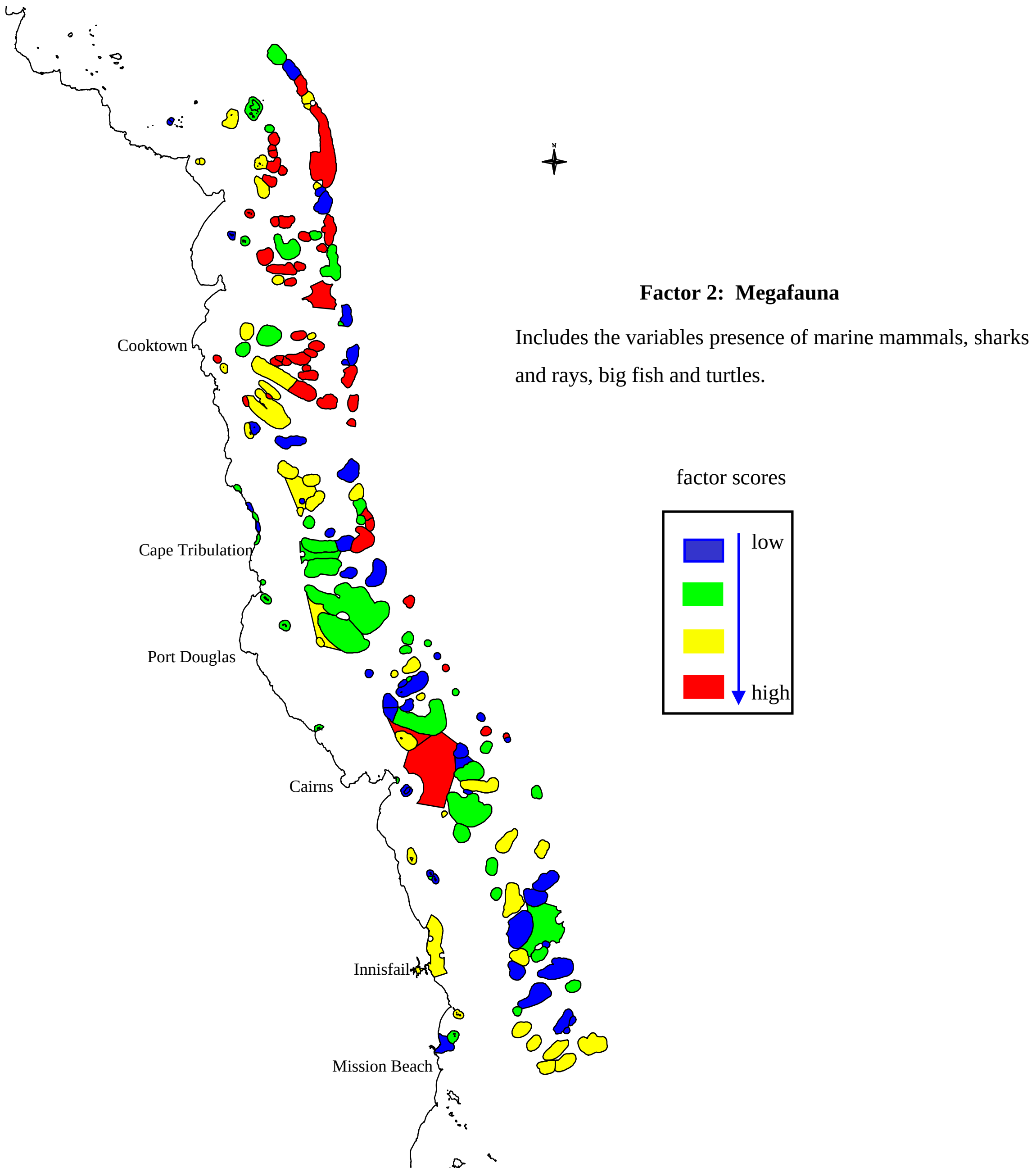

Figure 5.5: Map of the mean factor scores for the megafauna dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 17 quality variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey (above average to outstanding) for the groups of variables in the megafauna dimension.

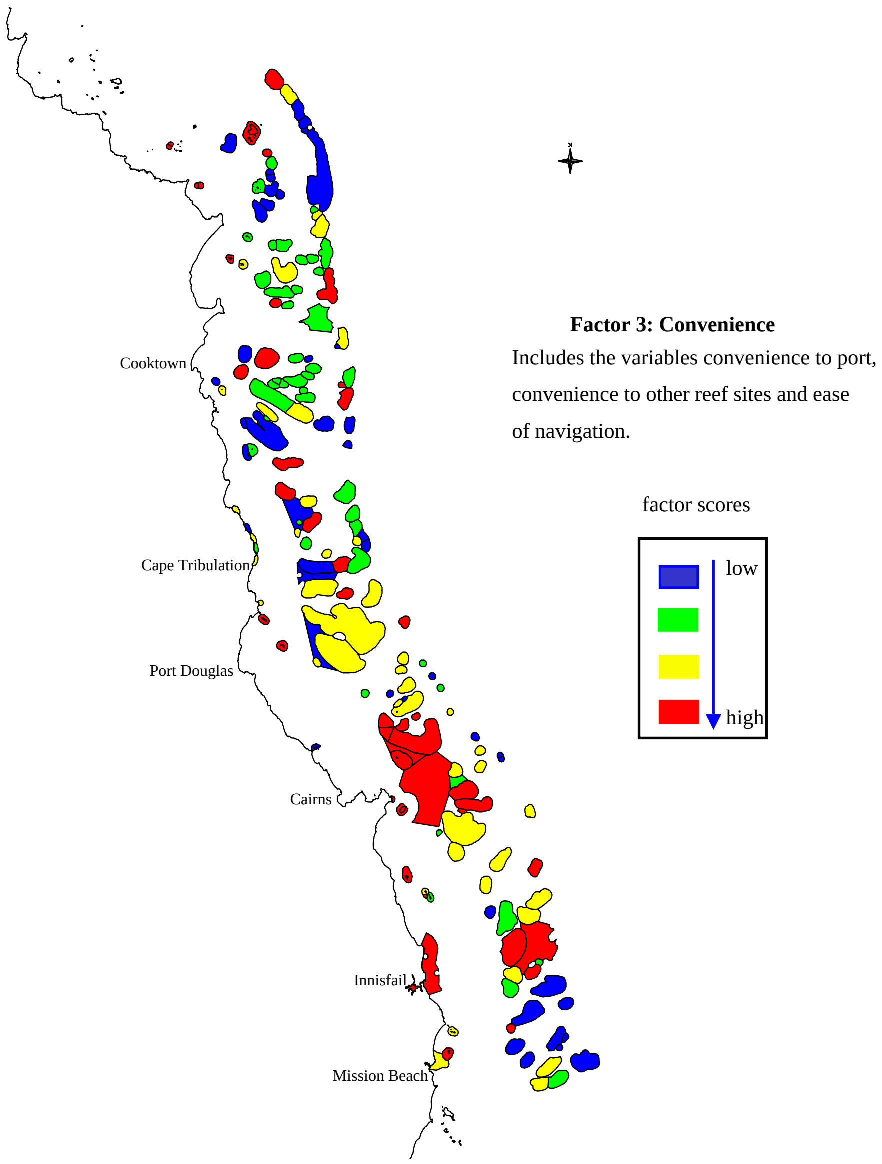

Figure 5.6: Map of the mean factor scores for the convenience dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 17 quality variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey (above average to outstanding) for the groups of variables in the convenience dimension.

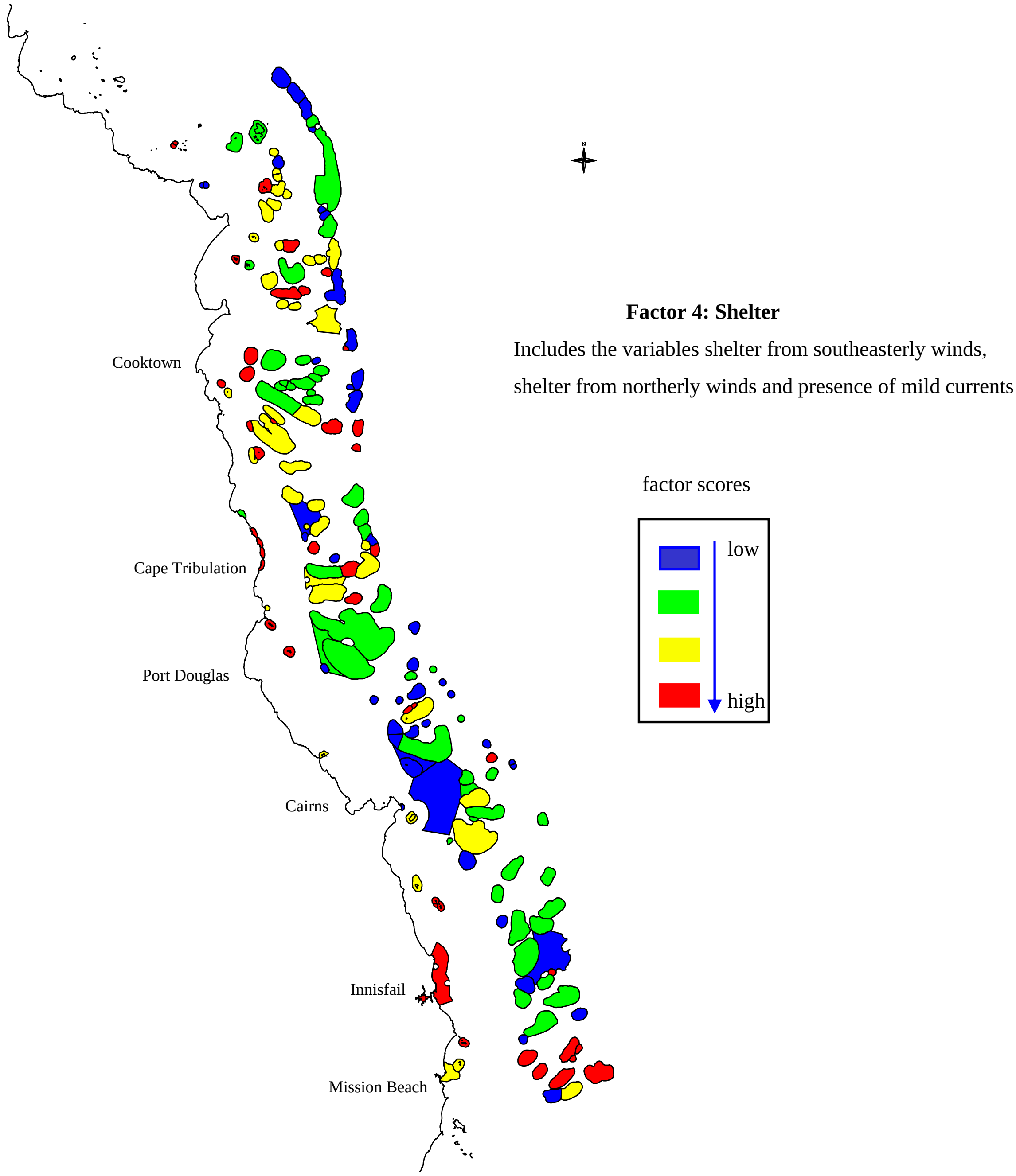

Figure 5.7: Map of the mean factor scores for the shelter dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 17 quality variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey (above average to outstanding) for the groups of variables in the shelter dimension.

5.3.3.3 Indicators of Overall Reef Quality

In the survey, respondents were asked to assess the overall quality of each site they frequented. In order to determine how the variable "overall quality" depended on the other 17 biophysical and social variables describing reef sites, a regression tree analysis was performed. Results of this analysis indicate that overall reef quality is jointly determined by coral, diversity of fish species and underwater topography. Other variables had only weak relationships to perceived overall quality.

Initially a regression tree analysis was run with overall quality as the numeric response variable and the explanatory variables of water clarity, presence of sharks and rays, shelter from SE winds, scenic beauty, coral, underwater topography, wilderness, presence of big fish, convenience to sites, convenience to port, shelter from N winds, marine invertebrates, ease of navigation, presence of marine mammals, diversity of fish species, mild currents and presence of sea turtles. Using all 17 variables was found not to be optimal, as only four variables split the data. Exploration of univariate trees showed that most variables had only marginal influence on the total sum of squares (SS).

Thus, I tested a different and potentially better model, looking at alternative splits as described by De'ath and Fabricus (2000) and using only the three main explanatory variables coral, underwater topography and diversity of fish species. This model generated a tree which had the smallest estimated error and was the best estimated predictive single tree.

Figure 5.8 illustrates the regression tree based on these three explanatory variables. The rating of overall reef quality was used as the numeric response variable. In general, overall quality was rated highly (mean 5.2, n = 1239) with over 70% of the responses giving the overall quality of their sites a rating of >4 (i.e. above average). Splits in the regression tree minimised the sums of squares within groups. The first split was based on the quality of coral cover at reef locations with ratings above average (rating of >4.5) on the right split and ratings below average (rating of <4.5) on the left split. In the graph, the relative length of the vertical line associated with each split is proportional to the total SS explained by the split. Thus, this first split explained most of the total SS. Following the left split, the data were further split by underwater topography with poor to very poor topography (rating of <2.5) on the left and below average to outstanding topography (rating of >2.5) on the right. The splitting was repeated, with ratings of excellent to outstanding fish diversity on the right and above average to very poor fish diversity on the left. One more split occurred from the latter group and was based on below average to very poor coral on the left and average to outstanding coral on the right.

On the right hand side of the tree where coral cover was rated above average, there was a further split in the data based on the diversity of fish species with ratings above average (rating of >5.5) on the right and below average on the left (rating of <5.5). Following the right split, the data were divided by outstanding to excellent coral on the right and above average to poor coral on the left. Following the left split data were divided by above average fish diversity on the right and below average fish diversity on the left.

This tree was complete with eight leaves and explained 49% of the total sum of squares. The bar charts at each leaf in the tree show the distribution of ratings for overall quality. The leaves show that areas rated poorly for overall quality were areas with below average coral and poor underwater topography.

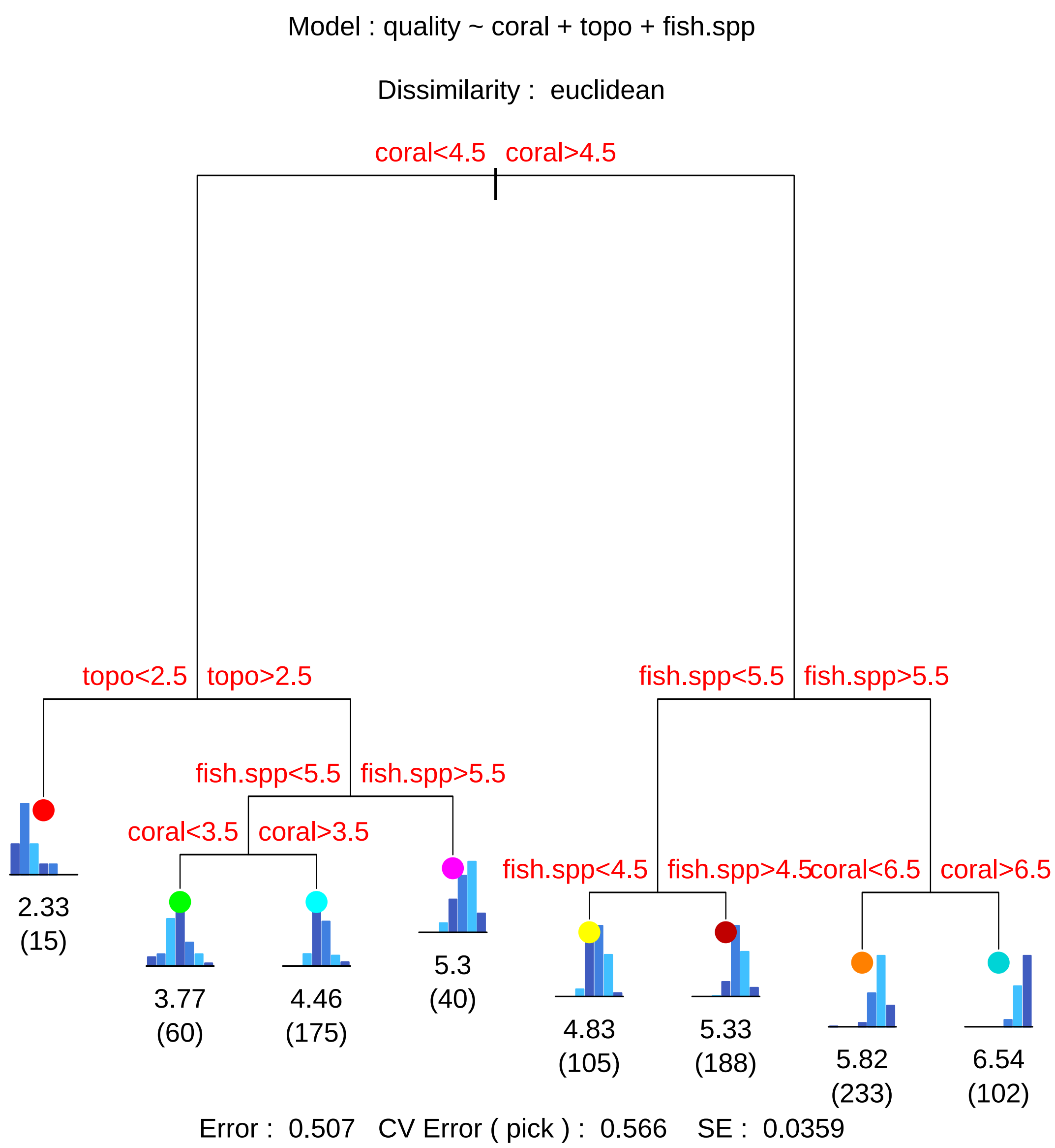

Figure 5.8: Regression tree analysis of the overall quality of reef sites. The explanatory variables were coral (coral), diversity of fish species (fish.spp) and underwater topography (topo). Each of the splits is labeled with the variable name and the values that determine the split. For each of the terminal nodes the distribution of observed values of overall quality is shown in a histogram. Each node is labeled with the mean rating and number of observations in the groups (in brackets).

Meanwhile, areas rated most highly for overall quality were locations with above average to outstanding coral cover and excellent to outstanding diversity of fish species.

A regression tree analysis was also conducted to test whether different measures of overall quality depended on the user groups who responded to the survey. Cross-validation of the trees showed that user groups predicted less than 6% of only three of the 18 quality variables, thus no real difference between user groups was found for the quality variables. This finding could, however, be a result of the fact that respondents assessed three locations and thus their perception of the quality variables for those sites may not be independent.

5.3.3.4 Perception of impacts from human use:

Few of the respondents reported observing damaging changes affecting the quality of their reef sites as a result of any of the 11 human and natural impact variables suggested by the survey. Where damage was perceived, the variables “overfishing”, “anchoring” and "cyclones" (hurricanes) were consistently perceived as causing the most damage. The frequency distributions of scores for these variables were different across different shelf positions. Inshore and midshelf reefs were perceived to have more damage from these variables than offshore reefs (overfishing vs shelf position: Pearson Chi-Square = 50.7, df = 12, p = 0.000; anchoring vs shelf position: Pearson Chi-Square=35.1, df=12, p = 0.000; cyclones vs shelf position: Pearson Chi-Square=23.6, df=10, p = 0.009).

Respondents were also given the opportunity to indicate that they had no opinion on the frequency of damage caused by these impact variables (Table 5.5). Overall, 10 to 16% of the respondents had no opinion on the frequency of damage they observed. This finding indicates that, in general, over 80% of the respondents were concerned enough to assess whether or not these variables had affected the quality of their reef sites.

However the percent of no opinion responses varied between different activity groups (Table 5.6). Between 23 and 44 percent of the commercial fishers did not assess the frequency of damage they observed, while over 90% of the SCUBA divers and snorkellers did.

Impact Variable	**% "no opinion" responses**
Algal growth	16.2
Overfishing	15.0
Spearfishing	14.8
Hunting by Indigenous people	14.8
SCUBA diving	14.3
Crown of Thorns	14.3
Cyclones or other natural disturbances	13.5
Vessel grounding	13.0
Anchoring	10.6
Snorkelling	10.5
Pollution	10.5

Table 5.5: Overall percentage of responses indicating that a respondent had "no opinion" regarding the frequency of impact from a particular variable to a reef site.

Impact Variable	Percent of "no opinion" responses to each variable						
	Recreational fishing	Commercial fishing	Game fishing	SCUBA diving	Snorkelling	Scientific research	Private boating
Vessel grounding	8.1	43.7	6.8	3.2	4.6	14.8	10.7
Anchoring	5.4	36.1	6.8	1.1	4.6	14.8	10.7
Algal growth	13.1	41.1	6.8	4.8	4.6	19.4	22.7
Overfishing	3.0	22.8	6.8	10.7	7.3	38.0	2.7
Snorkelling	7.8	24.7	6.8	4.3	3.7	18.5	12.0
Pollution	6.9	24.7	13.6	5.9	2.8	18.5	10.7
Crown of Thorns	14.0	32.9	13.6	2.1	3.7	15.7	25.3
Spearfishing	9.0	29.1	6.8	11.8	7.3	26.9	25.3
SCUBA diving	15.2	30.4	6.8	1.1	3.7	21.3	25.3
Hunting by Indigenous people	7.2	38.0	20.5	11.2	5.5	19.4	17.3
Cyclones or other natural disturbances	11.6	25.3	6.8	5.9	6.4	23.1	22.7

Table 5.6: Percent of responses indicating that a respondent had "no opinion" regarding the frequency of impact from a particular variable to a reef site for respondents who participate in the top seven activities as indicated in Table 5.1.

5.3.3.5 Indicators of resource damage

I used principle components factor analysis in this section to reduce the 11 impact variables to five domains and then plotted the single variable within each group to examine spatial relationships.

The five impact domains identified as important when survey participants were asked about damaging changes to their three most frequently visited reef sites were: human density impacts, snorkel/dive impacts, natural impacts, vessel impacts and fishing (Table 5.7). These five factor domains explained approximately 70% of the total variance.

IMPACT VARIABLE	Mean SCORE	Factor Loading	% total variance	Domain Mean	Alpha
Human Density Impacts			29.811	2.93	0.76
Pollution	2.50	0.743			
Crowding	3.11	0.734			
Overfishing	3.19	0.642			
Snorkel/Dive Impacts			11.982	2.57	0.73
SCUBA diving	2.54	0.886			
Snorkelling	2.59	0.803			
Natural Impacts			10.175	2.56	0.66
Algal growth	2.53	0.575			
Crown of Thorns	2.43	0.781			
Cyclones or other natural disturbances	2.71	0.793			
Vessel Impacts			8.872	2.28	0.66
Vessel groundings	1.63	0.763			
Anchoring	2.93	0.774			
Fishing Impacts			7.103	1.71	0.56
Indigenous hunting	1.69	0.743			
Spearfishing	1.73	0.798			

Table 5.7: Factor analysis of the impact to reef quality based on the frequency of damaging changes to the quality of the respondents' most frequently used reef sites in the Cairns Sector of the GBRMP. Mean scores were calculated using a seven point scale where 1=never, 4=sometimes and 7=constantly. Domain Mean values for Factor domains were calculated across items in that domain based on the seven point response scale. (n=1143)

The first factor, which is the perception of change from impacts related to human density, explains 30% of the variance. This dimension is best represented by the items “pollution”, “crowding” and "overfishing". The survey respondents believed that the reefs off Cooktown showed the most damaging changes from this factor, while those off Innisfail showed the least (Figure 5.9). On the maps shown here (Figures 5.10 – 5.14), reefs coloured in red had higher factor scores. In general, these scores correspond to higher ratings ("sometimes" to "constantly" observed damage) for the groups of variables in each dimension.

Damaging changes to the reef sites from tourism impacts, both “SCUBA” and “snorkelling”, were perceived to occur mainly on the reefs off Cairns and Port Douglas plus a few sites in the far northern ribbon reefs including the Cod Hole and Ribbon Reef Number 5. (Figure 5.11). This factor explained 12% of the variance.

The natural impact dimension is best represented by the variables “Crown of Thorns” [4], "algal growth" and “cyclones”. This factor explains 10% of the variance. The reefs around Lizard Island and several midshelf and inshore reefs were considered to exhibit the most damaging changes from these impacts (Figure 5.11).

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[4] There is controversy about whether or not ‘Crown of Thorns’ is solely a natural impact or whether the frequency of Crown of Thorns outbreaks has been altered by anthropogenic activities (Engelhardt 1997, De’ath 2000, Berkelmans *et al.* 2004).

Vessel impacts, best represented by “vessel grounding” and “anchoring”, were perceived to cause the most damaging changes at sites off Cairns, Port Douglas and south of Cooktown (Figure 5.12). The Frankland Island group and South Barnard Island were also areas of concern for vessel impacts. This factor explained 9% of the variance.

The fifth damage dimension identified was made up of two types of fishing impacts. This dimension explained 7% of the variance and was best represented by “spearfishing” and “Indigenous hunting” (Figure 5.13).

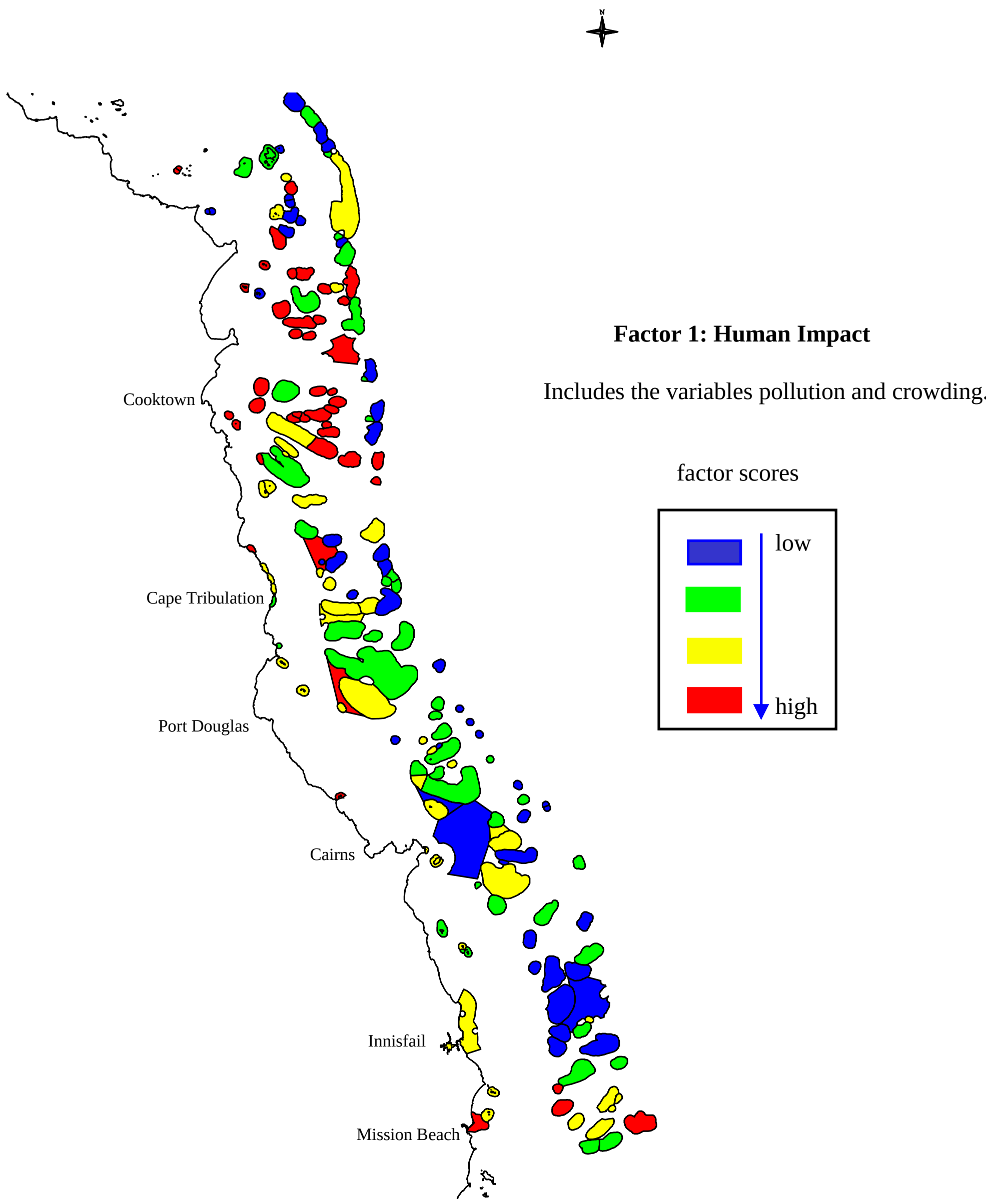

Figure 5.9: Map of the mean factor scores for the human impact dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 12 damage variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey (some to constant damage) for the groups of variables in the human impact dimension.

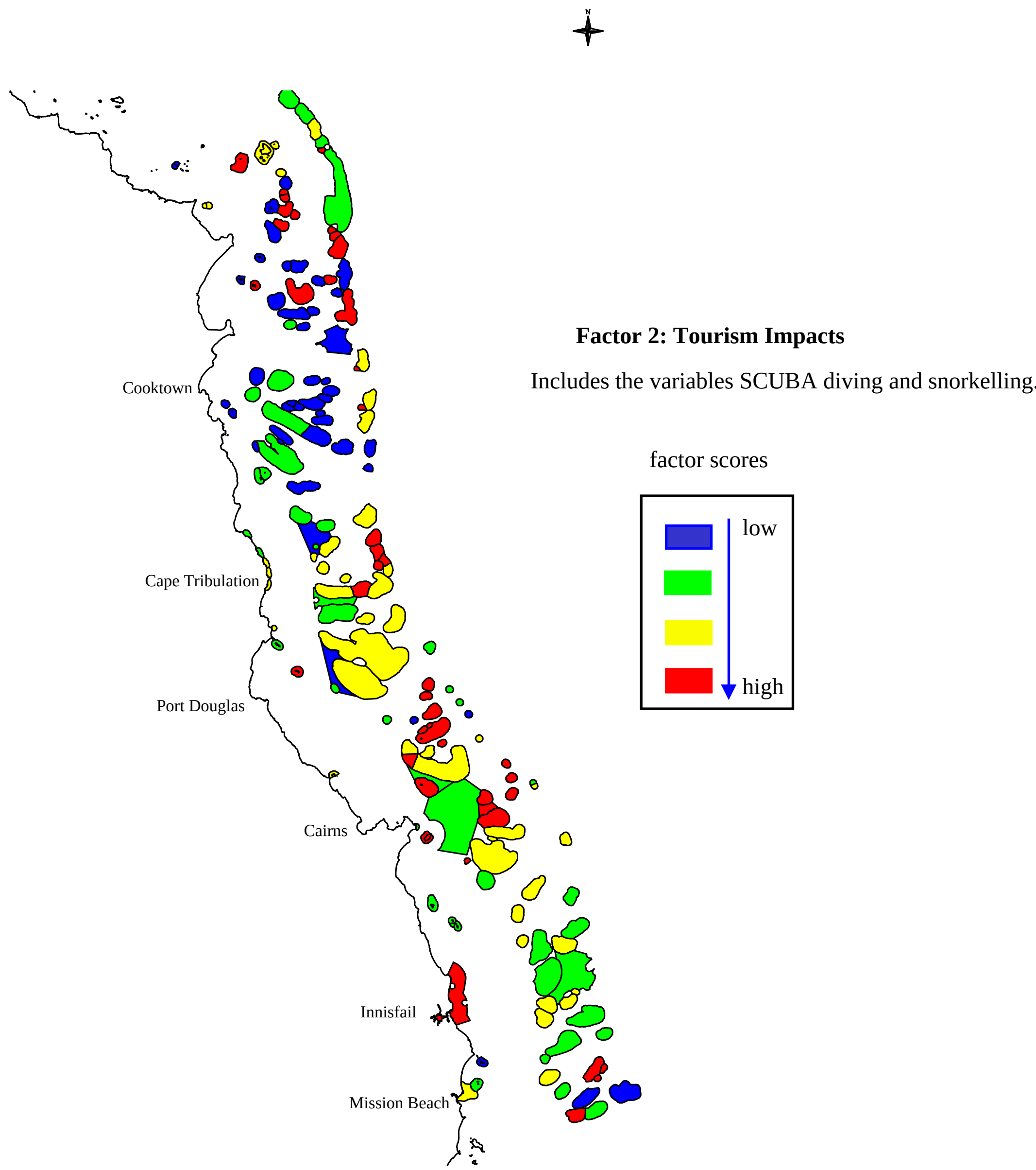

Figure 5.10: Map of the mean factor scores for the tourism impacts dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 12 damage variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey (some to constant damage) for the groups of variables in the tourism impacts dimension.

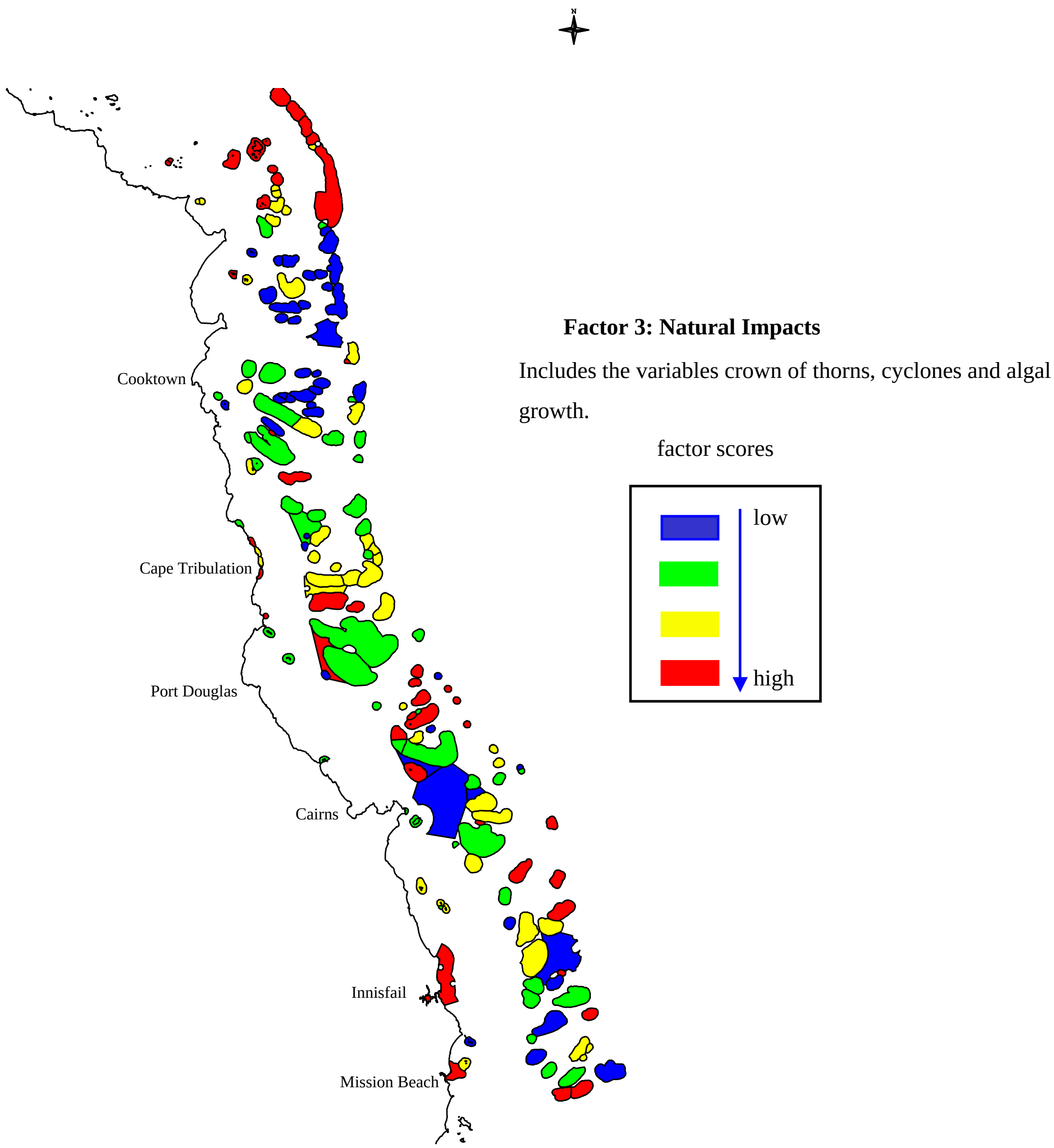

Figure 5.11: Map of the mean factor scores for the natural impacts dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 12 damage variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey for the groups of variables in the natural impacts dimension.

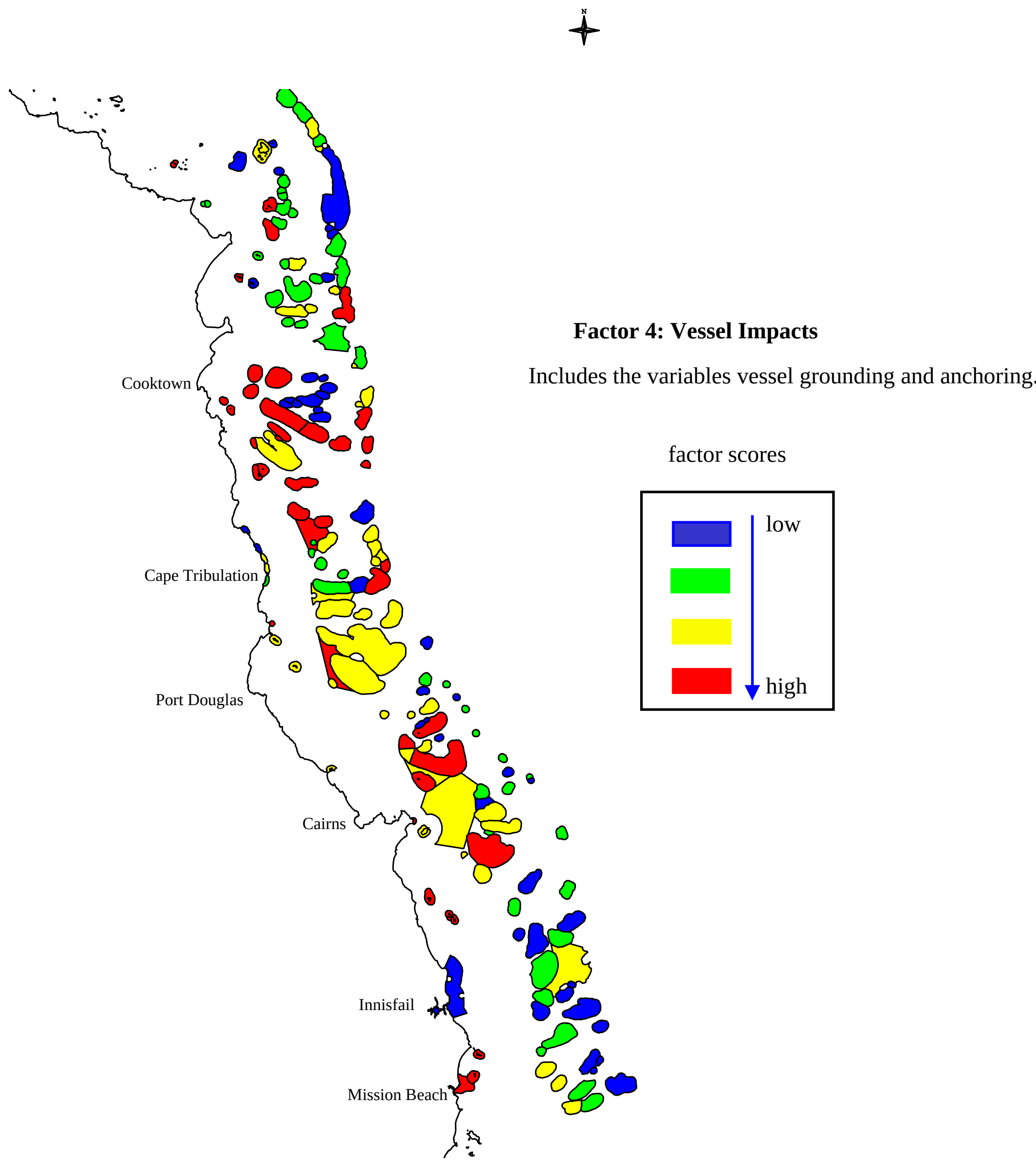

Figure 5.12: Map of the mean factor scores for the vessel impacts dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 12 damage variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey for the groups of variables in the vessel impacts dimension.

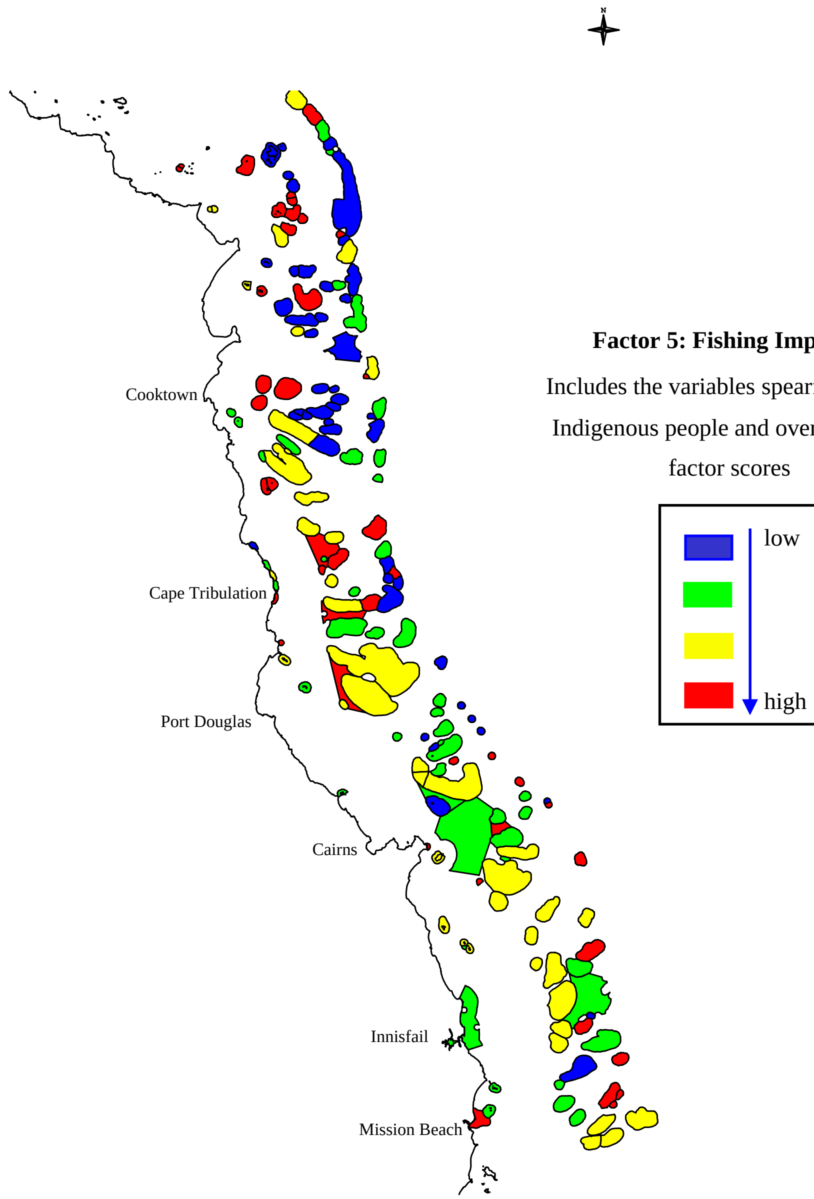

Figure 5.13: Map of the mean factor scores for the fishing impacts dimension of reefs and interreefal areas in the Cairns Sector from the principal component factor analysis of the 12 damage variables. Factor scores were classified into four categories in Arc View using the quantile classification method. On the maps, reefs coloured in red had higher factor scores as indicated in the legend. These scores correspond to higher ratings in the survey for the groups of variables in the fishing impacts dimension.

Figure 5.13 highlights the reefs where fishing impact was perceived to have caused damaging changes and the reefs where this impact has not been observed. The survey respondents perceived the most damaging changes from this type of impact to reefs off Cooktown.

5.3.3.6 Perception of Social Conditions

In order to describe the social conditions at reef sites, people were asked about their preferred levels of use. Although most respondents often saw other groups of reef users at their sites (86.5%), they would have preferred to see fewer people and vessels (86.6%). Forty four percent of the respondents considered that the actions of others actually decreased their enjoyment of the resource.

The frequency distribution of scores for perceived levels of crowding was different for reefs at different shelf positions (Pearson Chi-Square = 38.2, df = 12, p = 0.000). Inshore reefs were considered to be less crowded than offshore and midshelf reef sites. At most sites across all shelf positions (83%), respondents indicated that their enjoyment of the area was seldom enhanced by the presence of others.

On average, respondents noted that people usually anchored or moored within 20 to 100 m of each other at all reef locations. Most respondents indicated that the variable "current anchor distance" was the preferred distance between vessels (71%). Vessels tended to anchor or moor less than 50m apart inshore (57%) and up to several km apart offshore (62%).

On average, three other vessels were regularly seen by respondents during their visits to a reef (Table 5.8). However, five respondents reported instances when over 100 vessels were observed at Lizard Island, Upolu Cay, Tongue Reef. While this phenomenon is rare, the presence of such a large number of vessels at these locations has been of concern to both the Marine Park managers and tourism operators, as they have not assessed the environmental impacts of such a large number of vessels at these locations (GBRMPA and Reef Tourism 2000, pers. comm. 1996).

Respondents were also asked to specify an acceptable level of use for their sites (Table 5.8). The mean response was that five vessels was the maximum number that would be acceptable at the respondents' preferred locations. Respondents did, however, consider that some locations could sustain a larger number of vessels than others. Reefs where it was considered acceptable for the maximum number of vessels to range from 20 to 100 included Sudbury Reef, Elford Reef, Fitzroy Island, Green Island, Rudder Reef, Low Islets, High Island, Upolu Cay, Tongue Reef, Opal Reef, Frankland Islands, Arlington Reef and Lizard Island. These locations are mainly off Cairns and Port Douglas and are largely associated with tourism operations and major recreational fishing sites.

On average, the presence of 34 other people was considered the maximum respondents would tolerate before their experience became unacceptable (Table 5.8). However, the standard error for this question was large, with responses ranging from no additional people to 1000 at some locations. Those locations where respondents could tolerate up to 1000 additional people were mainly located off Cairns and were also well known tourist destinations. These sites included: Moore Reef, Green Island, Michaelmas Cay, Norman Reef, Agincourt Reefs, Low Islets, Upolu Cay, Hastings Reef, Fitzroy Island, Arlington Reef and Lizard Island.

In general, respondents were less concerned with the number of people than the number of vessels at their reef sites. Over 50% of the respondents considered that the number of people did not matter to their reef experience, while over 70% felt that the number of vessels did influence their experience (Table 5.8).

Social Condition	**Mean**	**SE**	**Upper Limit**	**% "does not matter" responses**
How many vessels are usually anchored or moored within sight of you at any one time?	3.4	0.16	99	19.2
What is the maximum number of vessels that you have seen using these sites?	8.4	0.36	99	11.5
At these sites, what is an acceptable number of vessels to have within sight of you at any one time?	5.1	0.24	99	26.0
At these sites, what is an acceptable number of people to have within sight of you at any one time?	34.0	3.2	1000	52.1

Table 5.8: Respondents perceptions of the social conditions at their reef sites

5.3.4 Comparisons between levels of tourism use and the perception of crowding

In order to understand the relationship between actual and perceived levels of use, correlation analyses using Spearman's rho were performed to compare the total number of tourists at permitted tourism reef sites in the Cairns Sector for the financial year 1995/96

(EMC Database, pers. comm. GBRMPA planning staff 1996) and perceived levels of use and crowding at the same reef sites. Results of these analyses are displayed in Table 5.9.

SURVEY QUESTION	Spearman's RHO
How often is your enjoyment of these reef sites decreased by the actions of other groups of reef users?	0.399**
How often is your enjoyment of these reef sites enhanced by the actions of other groups of reef users?	0.356**
How often do you see another vessel?	0.440**
How often would you prefer to see another vessel?	0.344**
How close do other groups of reef users normally moor or anchor to you?	-0.286*
What is the minimum distance that you prefer for another vessel to be anchored or moored from you?	-0.082
At these sites, what is an acceptable number of vessels to have within sight of you at anyone time? Please indicate the highest number you would *tolerate* before your reef experience becomes unpleasant.	0.149
What is an acceptable number of people to have within sight of you at anyone time? Please indicate the highest number you would *tolerate* before your reef experience becomes unpleasant.	0.807**

**Correlation is significant at the .01 level (2-tailed).
*Correlation is significant at the .05 level (2-tailed).

Table 5.9: Bivariate correlation analyses using Spearman's Rho comparing the survey respondents mean perception of crowding per reef (seven survey questions) and the sum total of tourism visitations per reef from 1 July 1995 to 30 June 1996. (N=63)

Table 5.9 demonstrates the significant relationships between the survey respondents' perception of existing use and levels of crowding at reef sites and the actual levels of tourism use. The strongest correlation existed between the actual levels of tourism use and the acceptable number of people in sighting distance of the respondent (Table 5.9). Larger numbers of people were more acceptable to the survey respondents at sites that historically had high numbers of tourists.

The likelihood of seeing others and of having either increased or decreased enjoyment of the reef experience increased significantly with more tourists. For example, some of the survey respondents preferred to see more people at reefs that traditionally have high numbers of visitors. With an increased number of people at a given reef location, the perceived distance between anchorages decreased.

5.4 Discussion

This survey was designed and administered in cooperation with the GBRMPA to increase understanding of regular use of the marine park. The survey targeted locals from the Cairns Sector who participated in recreational boating, yachting and fishing, commercial tourism, commercial fishing, scientific research, and other activities which allow for regular access to the area.

In order to survey this diverse group, I used several methods of distributing the survey, as detailed in Section 5.2. The most successful method for obtaining high return rates was through public meetings organised by the GBRMPA and the then Queensland Department of Environment (Figure 5.2). The response rate of 67% from these meetings can be considered "very good" for self administered surveys such as this (Babbie 1989). Although these meetings were mainly held to inform reef users of proposed changes to the marine park, they provided a convenient sample of interested reef users. Many individuals who attended the meetings also wished to participate in the survey and voice their opinions about the areas they regularly accessed as a part of their contribution to the Cairns Sector planning process. Other methods of distribution, while not as successful, allowed me to contact regular reef users by providing surveys at all access points, tackle and boating supply shops and mailing to all commercial users of the area. Thus the total sample of reef users who received the survey ended up representing a good balance of commercial and recreational interests and as such, provided insight into the attitudes and requirements of GBR users.

Although surveys were distributed to a wide proportion of the target population, the probability of a respondent's returning a survey was dependent on many factors, such as their interest in the marine park, their level of experience and the geographical location of their sites. Furthermore, there was no attempt to control for or allocate different factors to different population segments, geographical areas or activities. Given that, the returned surveys represent a reasonable estimate of the preferences shown by the target population.

However, this observation does not mean that causal relationships can be inferred amongst the different reef perception items. Individual ratings were most likely a combination not only of user group but also geographical location and individual subjective interpretation. Any attempt to disaggregate these factors is not possible as these observational data are likely to be confounded by the joint effects of these factors. Therefore the relationships I present in this thesis are meant only to generate hypotheses and provide general indications of patterns that do exist.

To investigate various sources of information in an experimental fashion would require allocating each user group to a range of geographic locations with differing environmental and biological situations. To do this in practice, at the scale of this study, would require having user groups (e.g. recreational fishers) travel and operate in geographical areas and environmental conditions which they would not normally use (for example: sending recreational fishers in small vessels to reefs 50km offshore and 100km north of their boat ramps; or sending SCUBA diving operators to reefs with no coral or fish; or locating offshore tourist pontoons and glass bottom boat tours on inshore reef habitats like those in Cairns Harbour). In addition, the zoning requirements operating at the time which spatially separated use also made an experimental approach impractical.

While the data from this survey were observational and recorded the perceptions of reef users and the sites to which they choose to travel, they cannot be used to define experimentally the exact role of different preferences and activities in rating reefs. There is a need for both experimental studies in controlled settings which are able to isolated causes scientifically (but with less certainty in generalising to real populations of users and conditions) and also for observational studies of patterns that actually exist in the field. This study focuses on the latter, and together other sources of inference, such as controlled experiments, modeling and theory should help provide a better understanding of the patterns and processes involved in the selection of reef sites.

5.4.1 Attributes of Survey Respondents

Most of the respondents had a great deal of experience in the reefs throughout the Cairns Sector of the Marine Park and regularly accessed the park. Although few had any formal academic training in reef science, most considered they had extensive knowledge of reef ecology and marine systems. In essence, this sample provided a group of highly experienced, knowledgeable, motivated and concerned reef users participating in consumptive and appreciative activities at different reef locations. These experienced visitors should, therefore, possess the fine-tuned perceptual skills necessary to describe the quality of the reef locations they regularly access and identify changes to those environments.

Environmental perception, particularly perception of resource quality, is influenced by an individual's knowledge of the environment (Fenton and Reser 1988). Repeated experience in an environment develops finer-tuned perceptual skills that allows humans to detect certain information. Hammitt (1981) showed that familiarity with natural areas influences environmental preferences. In essence, a more experienced visitor tends to be more sensitive toward the particular features of the place they regularly visit (Mugica and De Lucio 1996).

However, it is important to note that the activity in which one participates can either enhance or limit one's ability to perceive information (Pierskalla and Lee 1998). Hendee (1969) and later Tarrant and Green (1999) proposed that individuals who participate in appreciative activities (activities that typically provide enjoyment without altering the resources, such as coral and fish viewing) are more aware of the natural environment than those who participate in consumptive or extractive activities such as fishing or motorised sports like jet skiing. This pattern is illustrated in the Cairns Sector of the Great Barrier Reef Marine Park by the variation in the percent of "did not matter" and "no opinion" responses by the different user groups (Table 5.3, Table 5.6). Those respondents involved in consumptive activities were less likely to assess the quality of and damage to the underwater environment than those involved in appreciative activities.

Respondents assessed three locations which they frequented for the natural and social conditions of the area. While this method of selecting sites had the potential for spatial confounding when making comparisons between groups of reef users and locations of their sites, it highlighted the existing patterns of use in the Cairns Sector of the Marine Park and was potentially useful to the GBRMPA in revising their multiple use zoning system. Maps of the frequented locations for various user groups showed that different types of users access different reefs. However, this difference was partially dictated by current zoning, permit and other marine park management restrictions. Results of the correspondence analysis highlighted the fact that reefs with similar attributes were required by different and sometimes conflicting user groups (Figure 5.3). Planning for future resource allocation needs to acknowledge that different user groups regularly choose different reef attributes and different reefs for their activities.

Historically, planning for resource allocation in the Cairns Sector of the GBRMP has focused mainly on tourism and consumptive (e.g. fishing) uses of the resource and has not catered for the variety of other use opportunities that existed (Chapter 2, Section 2.3.4). The Cairns Area Plan of Management attempted to designate a range of settings based on vessel size, number of visitors, historic anchorage areas and tourism infrastructure (GBMPA 1998). While this Plan went a long way towards acknowledging the need for a variety of reef experiences in a large region, there is still a need for more information on the types of settings sought by various types of visitors to the area and the features of the natural environment that are most important for their experience (Shafer *et al.* 1998). The results of my survey are a first step in describing the natural and social requirements of regular reef users for a variety of locations throughout the Cairns Sector. Further studies are still needed to determine which reef attributes are most important to specific user groups and how their experiences are influenced by the different conditions present at reef sites throughout the GBRMP.

5.4.2 Environmental Perception and Indicators of Reef Quality

5.4.2.1 The perceived quality of reef resources

In addition to describing the attributes of the survey respondents, the survey aimed to produce an inventory of ecological and environmental perceptions of the resource in the area. Survey respondents were asked to assess the quality of the sites they frequented. As these respondents had a high level of experience in the local coral reef environment over many years (Section 5.3.2), I considered that their ability to distinguish between a good quality site and a poor quality site was high.

In general, the respondents considered that the reefs in this section of the marine park were of high quality (Section 5.3.3.1). The offshore reefs in particular were rated higher for most quality variables than the inshore reefs.

The use of factor analysis reduced the 17 quality variables to four groups: ecological landscape, megafauna, navigation and shelter (Table 5.4). By mapping the factor scores for each dimension it was possible to identify spatial patterns of reef quality (Figures 5.5 -5.8).

For example, reefs that rated highly for the ecological landscape dimension (coloured red in Figure 5.4) were mainly found in the more remote areas off Cooktown and along the northern ribbon reefs. Traditionally these areas are known for their pristine coral, wilderness settings, clear water and diverse fish populations (GBRMPA Planning Staff, pers. comm. 1996, Shafer and Benzaken 1998).

The ribbon reefs, several reefs off Cooktown and Port Douglas and a few interreefal sites off Cairns received the highest scores for the megafaunal dimension (coloured in red in Figure 5.5). The local tourism operators commonly refer to the sites off Cairns and Port Douglas as “whale alley”, because they frequently observe whales at these sites during the seasonal migration period (Ed Green, pers. comm. 1998). Two possible reasons why these areas may be particularly good for whale watching are that either there are more whales at these locations, or that the area is easily accessible because it is on the route to extensively used tourism sites.

The reefs immediately off Cairns were rated as the most convenient and easiest to access (coloured red in Figure 5.6). These reefs were regularly used by both tourism operators and recreational boaters (GBRMPA EMC Database, GBRMPA planning staff, pers. comm. 1997) and are thus available to large international and domestic markets. In the mid 1990s the high levels of use in this region of the Cairns Sector were of the great concern to tourism operators and planners at the GBRMPA and triggered the need for the Cairns Area Plan of Management (GBRMPA planning staff, pers. comm. 1995).

Finally, several inshore and midshelf reefs throughout the Cairns Sector of the marine park rated highly for the shelter dimension (Figure 5.7). These reefs were regularly used by recreational and commercial fishers. They are mainly accessed because of their closeness to shore and their safe anchorages.

My mapping of these groups of variables enabled managers to identify areas of high and low perceived quality for the different groups of users within the Cairns Sector. Understanding the types of variables that determine the perceived quality of reef sites helps managers to develop more appropriate zoning or opportunity classes for use of the resource. This information is compared to the proposed settings in the Cairns Plan of Management (see Chapter 7) to provide for a more informed planning process.

5.4.2.2 Indicators of overall reef quality

Few studies have investigated which attributes of coral reef conditions are most preferred by visitors. A study in Zanzibar indicated that "variety of reef fish" was the most important attribute for tourists (Andersson 1998). In their survey of dive tourists' preferences in the Carribean, Williams and Polunin (2000) found that the highest ratings were given to all fish attributes (e.g. abundance, variety, number of large and number of unusual fishes). On the other hand, Shafer *et al.* (1998) found that coral attributes had the most influence on underwater experiences in the GBR.

In this study, I also attempted to understand which of the 17 quality variables were the most important in determining the overall quality of a reef site. By understanding what features determine a high quality or poor quality site, managers can better plan the zoning of reef areas that are presently rarely visited, but may become more accessible with improvements in transportation or road access. Using a regression tree analysis, I was able to illustrate that overall reef quality in the Cairns Sector of the GBRMP was jointly determined by coral, diversity of fish species and underwater topography (Section 5.3.3.3 and Figure 5.8). In essence, perceived high quality sites were locations with excellent coral cover and high diversity of fish species, while perceived poor quality sites had poor coral cover and poor underwater topography.

In essence, management measures that enhance fish and coral attributes could increase the attractiveness of an area for the reef users of the GBRMP. Other studies in different marine protected areas have found that such measures do work to increase attractiveness of an area (Polunin and Roberts 1993, McClanahan 1994, Jennings *et al.* 1996, McClanahan and Kaunda-Arara 1996, Rakitin and Kramer 1996, Williams and Polunin 2000).

I believe that the variables “coral cover” and “diversity of fish species” can effectively be used as indicators of perceived ecological resource conditions in the Cairns Sector. These variables are easily and reliably measurable in field situations, they are sensitive to changes in environmental factors over short periods of time, they are sensitive to impacts from human related activities and they can be affected by alternative management actions (Whittaker 1992).

5.4.2.3 The perception of damage to coral reef assemblages

Damage to a natural environment can lead to both ecological and social impacts. Frissell and Stankey (1972) wrote that visitor perception of a declining aesthetic quality may be just as important to recreational managers as some ecological impacts. For example, in the GBRMP, a perceived loss of coral cover due to either a natural or man made impact may affect the quality of visitor experiences and in turn their choice of sites. However, there has been little research on the effects of resource damage on visitor experience. What research has been done has focussed on terrestrial environments. There have been suggestions that more experienced visitors are more perceptive of resource damage in US National Parks

(Hammitt and McDonald 1983, Hammitt and Cole 1987), while less experienced recreationists lack the knowledge of what a site was like before a recreational or other human activity and thus do not notice damage.

In a coral reef environment, Fenton *et al.* (1998) suggest that inexperienced recreationists may not notice specific environmental conditions. They believe that the unfamiliarity with the environment and the equipment required to view the underwater landscape will affect the ability to distinguish between a healthy and an unhealthy location. Rouphael (1997) suggested that experienced SCUBA divers in the GBRMP are more sensitive to resource damage than other marine and land based recreationists, as they able to observe individual coral colonies up close. However, his results were inconclusive because of the small amount of damage to corals at his study sites and thus he suggested that further research on this topic is required.

In the present study, survey respondents were asked to assess the frequency of damage at their frequented sites. Given their high level of experience in the local coral reef environment over many years, some of these reef visitors should have had a highly developed cognitive ability to distinguish between damaged and undamaged areas. It is interesting to note that most of the respondents rarely observed damaging changes affecting the quality of their reef sites, for any of the variables provided. When damage was observed however, the variables that were perceived to cause the most damage included “overfishing”, “anchoring” and "cyclones". These causes of damage were noted most frequently on inshore and midshelf reefs rather than on offshelf reefs.

The use of the factor analysis in this section of the survey reduced the 11 impact variables to five distinct groups: human density impacts, snorkel/SCUBA impacts, natural impacts, vessel impacts and fishing impacts (Section 5.3.3.5). I then plotted a single variable (mean factor score for each group) to examine spatial relationships. It is the grouping of these variables and the spatial patterns of responses that is of interest to management agencies. Understanding what types of impacts affect the quality of reef sites and where these impacts are perceived to occur helps managers to develop limits of use based on unacceptable levels of change to the natural environment.

For example, the dimension "human density impacts", which included perceived damage from pollution, overfishing and crowding, were most often observed on the reefs off Cooktown (Figure 5.9). Although traditionally a low use area, at the time of the survey the area was under increasing pressure from a rapidly expanding tourism industry and an increase in the live fishing industry. Respondents to the survey considered that this area was becoming unacceptably crowded and was suffering from increased levels of fishing and pollution from vessels and people, even though the actual levels of use in this area were amongst the lowest in the Cairns Sector of the GBRMP.

Snorkelling and SCUBA diving impacts were most apparent to respondents off Cairns and Port Douglas and at a few locations in the northern ribbon reefs (Figure 5.10). Areas of most concern were associated with major tourism operations. Together, the tourism operators who regularly access these reefs carried more than 500,000 passengers during the 1995-1996 financial year (GBRMPA EMC Database, GBRMPA planning staff, pers.

comm. 1998). These passengers participated in a number of activities, including snorkelling, SCUBA diving, glass bottom boat tours and helicopter tours.

Damaging changes from natural impacts, which include the variables "Crown of Thorns" and "cyclones", were most apparent to respondents on the reefs around Lizard Island and on several other midshelf and inshore locations (Figure 5.11). At the time of this survey, there was an outbreak of Crown of Thorns Starfish (COTS) at Lizard Island and on several northern midshelf reefs (Engelhardt 1997, Sweatman 1997, Engelhardt *et al.* 1999). Most (69%) of the respondents describing Lizard Island were scientists involved in monitoring the conditions of the coral reefs and associated organisms. Therefore, the high level of reporting of natural impacts described at this location may be a function of the number of scientists using the site. However at many other midshelf locations which scientists did not assess in the survey, respondents were able to detect natural impacts from COTS that had only just been detected by long term scientific monitoring programs. Engelhardt notes that local resource users provide an excellent source of information on the outbreaks of COTs and reports that he has regularly used them to provide an early warning system triggering the need for intensive scientific monitoring (Engelhardt 1997, Wachenfeld 1998).

Respondents also detected damaging changes to their reef sites from vessel impacts from anchoring and groundings. The areas of most concern were at sites off Cairns, Port Douglas, inshore areas south of Cooktown and in the Frankland Island group (Figure 5.12). These areas are most commonly used by recreational boaters and fishers and the smaller tourism operations (Chapter 4, Section 4.5.1.3). The damage from anchoring observed by GBRMPA staff at the Frankland Islands signalled the need for more protection to the area and was part of the trigger for the subsequent development of the Cairns Area Plan of Management (A. Williams, pers comm. 1994)

The final grouping of impact variables was related to fishing. This dimension was best represented by the variables spear fishing and Indigenous hunting. The most concern for this type of damage was for the reefs off Cooktown (Figure 5.13). These areas are heavily fished by the commercial fishing industry, have a higher level of Indigenous use than most other parts of the Cairns Sector (Britnell 1996) and are areas of ongoing conflict between commercial and recreational and Indigenous users of the resource (GRMPA planning staff, pers. comm. 1996). While the Cairns Area Plan of Management (GBRMPA 1998, 2005b) did not cover this area, I suggest that future management planning in the Cairns Sector of the Marine Park should focus on use of the offshore Cooktown region.

5.4.3 The Perception of Social Conditions

In outdoor recreation research, crowding can be defined as the point where use density becomes unacceptable. Most of the research on crowding has focussed on terrestrial parks, where researchers have found that group size (Lime 1972), type of group (e.g. Inglis *et al.* 1999) and mode of travel (Stankey 1973, 1980) affect the definition of crowding and acceptable levels of use.

In addition, a person’s level of experience also affects their definition of crowding, through either a refinement of tastes or by exposure to lower density conditions as a result of earlier participation (Manning 1985). More experienced users are more sensitive to higher use densities. Inglis *et al.* (1999) found that past recreational experience in the GBRMP was related to visitors' use level preferences.

In this survey, the respondents considered that the current levels of use were too high for most locations in the Cairns Sector of the GBRMP (Section 5.3.3.6). They would have preferred to see fewer people and vessels while visiting their favoured reef sites (Table 5.8). Other studies have found that preferred use levels are generally lower than maximum tolerable conditions (summarised in Manning *et al.* 1999).

When asked to determine an acceptable level of use for their sites, the respondents identified a wide range amongst the various reef locations (Table 5.8). Inglis *et al.* (1999) also found a wide range of personal crowding norms within four groups of people surveyed about perceived crowding on the GBR. In essence, there is diversity in the use settings preferred by different visitors to the marine park and it is the management agencies' challenge to provide for these different settings within the boundaries of their park through the various management instruments described in Chapter 2.

Those reefs where respondents considered they could tolerate a large number of vessels (20-100) and people (100-1000) were reefs that were currently well known tourism destinations and major recreational fishing sites. This result suggests that survey respondents may have experienced a product shift with regard to these high use locations during the past decade. Product shift is a cognitive ability to adapt to adverse conditions (such as increased use) whereby visitors change their definitions of recreation experiences (Shelby *et al.* 1988, Shindler and Shelby 1995). In essence, the respondents may be able to cope with the increased use of certain reef sites in the Cairns Sector from tourism operators and recreational fishers by changing their standards to correspond with the area's changing condition (Shelby and Herberlein 1986). Shafer *et al.* (1998) also proposed that reef visitors with more experience may have "shifted" their perception regarding an acceptable number of people to better match the current social conditions on the reef. This finding has wide implications for further increases in reef use over the next decade or so. Future studies should investigate the possibility of a continuing product shift with regard to high use sections of Great Barrier Reef Marine Park.

In addition, Pauly (1998, 2001) and Jackson *et al.* (2001) warn that while monitoring change in marine systems it is important to be aware of the issue of "shifting baselines". Pauly (2001) states

"*each generation accepts the species composition and stock size they first observe as a natural baseline from which to evaluate change. This ignores the fact that this baseline may already represent a disturbed state. The resource then continues to decline, but the next generation resets their baseline to this newly disturbed state. The result is a gradual accommodation of the creeping disappearance of resource species and inappropriate reference points….*"

As in other terrestrial and marine studies on crowding (e.g. Manning 1985, Inglis *et al.* 1999), most respondents had measurable preferences for the number of vessels and people they found acceptable at their favoured reef sites. However, respondents were more concerned with the number of vessels at reef sites than with the number of people (Table 5.8). This result suggests that vessels are more of a visual impact at reef locations than people *per se* and as such require appropriate limits of access (Chapter 7). In addition, my results suggest that the number of vessels observed at a given reef location may be a more appropriate indicator of social impact in the Cairns Sector of the GBRMP than the number of people. In the current Cairns Area Plan of Management, the settings are determined primarily by the number of people on a vessel and not by the number of vessels at a given location GBRMPA 1998, 2005b).

5.5 Conclusions

The results of this survey are a first step in describing the natural and social conditions required by users of the Cairns Sector of the Great Barrier Reef Marine Park. The aims of the survey are to describe the attributes of the reef users, produce an inventory of environmental perceptions, identify biophysical indicators of environmental conditions, provide an inventory of the social conditions of the region and provide the data necessary to make comparisons between human perceptions and the ecological status of the resource. These aims and subsequent findings were discussed in this chapter and are summarised below.

5.5.1 Attributes of the stakeholders:

The respondents to this survey represented a group of highly experienced, knowledgeable, motivated and concerned reef users participating in both consumptive (e.g. commercial fishing and collecting) and appreciative (e.g. sightseeing, SCUBA diving and snorkelling) activities at a variety of reef locations. They were able to describe the environmental quality of the reefs that they frequented, identify changes and describe the social conditions of their reef sites.

Patterns of responses indicate that different user groups required different reef locations and hence different reef attributes. However, additional and experimental research is required to determine which specific attributes are important to specific user groups and how the users experiences are influenced by these attributes.

5.5.2 Inventory of environmental perceptions

The results of the survey suggested that the respondents considered the reefs in the Cairns Sector were of high quality, with the offshore reefs receiving higher ratings for most variables than the inshore reefs. Reefs that rated highest for their ecological landscape were mainly found in the more remote areas of the Section and along the offshore Ribbon Reefs. The presence of marine mammals and other megafauna was rated highly at the offshore ribbon reefs and in other locations where regular whale sightings occur. Those reefs rated as the most convenient and easiest to access were found immediately off Cairns, while the most sheltered locations in the section were found on inshore and midshelf reefs throughout the Section.

Most of the respondents considered that damage rarely occurred to the reef locations that they frequented. When it did occur, the variables that were perceived to cause the most damage were overfishing, anchoring and cyclones. These causes of damage were most frequently noted on inshore and midshelf reefs.

Density impacts were most apparent in the reefs off Cooktown, even though these reefs were relatively lightly used, while impacts related to tourism (from snorkelling and SCUBA diving) were most apparent to the respondents off Cairns and Port Douglas, the main tourism centres in the region. Natural impacts were most apparent near Lizard Island and other northern midshelf reefs in the Section. I attribute this to severe cyclone damage and COT outbreaks in the area. Impacts from vessels were most apparent at inshore and midshelf reef locations frequented by recreational fishers and boaters and small tourism operators.

5.5.3 Biophysical indicators

The variables coral cover and diversity of fish species were the best indicators of overall reef quality for reefs in the Cairns Sector of the Great Barrier Reef Marine Park. In essence, high quality sites were locations with excellent coral cover and high diversity of fish species, while poor sites had poor coral cover and poor underwater topography.

5.5.4 Inventory of social conditions

While results of the survey indicated that current levels of use were perceived as too high for most locations in the Cairns Sector, there was a wide range of acceptable levels of use amongst the various reef locations.

Reefs that were currently well known tourist locations and major recreational sites were locations where respondents could cope with large numbers of vessels and people. It is possible that the respondents may have shifted their requirements to better match the current conditions.

Respondents were more concerned with the number of vessels at reef locations than with the number of people. Vessels may constitute a greater visual impact at reef locations than people per se and as such require limits of access. In addition, the number of vessels observed at a reef location could be a more appropriate indicator of social impacts than the number of people per vessel. Current management practices however, restrict the number of people and not the number of vessels at locations within the Cairns Sector of the Marine Park. In light of the findings of this study, these restrictions need to be reviewed.

5.5.5 Provision of data to compare between perceptions and ecological status of the resource

In the next chapter, comparisons are made between the survey respondents' perceptions of coral and fish diversity at reef sites and scientific monitoring data collected at these same locations. These comparisons provide an independent evaluation of the socially perceived patterns of reef quality.

The information provided through the survey of reef users can be used to assist managers in developing more appropriate management settings and zones for use of the resource. The implication of these findings for the management of the area is discussed in Chapter 7.

Chapter 6. Indicators of Reef Quality in the Cairns Sector of the Great Barrier Reef Marine Park

Results from Chapter 5 showed that the variables coral cover and diversity of fish species were the best indicators of experienced reef users' perceptions of overall reef quality for reefs in the Cairns Sector of the Great Barrier Reef Marine Park. In this chapter, comparisons are made between the survey respondents' perceptions of coral and fish diversity at reef sites and scientific monitoring data collected at these same locations. These comparisons aim to explore the strengths and limitations of the data obtained from the users' survey with a view to evaluating the likely usefulness of data collected from experienced users of the marine park in planning and management. The next chapter (Chapter 7) then explores the relationship between perception of reef quality, use of the Marine Park and management of the area and incorporates this information into a decision support system.

6.1 Introduction:

All of the current frameworks for developing protected area management, e.g. Limits of Acceptable Change, Carrying Capacity Assessment Process and Visitor Impact Management (see Chapter 3), stress the importance of setting standards or limits of acceptable or unacceptable change for relevant impact variables or "indicators" (Stankey *et al.* 1985, Shelby and Heberlein 1986, Graefe *et al.* 1990, Whittaker 1992). Following the development of management plans or policies for protected areas, evaluation of the effectiveness of the management outcomes requires detailed monitoring of the specified indicators. Outcome evaluation is the true test of management effectiveness (Hockings *et al.* 2000). Protected areas such as the Great Barrier Reef Marine Park (GBRMP) are threatened from increasing levels of recreational and commercial use and require focused and detailed levels of assessment (Hockings *et al.* 2000). Since managers cannot afford to measure every impact that may affect the natural or social environment, specific indicators need to be selected (Merigliano 1990, Whittaker 1992). It is important that selected indicators can be measured and compared to standards and that changes are easily detected through monitoring programs (Merigliano 1990).

Using a subset of the data from the survey described in Chapter 5, I suggest that the respondents' perception of the quality of the variables "coral cover" and "diversity of fish species" can be used as indicators of perceived ecological resource conditions in the Cairns Sector, for the following reasons (summarised from Whitakker 1992 and Hockings *et al.* 2000):

- They are both dominant visual features of the underwater landscape in the GBRMP;
- They are the main determinants of the perception of overall quality of reefs in the Cairns Sector of the GBRMP (Chapter 6, Section 6.4.1b);
- They are measurable in field situations;
- They are sensitive to changes in impacts over short periods of time;
- They are sensitive to impacts from human related activities;
- They can be affected by alternative management actions;
- They can reflect changes at spatial and temporal scales relevant to management;

- They are fundamentally important to the ecology of the area ;
- They are fundamentally important to the users of the resource.

In the Cairns Sector of the GBRMP, reef sites with perceived above average to outstanding coral cover and excellent to outstanding diversity of fish species were perceived to have the highest overall quality (Chapter 5, Section 5.3.3.3).

Such sites have been regularly monitored by scientists at many offshore reef locations since the declaration of the Great Barrier Reef Marine Park in the mid 1970s, thus providing a large dataset of natural variability.

As outlined in Chapter 4, two major research programs that have been conducted to describe the reef resources in the Cairns Sector of the GBRMP: the long term monitoring program (particularly the broad scale monitoring task) conducted by the Australian Institute of Marine Science (AIMS) and the monitoring research conducted by Mapstone *et al.* (1995) for the Marine Park Authority (Chapter 4, Section 4.3.2.1 and Section 4.3.2.2). These programs can provide a basis for evaluating the outcome of existing management schemes.

As described in Chapter 4, the Australian Institute of Marine Science has collected data on reefs in the Marine Park since 1985. Using the manta tow technique, AIMS researchers have described many of the patterns in reef processes. The objectives of the program were to monitor the status and changes in the distribution and abundance of reef biota on a large scale; and to provide environmental managers with a context for assessing impacts of human activities within the GBRMP and with a basis for managing the GBR for ecologically sustainable use (Sweatman *et al.* 1998).

Mapstone *et al.* (1995) also aimed to describe broad scale patterns of distribution and abundance of coral reef organisms (see Chapter 4, Section 4.3.2.2). It was hoped that this research would assist with planning for use of the marine park and result in the development of management strategies that take into consideration patterns in the distribution and abundances of various reef biota.

In this section of the thesis, I make comparisons between the quality variables "coral cover" and "diversity of fish species" obtained from my survey of reef users (Chapter 5) and the monitoring data collected by AIMS and Mapstone *et al.* (1995). I use these comparisons to validate the survey respondents' perceptions of the natural resource. These comparisons may also provide insights into the ability of local reef users to collect data on the natural conditions of coral reefs and the usefulness of these variables as indicators for management of marine protected areas.

Local knowledge can play an important role in the management and monitoring of marine protected areas (Johannes *et al.* 2000). Selection of relevant indicators helps to focus the monitoring process. The main findings of this chapter suggest that regular reef users were able to detect differences in the quality of reef locations across the entire Cairns Sector of the GBRMP. Those reefs perceived to be of higher quality had more hard coral and less soft coral in back reef locations. The presence of fish species commonly associated with branching corals also improved perceptions of the quality of their reef sites.

In addition, the results suggest that scientific information can be used to predict which areas will be considered of high quality by marine park users. This approach is especially useful in areas that are not already accessible but may become so in the future (e.g. the northern, more remote areas of the Cairns Sector).

Conversely, regular reef users could play an important role by conducting a rapid assessment of the suggested indicators "coral" and "fish diversity" and providing this feedback to the GBRMPA. The combination of local knowledge and scientific information gathered at many reef locations could provide the management authority with a broader information base to determine the effectiveness of the Authority in achieving its primary goal of protecting the coral reef environment.

6.2 Methods:

6.2.1 Perception of overall reef quality

A regression tree analysis was used in the previous chapter (Chapter 5) to determine how overall reef quality depends on 17 biophysical and social variables. In summary, regression trees were used to explain the variation of overall perceived quality, by repeatedly splitting the data into more homogeneous groups, using combinations of the 17 biophysical and social variables (De'ath and Fabricus 2000). Splits were selected by maximising the homogeneity of the two resulting groups and minimising the sum of squares within groups. Models were ascertained by cross-validation (De'ath and Fabricus 2000). For each tree, a series of 50, 10-fold cross-validations were run and the most frequently occurring tree size was chosen using the 1-SE rule as outlined in De'ath and Fabricus (2000). As reefs were the sampling units, they were not included in the models as explanatory variables, but were used to form the subsets for cross-validation.

6.2.2 Selection of ecological indicator variables

Results of the Regression Tree Analysis indicated that coral cover, diversity of fish species and underwater topography jointly determined user perceptions of overall reef quality in the Cairns Sector of the GBRMP. In essence, locations with excellent coral cover ("excellent" indicates scores of ≥6, where 1=very poor and 7=outstanding) and a high diversity of fish species (scores ≥ 5) obtained high quality scores, while poor quality sites (scores ≤ 2) had poor coral cover and poor underwater topography (both with scores ≤ 2).

Thus I believe that experienced reef users' perceptions of the variables "coral cover" and "diversity of fish species" can be used in a rapid assessment process as indicators of ecological resource conditions in the Cairns Sector. I do not recommend the use of underwater topography, as it is not sensitive to change from human activities and is not affected by alternative management actions (Whittaker 1992, see Chapter 7, Section 7.1). The variable "overall quality" is also important as an indicator of the overall condition of a reef site and as a means of cross checking the perception of the other quality variables. Collecting information on these variables can give a quick indication of the stakeholders' perception of the quality of the resource and assist management in focusing further research effort.

6.2.3 Comparison between monitoring data and reef quality variables

6.2.3.1 Monitoring data:

6.2.3.1.1 Data collected by the Australian Institute of Marine Science (AIMS) (Chapter 4, Section 4.3.2.1):

In the Cairns Sector of the GBRMP, the perimeters of 119 reefs have been surveyed using the AIMS manta tow technique (Moran and De'ath 1992). These surveys have been conducted regularly since 1985. The AIMS data used in this thesis were collected between 1994 and 1996. Variables recorded during the manta tows were: numbers of Crown of Thorns Starfish (COTS), presence of feeding scars, extent of COTS activity, percent cover of live hard coral, dead hard coral, soft coral and sand and rubble. Cover of coral (live, dead and soft) was measured using a rank scale where category 0 = 0% cover, category 1 = 1-10% cover, category 2 = 11-30% cover, category 3=31-50% cover, category 4 = 51-75% cover and category 5 = 76-100% cover (Sweatman *et al.* 1997). For the purpose of comparisons with the resource use survey data (see Chapter 5) and the data collected by Mapstone *et al.* (1995), each tow was categorised into its reef habitat (front reef, back reef and reef flank) and location within that habitat (north, south and middle).

6.2.3.1.2 Data collected by Mapstone et al. (1995)

As outlined in Chapter 4, the data provided by Mapstone *et al.* (1995) were collected throughout the Cairns Sector in 1991 and at the Frankland Islands in 1998. Data were provided for 45 reefs, sampled at three locations per reef within back and front reef habitats. Belt and line transects were sampled within each location for fish and sessile benthos. All sampling was conducted by divers using SCUBA. Details of the sampling methods used are provided in Chapter 4 and in Mapstone *et al.* (1995). The researchers collected information on 53 variables and provided means for each location on each reef. Some of the variables are as follows:

- Numbers of *Acanthaster planci*, *Linkia laevigata* and *Tridacna* spp;
- Percent coverage of hard and soft corals and non living substrata
- Numbers of fish with medium to great mobility over short periods
- Numbers of fish with restricted home ranges and limited mobility over short periods.

6.2.3.2 Analyses

Bivariate correlations using Spearman's rho were calculated to compare means for the same back reef locations of (i) live and dead coral cover from the AIMS monitoring data from the years 1994 to 1996, (ii) reef biota variables provided by Mapstone *et al.* (1995), and (iii) the survey respondents' perceptions of coral, fish diversity and reef quality. Data were checked using boxplots to identify outliers and extreme values before calculating correlation coefficients. Cases with missing values for one or both of a pair of variables for a correlation coefficient were excluded from the analyses. When more than 20 correlation analyses were performed, p-values were corrected for type 1 error by dividing by the number of separate tests.

A Cannonical Correlation Analysis (using the software StatSoft) was used to compare the back reef data collected by Mapstone *et al.* (1995) with the survey respondents' perceptions of the quality of coral, fish diversity and overall quality, in order to determine how much of the variance in the ecological variables was explained by the survey data and *vice versa*. The datasets were checked for multivariate normality, outliers and reliable sample sizes. They did not violate the major assumptions of the analysis. Miller's test of the total redundancy was used to determine the significance of the redundancy value, as described by McArdle (1999). Bubble plots were used to explore the relationship between the canonical variates from the Mapstone *et al*. (1995) data and the survey respondents' perception variables.

6.2.4 Limitations

As discussed in Chapter 5, a readily available sampling frame that would include the diversity of reef users in the GBRMP does not exist. Although surveys were distributed to a wide proportion of the target population (i.e. regular reef users), the probability of a respondent's returning a survey was dependent on many factors, such as his or her interest in the marine park; level of experience and the geographical location of sites. Given that, the returned surveys represent a reasonable estimate of the preferences shown by the regular reef users (Chapter 5). However, the probability of all types of reef users receiving and responding to this survey is unknown and thus this sample may not be representative of the full range of users.

Each respondent was asked to assess three sites that they access most frequently, thus these sites are not independent. Several reef locations were dominated by one or two user groups and thus the probability of spatial confounding of use type is high. Therefore, analyses of separate user groups were not conducted.

In addition, comparisons made in this chapter between survey data and scientific monitoring data are meant only to generate hypotheses and provide general indications of patterns that may exist. The survey data and scientific monitoring data were collected at different times over several years and as a consequence, the results of these analyses need careful interpretation.

6.3 Results:

6.3.1 AIMS coral cover vs perception of ecological indicators

The comparisons between the AIMS monitoring data and the survey respondents' perception of the variables "coral", "diversity of fish species" and "overall quality" demonstrate the respondents' ability to describe reefs of differing quality. Back reef locations with higher percentages of live and dead coral cover were perceived to have significantly higher ratings for the three survey variables (Table 6.1).

RESPONDENTS' PERCEPTION		Live coral	Dead Coral
Coral	Correlation Coefficient	0.458**	0.351*
	Significance (2-tailed)	p=0.001	p=0.013
Diversity of Fish	Correlation Coefficient	0.403**	0.563**
	Significance (2-tailed)	p=0.004	p=0.000
Overall Quality	Correlation Coefficient	0.368**	0.392**
	Significance (2-tailed)	p=0.009	p=0.005

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 6.1: Comparisons between the mean AIMS variables "live coral" and "dead coral" (ranks of 0 = no coral to 5 = 76-100% coral cover) and the mean survey respondents' perception of total "coral", "diversity of fish species" and "overall quality" (ranks of 1 = very poor to 7= outstanding) at 50 back reef locations using nonparametric correlation analyses (Spearman's Rho). (n = 50)

6.3.2 Mapstone *et al.* (1995) data vs perception of ecological indicators

The Mapstone *et al.* (1995) dataset provided a more comprehensive assessment of the reef biota than the AIMS dataset. By using this data set, I was able to identify which benthic organisms and groups of fish had the most influence on the perceived quality of a reef site. The results of the comparisons between the survey data and Mapstone *et al.* (1995) are separated into (i) benthic organisms and (ii) fish species.

6.3.2.1 Benthic organisms

Results of the correlation analyses suggest that back reef sites with a high cover of branching and massive hard corals (e.g. Acroporids, *Porites*, dead standing coral and other hard corals) received higher ratings by the survey respondents for coral, fish diversity and overall quality (Table 6.2). In contrast, sites with a high percentage cover of soft coral were rated lower for coral, fish diversity and overall quality. Back reef locations with greater numbers of *Drupella* received higher ratings for the diversity of fish species and overall quality of the location. Front reef locations with high cover of hard corals received higher ratings for overall quality, coral and diversity of fish species by the survey respondents (Table 6.3)

RESPONDENTS' PERCEPTIONS	**Coral**	**Diversity of fish species**	**Overall quality**
Acropora other	0.325*	0.366*	0.379*
Acropora plate	0.229	0.337*	0.346*
Dead standing coral	0.327*	0.306	0.374*
Hard coral other	0.196	0.345*	0.362*
Linkia	-0.212	-0.297	-0.273
Porites	0.207	0.255	0.442**
Drupella	0.095	0.320*	0.298*
Soft coral	-0.505**	-0.591**	-0.474**
Sponge	0.141	0.020	0.050
Total hard coral	0.238	0.350*	0.484**

** Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed).

Table 6.2: Comparisons between the Mapstone *et al.* (1995) mean benthic data and the survey respondents mean perception of "coral", "diversity of fish species" and "overall quality" at back reef locations, using the nonparametric Spearman's Rho correlation analyses. Correlation Coefficient provided for each set of variables. N=39 reefs.

RESPONDENTS' PERCEPTIONS	**CORAL**	**DIVERSITY OF FISH SPECIES**	**OVERALL QUALITY**
Acropora other	0.146	0.137	0.112
Acropora plate	-0.038	-0.035	-0.056
Dead standing coral	0.001	-0.071	0.005
Other Hard Corals	0.082	0.461**	0.531**
Linkia	-0.252	-0.115	-0.205
Porites	0.208	-0.015	0.166
Drupella	-0.076	0.119	0.110
Soft coral	0.252	0.025	0.086
Sponge	0.249	-0.046	0.116
Total hard coral	0.176	0.340*	0.417**

** Correlation is significant at the 0.01 level (2-tailed);
*Correlation is significant at the 0.05 level (2-tailed).

Table 6.3: Comparisons between the Mapstone *et al.*, (1995) mean benthic data and the survey respondents mean perception of "coral", "diversity of fish species" and "overall quality" at FRONT reefs, using the nonparametric Spearman's Rho correlation analyses. Correlation Coefficient provided for each set of variables. n = 39 reefs

6.3.2.2 Fish species

Results of bivariate correlation analyses between a subset of the Mapstone *et al.* (1995) fish data (only major groups of fish were analysed because of the rarity of some of the fish species) and the survey respondents' perception data indicated that back reef sites with more *Zebrasoma scopas* (Brushtail Tang) and *Plectroglyphidodon lacrymatus* (Jewel Damsel) received higher ratings for coral (Table 6.4). Locations with more Brushtail Tang, Big Eye Bream (*Monotaxis grandoculis*) and Chaetodontids received higher ratings for overall quality (Table 6.4).

Front reefs with more Acanthurids received higher ratings for coral and diversity of fish species by the survey respondents (Table 6.5). Locations with more Chaetodontids received higher ratings for fish diversity and overall quality (Table 6.5). Front reef locations with few coral trout, *Plectropomus leopardus*, and *Plectroglyphidodon lacrymatus* received higher ratings for coral, diversity of fish species and overall reef quality (Table 6.5).

RESPONDENTS' PERCEPTIONS	**CORAL**	**DIVERSITY OF FISH SPECIES**	**OVERALL QUALITY**
Total Acanthurids	0.235	0.107	0.248*
Zebrasoma scopas	0.351*	0.309	0.464**
Total Chaetodontids	0.145	0.376*	0.489**
Total Lethrinids	0.148	0.209	0.278
Total Lutjanids	0.070	0.258	0.262
Monotaxis grandoculis	0.276	0.270	0.335*
Total Pomocentridae	-0.069	-0.015	-0.042
Plectroglyphidodon lacrymatus	0.354*	0.259	0.265
Total Serranidae	-0.141	-0.225	-0.299
Plectropomus leopardus	-0.225	-0.195	-0.285

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 6.4: Comparisons between the Mapstone *et al.* (1995) fish data (mostly pooled to genus with some predominant species analysed) and the survey respondents' perception of coral, diversity of fish species and overall quality at BACK reef locations, using the nonparametric Spearman's Rho correlation analyses. Correlation Coefficient provided for each set of variables. n=39

RESPONDENTS’ PERCEPTIONS	CORAL	DIVERSITY OF FISH SPECIES	OVERALL QUALITY
Total Acanthurids	0.364*	0.343*	0.304
Zebrasoma scopas	0.282	0.239	0.206
Total Chaetodontids	0.123	0.337*	0.437**
Total Lethrinids	-0.219	0.043	0.020
Total Lutjanids	-0.289	0.046	0.062
Monotaxis grandoculis	0.008	0.207	0.182
Total Pomocentridae	-0.255	-0.256	-0.225
Plectroglyphidodon lacrymatus	-0.395*	-0.381*	-0.426**
Total Serranidae	-0.263	-0.315	-0.302
Plectropomus leopardus	-0.263	-0.433**	-0.430**

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 6.5: Comparisons between the Mapstone *et al.*, (1995) fish data (mostly pooled to genus with some predominant species analysed) and the survey respondents’ perception of coral, diversity of fish species and overall quality at FRONT reef locations using the nonparametric Spearman's Rho correlation analyses. Correlation Coefficient provided for each set of variables. (n = 38)

These correlations were further explored in multivariate space using canonical correlation analysis between the back reef data for the main groups of benthic organisms and fish species from the Mapstone *et al.* (1995) monitoring program and the survey respondents' perceptions of the variables “coral”, “fish diversity” and “overall quality”. A significant correlation between the two datasets existed (Table 6.6).

DATASET	NUMBER OF VARIABLES	% VARIANCE EXTRACTED	TOTAL REDUNDANCY GIVEN THE OTHER SET
Mapstone *et al.* (1995)	18	22.54%	13.74%
Perception variables	3	100%	63.75%

Table 6.6: Results of the Canonical Correlation Analysis between the main groups of benthic and fish species from Mapstone *et al.* (1995) and the survey respondents' perception of "coral", "fish diversity" and "overall quality" for back reef locations.
(n = 39)   Canonical R: 0.8833
Chi Squared 90.17   DF=54, p=0.011

The analysis identified linear combinations of the two data sets that have the highest correlation with each other. The first canonical variates explained most of the variance and provided the best linear combination of the data sets (Figure 6.1).

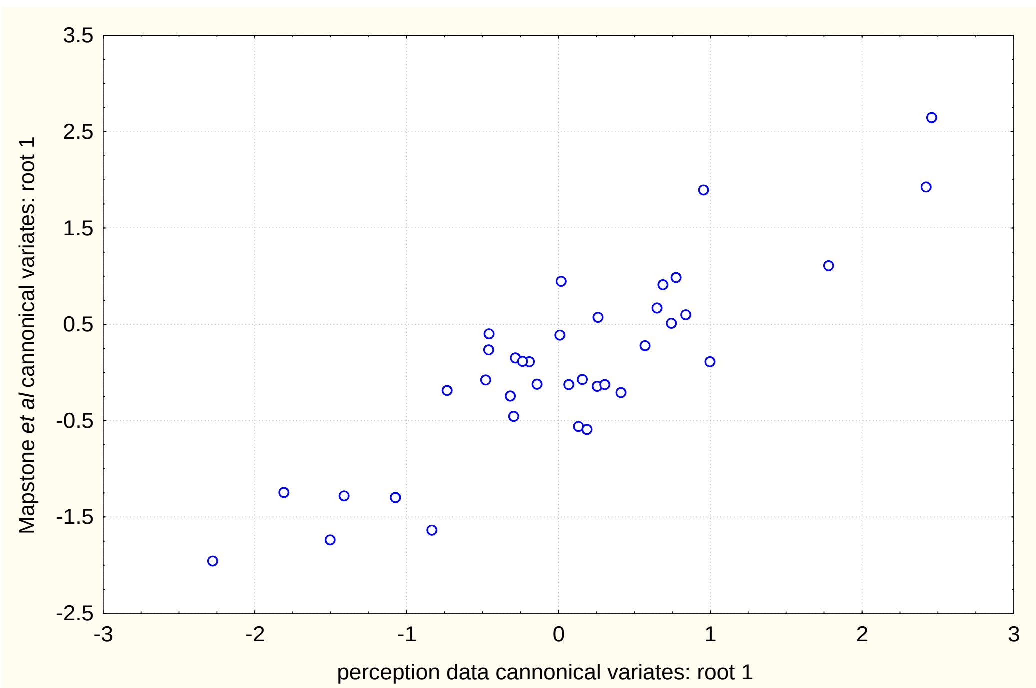

Figure 6.1: Scatterplot of the first root of the Mapstone *et al*. (1995) canonical variates explained by the survey respondents' perception of coral, fish diversity and overall quality of the same reef sites. The canonical variates in the first root were chosen to correlate maximally with each other.

The proportion of the total variance of one variable set explained by the other set is the total redundancy and is the most important indicator of the overall adequacy of the analysis (McArdle 1999). In this case, there were two redundancy values: one for the variance in the Mapstone *et al.* (1995) data set explained by the survey data set (13.74%) and one for the variance in the survey data set explained by the Mapstone *et al.* (1995) data (63.75%) (Table 6.6). These results suggest that while the survey data does not readily explain the variance in the Mapstone *et al.* (1995) data, the Mapstone *et al.* (1995) data could be used to explain some of the survey data variance. Miller's test of redundancy (McArdle 1999) indicates that the Mapstone *et al.* (1995) data explains more variance in the survey respondents' perception data than would be expected by chance alone ($F=11.5$, df 57, 665, $p<0.0001$). The survey respondents' perception of "coral", "fish diversity" and "overall quality" does not explain the variance in the Mapstone *et al.* (1995) data ($F=0.79$, df 57, 57, $p>0.851$) and therefore does not require further interpretation.

I then looked at the respondents' location of reef sites and mean rating of "coral" "diversity of fish species" and "overall quality" plotted in the space of the first two Mapstone *et al.* (1995) canonical variates (Figures 6.2 to 6.4). Using this ordination, the locations appear to separate out to the easily accessible inshore to midshelf reefs, islands and cays (e.g. Endeavor Reef, the Barnard Islands, Lizard Island, Green Island, Low Island, Mackay and Moore Reefs) and the more remote offshore reefs (e.g. Eyrie, Carter, Potter, Hicks, the Agincourts, Escape, Euston and Chinaman). Reefs with higher rankings for coral, fish diversity and overall quality tend to have less soft coral (Figure 6.5), more total hard coral (Figure 6.6), more *Zebrasoma scopas* (Figure 6.7) and more *Plectroglyphidon lacrymatus* (Figure 6.8).

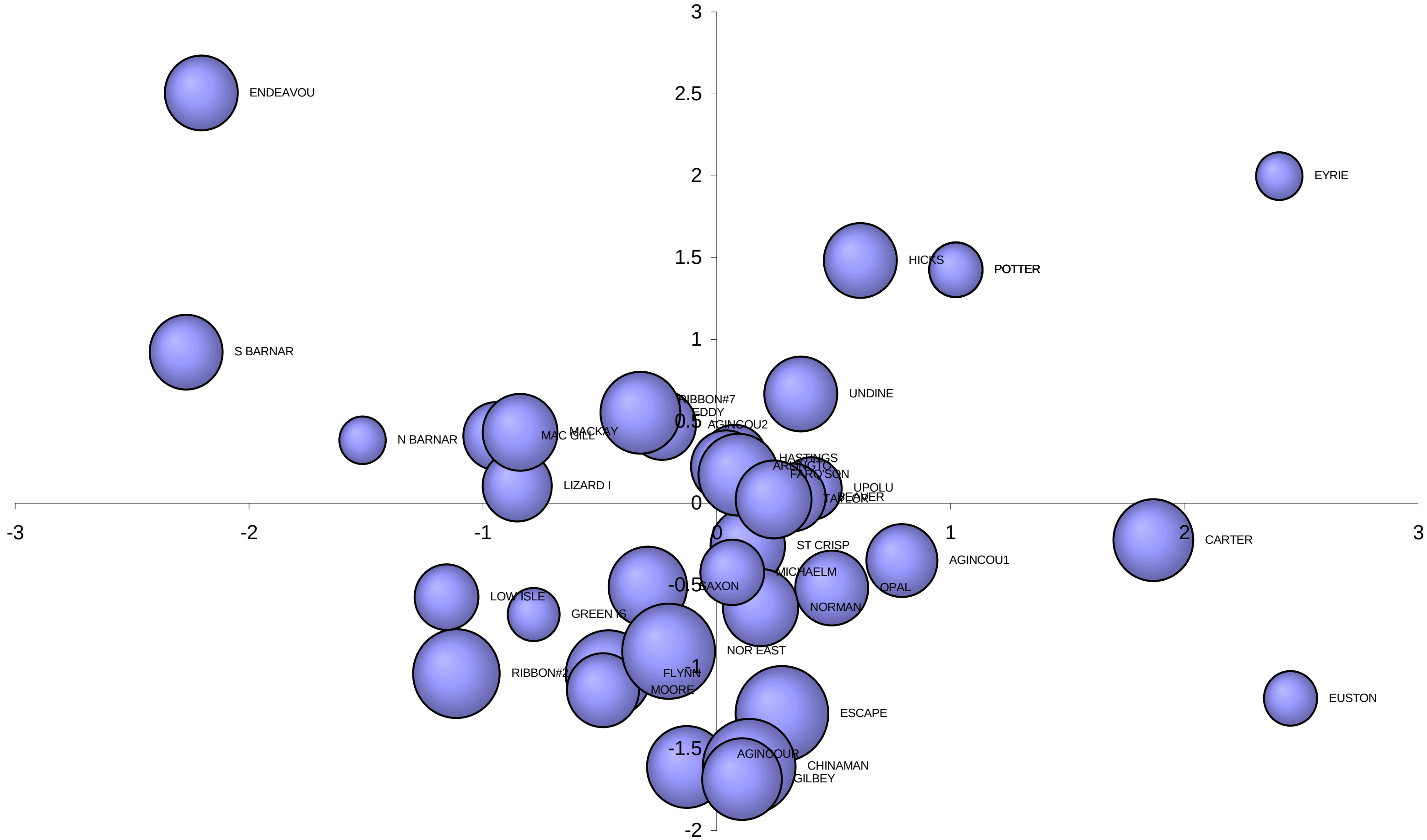

Figure 6.2 Bubble plot of the survey respondents' most frequented reef sites and perception of the quality of coral (ratings of 1 = very poor to 7= outstanding) in the space defined by the first two canonical variates of the Mapstone *et al.* (1995) data set. The mean quality of coral rating for each reef site determines the size of the bubble.

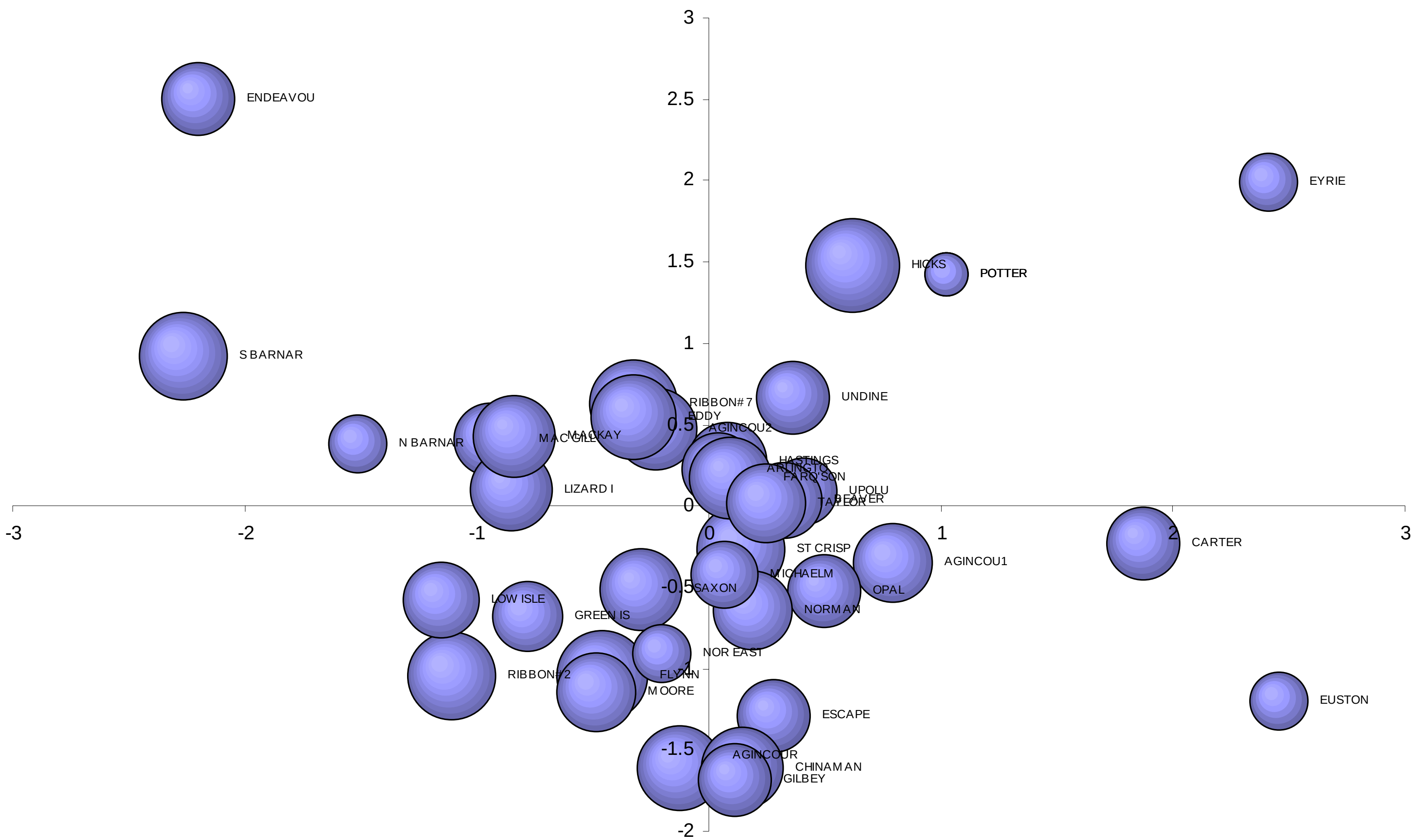

Figure 6.3: Bubble plot of the survey respondents' most frequented reef sites and their perception of the diversity of fish species (ranks of 1 = very poor to 7= outstanding) in the space defined by the first two canonical variates of Mapstone *et al.* (1995). The mean rating of the diversity of fish species for each reef site determines the size of the bubble.

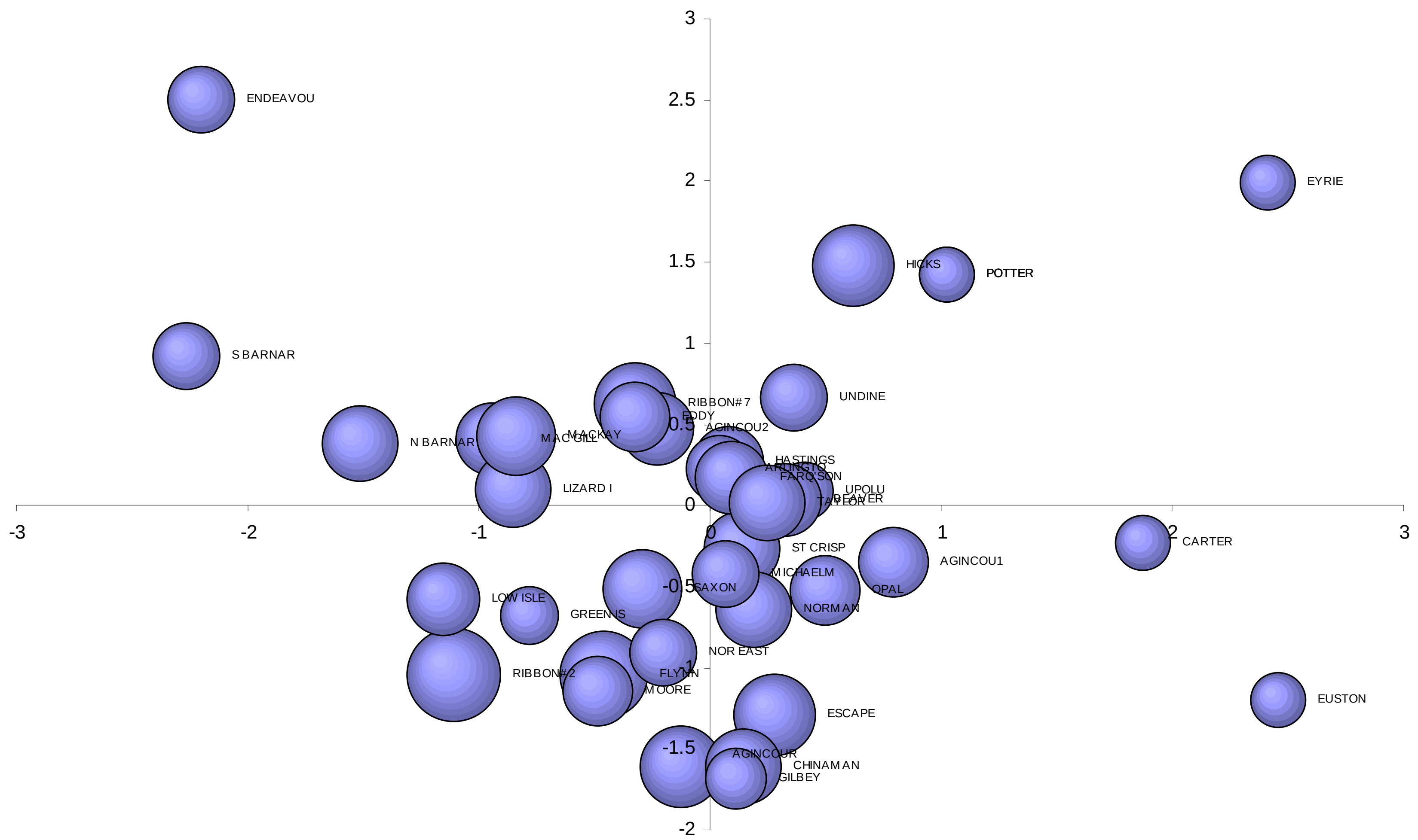

Figure 6.4: Bubble plot of the survey respondents' most frequented reef sites and their perception of overall quality (ranks of 1 = very poor to 7= outstanding) in the space defined by the first two canonical variates of the Mapstone *et al.* (1995) data set. The mean rating of the overall quality for each reef site determines the size of the bubble.

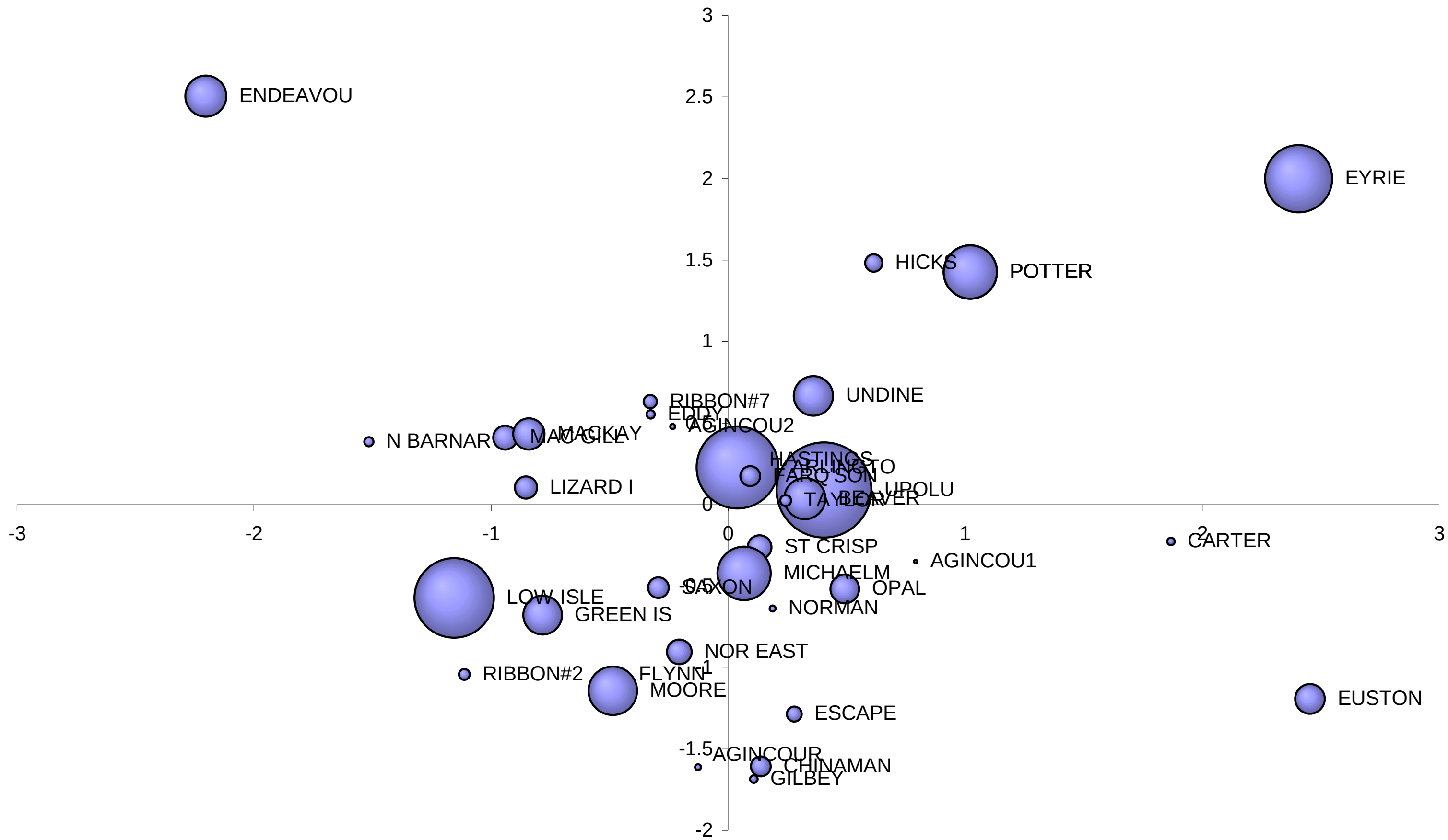

Figure 6.5: Bubble plot of the survey respondents' most frequented reef sites and percent cover of soft coral (from Mapstone *et al.* (1995))in the space defined by the first two canonical variates of the Mapstone *et al.* (1995) data set. The mean percent cover of soft coral for each reef site determines the size of the bubble.

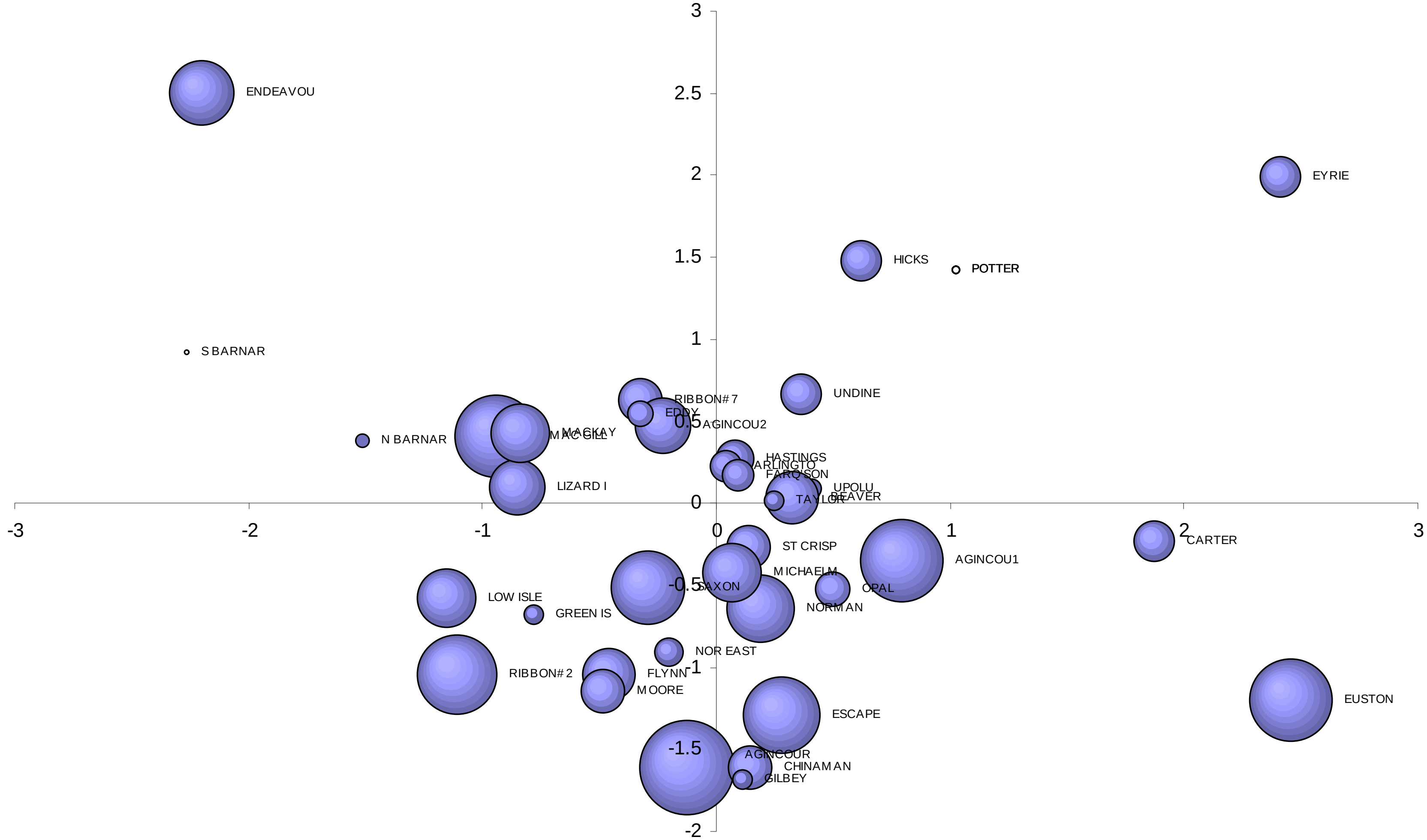

Figure 6.6: Bubble plot of the survey respondents' most frequented reef sites and percent cover of hard coral in the space defined by the first two canonical variates of the Mapstone *et al.* (1995) data set. The mean percent cover of hard coral for each reef site determines the size of the bubble.

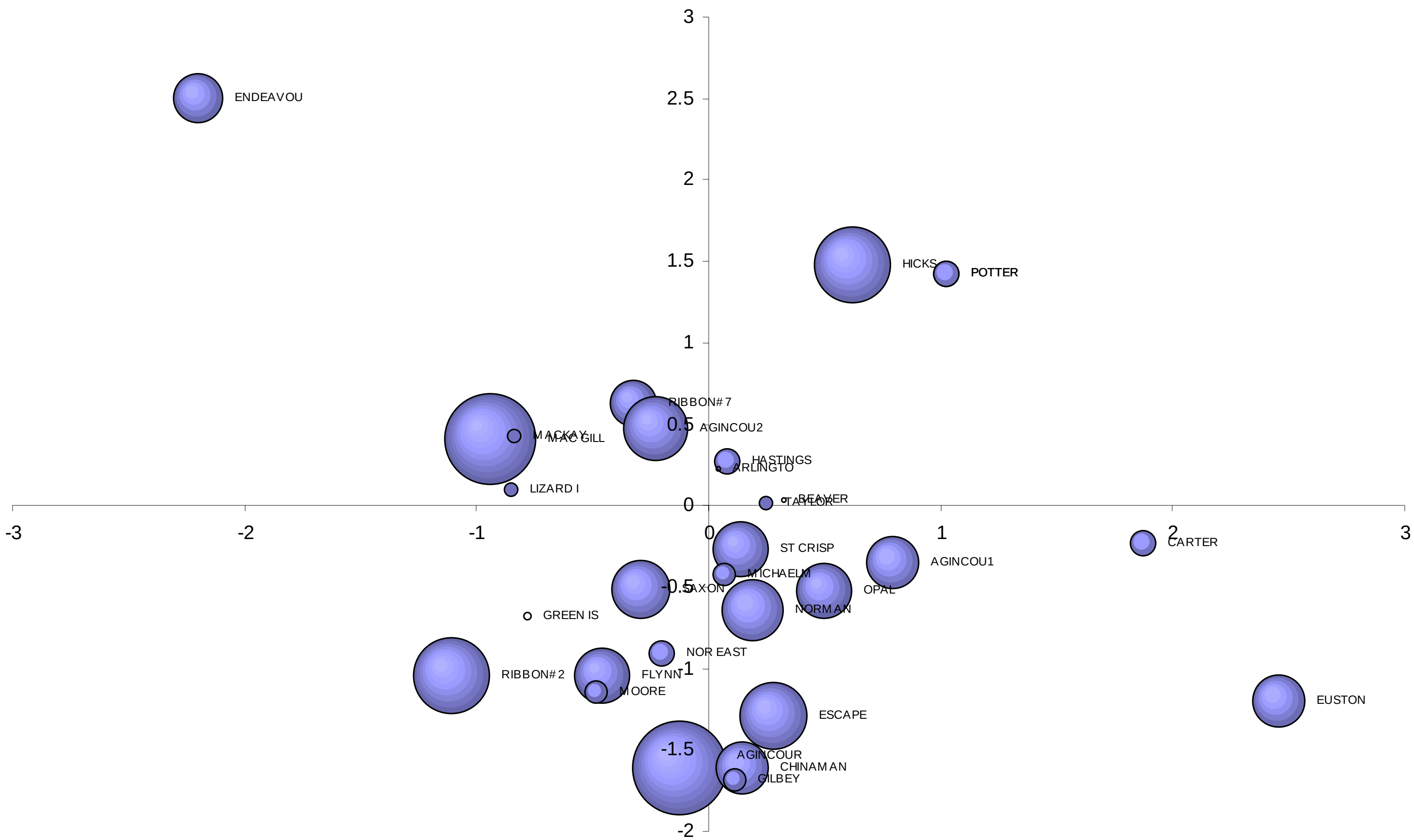

Figure 6.7: Bubble plot of the survey respondents' most frequented reef sites and the mean number of *Zebrasoma scopas* in the space defined by the first two canonical variates of the Mapstone *et al*. (1995) data set. The mean number of *Zebrasoma scopas* for each reef site determines the size of the bubble.

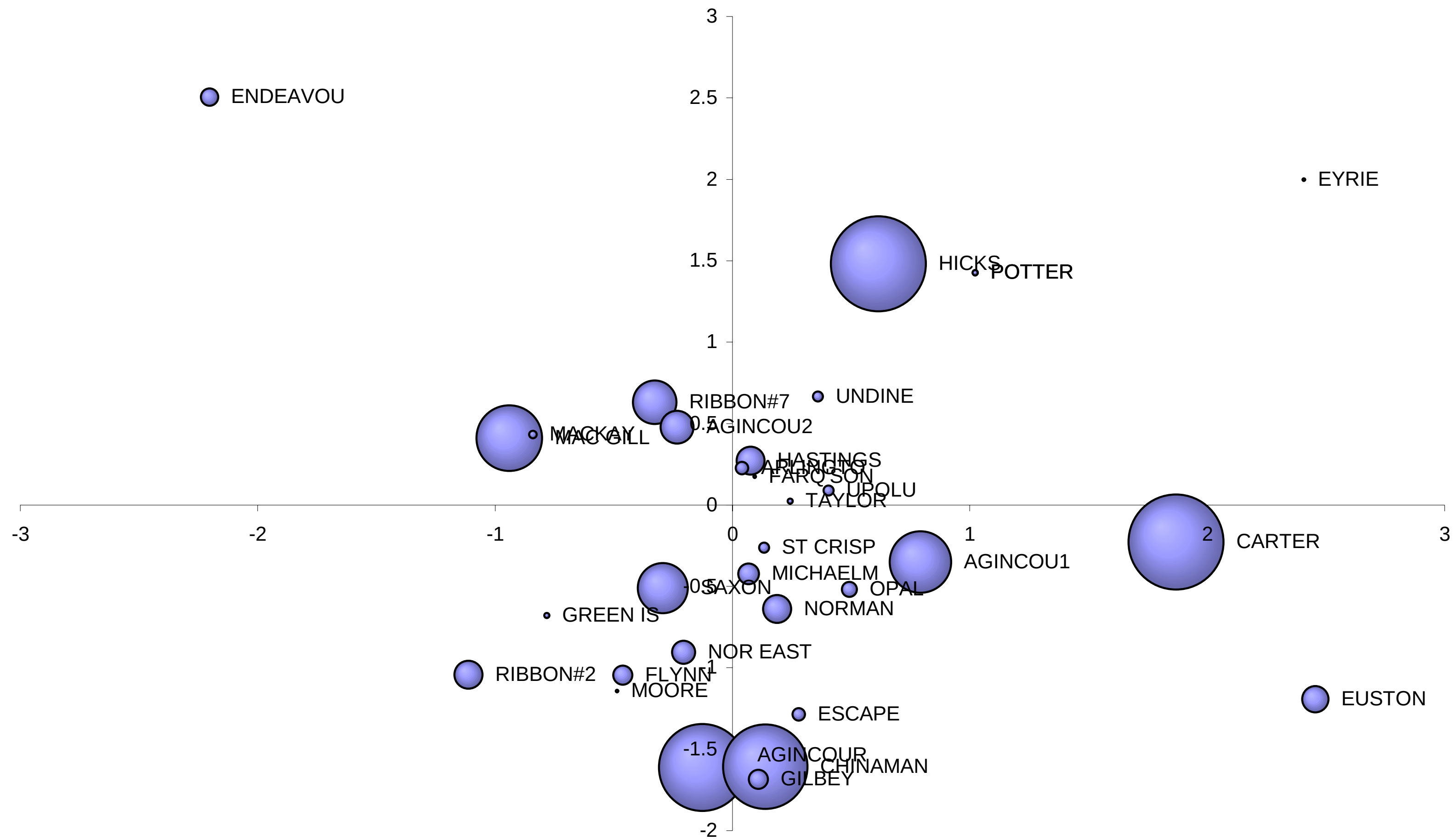

Figure 6.8: Bubble plot of the survey respondents' most frequented reef sites and mean number of *Plectroglyphidodon lacrymatus* in the space defined by the first two canonical variates of the Mapstone *et al.* (1995) data set. The mean number of *Plectroglyphidodon lacrymatus* for each reef site determines the size of the bubble.

6.4 Discussion:

The main findings of this chapter suggest that experienced reef users were able to detect differences in the quality of reef locations across the entire Cairns Sector of the GBRMP. When respodents' perceptions were compared with scientific monitoring data, it was found that those reefs perceived to be of higher quality had more hard coral and less soft coral in back reef locations. The presence of fish species commonly associated with branching live and dead corals and found in large groups also improved the perceived quality of reef sites (Table 6.4).

Results of the Canonical Correlation analysis suggest that the biological survey data from Mapstone *et al.* (1995) for back reef locations can be used to predict survey responses for coral, diversity of fish species and overall quality (Table 6.6).

6.4.1 Validity of reef quality data collected by regular reef users

Comparisons between ongoing reef monitoring data and a subset of the survey respondents' perception data from Chapter 5 were conducted in order to explore the survey data further and evaluate the validity of using it in marine park management. Given the limitations of the survey data (Chapter 5, Section 5.2.4), the variables "coral", "diversity of fish species" and "overall quality" were found to have significant correlations with many of the biological monitoring variables. Using the AIMS data set, the biological variables from 50 locations were compared with the perception variables (Chapter 5) from the same locations. All of the variables from these two data sets had positive correlations. In essence, reefs with more coral (live or dead) were perceived to be of higher quality. Using this information, managers could potentially identify areas of high value to the marine park users. Conversely, in areas where scientific monitoring has not yet occurred, regular reef users' perceptions of these three variables could indicate potential areas of high coral cover. However, the AIMS data are limited in that they provide only general information on broad taxonomic groupings (e.g. live coral, dead coral).

By comparing the perception data with the Mapstone *et al*. (1995) data set, I was able to provide an assessment of which benthic organisms and fish species had the most influence on the perceived 'quality' of reef sites. The strongest correlations between the perception variables (coral, diversity of fish species and overall quality) and the Mapstone *et al*. (1995) data were with soft coral. Back reef sites with more soft coral were generally perceived to be of lower quality for the three perception variables. Such sites were mainly inshore and mid-shelf reefs, islands and cays. In addition, reefs with a higher perceived ranking for coral, fish diversity and overall quality had more Chaetodontids, *Zebrasoma scopas* and *Plectroglyphidodon lacrymatus* in back reef locations. These fish are commonly associated with coral reefs, are highly visible, found mostly in lagoon areas of mixed coral and rubble and feed mainly on benthic algae (Randall *et al.* 1997). Thus reef visitors are likely to observe them while viewing the underwater landscape. Front reef locations with more Chaetodontids received higher ratings for diversity of fish species and overall reef quality. While those front reef locations with high numbers of *Plectroglyphidodon lacrymatus* and *Plectropomus leopardus* were perceived to be of lower quality.

In addition, the results of this chapter indicate that the Mapstone *et al.* (1995) data for back reef locations can be used to predict survey responses for coral, diversity of fish species and overall quality (Table 6.6). This relationship is especially useful for management agencies in areas where scientific monitoring regularly occurs and levels of use are currently low owing to their remoteness (e.g. Northern reefs in the Cairns Sector, Far Northern Section of the GBRMP, etc). Knowing which sites could potentially be of high quality to reef visitors if accessibility were to increase would allow managers to plan in advance for appropriate levels of protection.

6.4.2 Using local knowledge for rapid assessment of reef resources

Local knowledge can play an important role in the management and monitoring of marine protected areas (Johannes *et al.* 2000, Evans and Brichenough 2001). Involving local stakeholders in the ongoing assessment of a marine protected area will most likely result in a more transparent and supported decision-making process concerning use allocation. Active participation in management leads to a well developed sense of ownership and knowledge of the local environment (Evans and Birchenough 2001). Agrawal (2000) found that local residents are far more likely than visitors to have the longer term horizons that are necessary for adaptive management of marine protected areas. The involvement of local users in research can assist low cost data collection and enforcement and has the potential both to generate far better information for management and to help extend the time horizon over which managers make decisions (Agrawal 2000). Stakeholder participation should be an integral part of conservation management and should be used in the development of management strategies for all marine protected areas.

Selection of relevant indicators helps to focus the process of collecting information on the condition of reef resources from regular reef users. The results of this chapter suggest that the perception of coral, diversity of fish species and overall quality can be used as indicators of the ecological conditions of a site. In the absence of adequate scientific information, it may be possible to extrapolate from these variables to identify locations of high priority for management action and further scientific monitoring. In addition, the combination of local knowledge and scientific information would provide the management authority with a broader information base to determine the effectiveness of the Authority in achieving the primary goal of protecting the coral reef environment.

6.4.3 Implications for GBRMP and MPAs

Feelings of ownership of the environment can be promoted by encouraging people to participate in projects that are guided by experienced scientists (Evans and Birchenough 2001). These projects generate valuable data, which means that the community actually makes important contributions to environmental knowledge and the management decision-making process. Such an approach has been successful in surveys of waders and wildfowl in Great Britain (Prater 1981), bird surveys in England (Stowe 1982), coral reef surveys in Singapore (Chou 1994) and Belize (Mumby *et al.* 1997), and North Sea Pollution Studies (Evans *et al.* 2000). This approach has also been successfully used in Queensland with community volunteers and programs such as Seagrass Watch, COTSWATCH and Eye on the Reef. Seagrass Watch, for example, is a community-based monitoring program developed by Queensland's Department of Primary Industries and Fisheries (QDPI&F) in conjunction with CRC Reef, Queensland Parks and Wildlife Service and community groups. Seagrass-Watch volunteers collect data about the condition and trend of near-shore seagrasses throughout Queensland and provide an early warning of major changes in seagrass abundance, distribution and species composition.

In the Cairns Sector of the Great Barrier Reef Marine Park, continued collection of data on regular reef users' perceptions of the variables “coral”, “fish diversity” and “overall quality” would assist in the development of plans of management, zoning plans, policy and other management instruments at the GBRMPA. Following the development of plans or policy, evaluation of the effectiveness of the management outcomes would benefit from detailed monitoring of these indicators.

In addition, this information could feed directly into much broader programs such as Marine BioRap. Marine BioRap is a methodology and set of tools for identifying and assessing priority areas of marine biodiversity (Ward *et al.* 1998). It is currently being applied on the East Coast of Australia and in several overseas countries. Local reef users could provide information on their perception of the quality of reef sites to help identify priority sites for conservation management and assist in a continuous review and improvement of management measures. This program could be initiated by asking all permit holders and other regular reef users to submit assessments of their perception of the variables “coral cover”, diversity of fish species and overall quality of their most frequented sites on a regular basis.

On the other hand, results from ongoing scientific monitoring programs in the GBRMP could be used to identify potential high quality reef sites that may require a range of management settings to control for current and future use. Scientific information could also be used by the various stakeholder groups to highlight areas of high quality for their type of reef use.

6.5 Conclusion

Comparisons between the quality variables "coral cover" and "diversity of fish species" obtained from my survey of regular reef users (Chapter 6) and the monitoring data collected by AIMS and Mapstone *et al.* (1995) suggest that regular reef users were able to detect differences in the quality of reef locations across the entire Cairns Sector of the GBRMP. Higher quality sites had more hard coral, less soft coral and fish species commonly associated with branching corals in back reef locations.

In addition, the results of this chapter suggest that scientific information can be used to predict areas that are perceived to be of high quality by marine park users. This finding is potentially especially useful for the identification of sites that will be perceived by users as high quality in areas which are not already accessible but may become so in the future.

In the next chapter (Chapter 7) I explore the relationship between regular reef users' perception variables, use of the Marine Park, and management of the area. On the basis of this exploration I make recommendations on the spatial allocation of use in the area.

Chapter 7. The allocation of resource use in the Cairns Sector of the Great Barrier Reef Marine Park.

This chapter examines the relationships between the social and biophysical values examined in Chapters 4 and 5 and the management strategies adopted in the Cairns Sector of the Great Barrier Reef Marine Park. Understanding the variables that influence perceptions of reef quality and where these values are rated highly can assist managers to develop zoning that accommodates a wide range of opportunities for human use. Information from the survey of regular reef users (Chapter 5), data from biological monitoring programs (Chapters 4 and 6) and monitoring of actual levels of use (mainly tourism) (Chapter 4) were used to assess the management settings permitting different levels of use in the Cairns Area Plan of Management.

7.1 Introduction:

The objectives for the management of the Great Barrier Reef Marine Park (GBRMP) are designed to achieve a balance between conservation and sustainable use with an overall goal of providing for “protection, wise use, understanding and enjoyment of the Great Barrier Reef World Heritage Area in perpetuity" (see Chapter 1). In order to allow for reasonable use [1] of the marine park, it is important for managers to consider the types and

[1] **Reasonable use:** Reasonable use can be defined as human activity which can take place within a managed area without violating management principles. A reasonable use may be subject to controls but will not be totally excluded from the managed area. Uses are usually regarded as reasonable if they occur at a level that can be considered ecologically and economically sustainable.

levels of use and the values they wish to maintain in the area. This approach requires an understanding of the how people perceive the resources they use and what conditions in the environment influence their choice of reef site (Shafer *et al.* 1998).

As explained in Chapter 1, the Cairns Sector of the Great Barrier Reef Marine Park extends from Dunk Island in the south to just north of Lizard Island (Figure 1.1). The first zoning plan for the section was completed by November 1983 and the second was completed by November 1992.

This Section has the highest concentration of human use in the entire GBRMP, including some of the highest levels of tourism use (both large and small operations), scientific research, traditional hunting, and commercial and recreational fishing. In particular, growth in tourism and recreational use occurred so rapidly between 1985 and 1995 that there was widespread concern among managers and many users that current and future levels of human activities may no longer be compatible with the objective of ecological sustainability. In response, the GBRMPA developed the Cairns Area Plan of Management (the Plan) to address planning issues in that subsection of the Cairns Sector where most use was concentrated. This area included the reefs and islands off Port Douglas and Cairns, the outer shelf Ribbon Reefs to the north and the Frankland Islands in the south. The Plan was released in 1998 and came into force in the following year (GBRMPA 1998). The Plan was designed to provide a detailed regulatory framework within the broader-scale zoning plans (Kenchington *et al.* 2003).

The three main objectives of the Plan were to:

1. Maintain natural conservation values to aid in the protection and recovery of threatened species and ecological communities, by:

    - maintaining coral reefs and associated biota
    - maintaining populations of *Dugong dugon*, sea turtles and cetaceans
    - maintaining sea bird habitats.

2. Maintain or enhance cultural values by:

    - maintaining locations of cultural and heritage significance to Indigenous and non Indigenous peoples
    - maintaining traditional subsistence activities.

3. Maintain or enhance use values by:

    - managing human activities according to the principles of ecologically sustainable use
    - reducing conflict among different types of use
    - limiting damage to the natural environment from human activities
    - maintaining scenic integrity and quality of reefs
    - providing for a wide range of recreational activities (GBRMPA 1998, Kenchington *et al.* 2003).

The Plan regulated levels of access by designating different management settings for low, moderate or intensive use (GBRMPA 1998). These limits were developed to reduce conflict among users, while still providing for a range of opportunities for different activities across the planning area. Settings were used to determine the number of moorings and pontoons allowed at different reefs, to set size limits on boats according to the number of people they carry and generally to regulate the numbers of people and types of activities permitted in different areas.

The settings and group size limits laid down were as follows:

- Low Use: 15 people or less per vessel
- Moderate Use: 16 to 60 people per vessel
- Intensive Use: no limit

Research for this thesis was conducted at the same time as the GBRMPA developed the Plan. It was hoped that this research would provide an independent assessment of the effectiveness of the settings (GBRMPA Planning Staff pers. comm. 1997). This chapter therefore compares the settings laid down in the Plan with the results of my survey of reef users (Chapter 5), data from scientific monitoring programs (Chapter 6), data on threatened species (Chapter 4), and current levels of tourism use (Chapter 4). I use this comparison to evaluate the effectiveness of the settings at meeting the Plan's overall goal of "reef conservation" and the three main objectives provided above.

7.2 Methods

7.2.1 Management settings and perceived resource value in the Cairns Planning Area

The GBRMP Management settings for levels of use for reefs and islands in the planning area aimed to manage the rapid growth in use (mainly tourism and recreational use) in the Cairns Planning Area to "…reduce conflict and provide now and into the future for a range of opportunities consistent with nature conservation, scientific, cultural and World Heritage values" (GBRMPA 1998).

To determine whether these settings were likely to protect the quality of the coral reef environment, minimise conflict among users, or help ensure that visitor experiences were not devalued, management settings were compared with the results of the survey of regular reef users. Details of the survey and results are provided in Chapter 5. The comparisons reported in this chapter address the following questions:

- is there a relationship between management settings and the primary activities of respondents to the survey?
- is there a relationship between management settings and how respondents rated reef quality for a range of values?
- is there a relationship between management settings and the perceived frequency of damage and perceived levels of crowding?

A subset of 859 survey responses was used in these analyses, as not all reefs in the Cairns Sector were included in the management plan. There were 454 responses for reefs in the Low Use setting, 235 responses in the Moderate Use setting and 169 in the Intensive Use setting. The number of responses per reef ranged from 3 to 55, with a mean of 11 responses per reef. Reefs with less than 10 responses were not used in the statistical analyses in this chapter.

7.2.2 Analysis

Correspondence analysis was used to examine the relationships between the proposed management settings and the main activity of the respondents (www.spss.com).

Multivariate analysis of variance (MANOVA) was used to test whether the mean scores for reef quality and reef damage were statistically different among management settings. The mean values averaged across individual survey responses for each reef were used as the response variables in the analyses with settings as a fixed factor.

Multivariate relationships among variables and management settings were displayed using a canonical discriminate analysis (CDA). The analysis attempts to display as much variation as possible among centroids (or multivariate means) for each management setting within a reduced space. The CDA allowed me to view the dominant relationships among variables and site means in a reduced space (the 2-3 axes that separate the sites maximally) rather than attempting to visualise 15 dimensions (i.e. variables) simultaneously. The method displayed the relationships between the "quality" and "damage" variables from the survey and the two canonical variates (CV1 and CV2) and the centroid for the management setting.

Chi-Square analyses were also used to test whether the number of reefs in: (1) quality and (2) damage classes (e.g. very poor, poor, average, above average, outstanding, etc) were independent of the level of management setting. Cells with expected values of less than five were pooled.

7.2.3 Evaluating Management settings using multiple criteria decision trees

Making a decision on how to limit use appropriately at a range of reef locations requires an understanding of the impact of different planning options on the natural and social environment. Making this sort of decision involves considering a number of options or alternatives that can best satisfy an overall objective or goal. Using the Simple Multi-

Attribute Rating Technique (SMART) (Edwards 1977), I explored the decision making process of assigning different management settings to reefs in the Cairns Sector based on the relative weights of the biological and social data sets.

The technique allows for alternative weighting of different criteria, representation of uncertainty and sensitivity analyses of the relative influence of criteria and provides the ability to combine and evaluate alternative models (Breen *et al.* 2004). This technique is commonly used in other disciplines such as marketing and management (Edwards 1977), environmental impact assessment, fisheries (Mardle and Pascoe 1999) and in the selection of reserve networks (Bakus 1982, Edwards 1977, Fernandes 1996, Rothley 1999).

In the present assessment, multiple criteria analysis was used to evaluate reefs in the Cairns Sector and to review the effectiveness of the settings in the Plan in meeting the management goal and criteria. The Simple Multi-Attribute Rating Technique (SMART) available in 'Criterium Decision Plus' (CDP) (InfoHarvest 2000) was used to model the relative performance of settings in meeting overall goals of the Plan as a function of individual criteria derived directly from the Plan's objectives (GBRMPA 1998).

The overall conservation goal was derived from the Plan's objective to "provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef World Heritage Area in perpetuity". I identified general criteria (and more specific sub-criteria) that I considered important in meeting these objectives from the values, issues and strategies sections in the Plan (GBRMPA 1998). I grouped these criteria into the main categories of: ECOLOGY - Maintenance of natural conservation values; CULTURAL - Maintenance or enhancement of cultural values; and USE - Maintenance or enhancement of human activities and uses. Sub-criteria and a range of associated datasets (Table 7.1) were used to assess different reefs according to how well they satisfied the overall goal.

I assigned relative weights (based in my interpretation of the priorities in the Plan) to the criteria and sub-criteria, allowing for the scoring of the each reef based on these weights. The weighting was performed in sets by selecting a criterion (e.g. ECOLOGY; CULTURAL; or USE) and rating all of its sub-criteria with respect to each other. The alternative reef locations were rated against the lowest criterion in each group (e.g. actual datasets). Data from each of the datasets (see Table 7.1) were averaged for each reef before the analysis. The basic algorithm in Multicriteria Decision Analysis is to multiply how each reef scores against each lowest criterion by the relative importance of that criterion. The relative weights of the lowest criteria (the different biological and social data sets shown in Table 7.1) were interpreted from the Plan. Weights were determined by weighting each criterion and subsequent sub-criteria relative to the others in order beneath the overall goal. CDP software multiplied these preferences down the structure of the hierarchy, so that all the criteria against which the reefs were rated acquired a relative importance with respect to all other lowest criteria.

While there are many other weighting techniques available (e.g. direct tradeoffs, scales, etc), the Hierarchy Weight technique available in CDP provides a qualitative and intuitive approach by directly weighing the importance of one criterion against another using terms such as critical, very important, important and not important. In this model, I rated Ecological Criteria as “critical”, because these criteria were identified as the most important values for the area in the Plan and have the highest priority in reef conservation for the entire GBRMP. I rated Cultural Criteria as “very important”, because these criteria were identified in the Plan as the second most important values of the area. I then rated Use Criteria as “important”, because they were identified as the third most important values in the Plan and play an important role in the management of the area.

Prior to analysis, all datasets (see Table 7.1) were normalised in CDP by converting the data to a common internal scale between 0 and 1. For each dataset, I chose one of three possible value functions available within the CDP software for rating the data: a linear function, an exponential function or a piecewise linear function. A positive or negative slope was determined for each data variable (lowest criterion) in order to identify which end of the scale should result in a higher decision score.

While the choice of criteria, weighting and finally the value function for each dataset was based on my interpretation of the plan and understanding of the relationships between datasets (based on analyses in Chapter 6), the process of applying CDP systematically calculates alternative decision scores for each reef. By varying any of the weightings and/or value functions it is possible to model a series of alternative outcomes and thus explore a range of alternative management scenarios.

Following the application of CDP, a univariate ANOVA with *post hoc* multiple comparisons was conducted to determine whether decision scores for each reef and Management Settings were independent. I used this process to provide insight into the decision process used by managers to determine which reefs received which setting.

MANAGEMENT OBJECTIVES and subcriteria (*in order of importance from my interpretation of the Plan*) Sub criteria identified by bullets.	**Relative importance of main objective** (Priority Σ=100%)	**Available datasets for each subcriteria**	**Relative importance of each dataset** (Priority Σ=100%))
ECOLOGY – Maintain or enhance natural conservation values by helping protect and recover of threatened species and ecological communities.	Critical (44.5%)		(Σ=44.5%)
• Maintain coral reefs and associated biota		-Mapstone *et al.* 1995 -AIMS database; -Sweatman *et al.* 1998 -Perception of reef quality, Chapter 5	Critical (8.9%)
• Maintain populations of *Dugong dugon*		-Marsh *et al.* 1994 -Anecdotal sightings database,GBRMPA 1998 -Perception of marine mammals, Chapter 5	Critical (8.9%)
• Maintain populations of sea turtles		-Marsh *et al.* 1994 -Anecdotal sightings database,GBRMPA 1998 -Perception of marine mammals, Chapter 5	Critical (8.9%)
• Maintain populations of cetaceans		-Marsh *et al.* 1994 -Anecdotal sightings database,GBRMPA 1998 -Perception of marine mammals, Chapter 5	Critical (8.9%)
• Maintain seabird habitats		-Seabird nesting and roosting locations (GBRMPA 1998)	Critical (8.9%)
CULTURAL - Maintain or enhance cultural values	Very important (33.3%)		(Σ=33.3%)
• Maintain locations of cultural and heritage significance to Indigenous and non-Indigenous people, maintain traditional subsistence activities		-Locations of cultural and heritage significance (GBRMPA 1998), -Symth 1990 and 1991	Very important (33.3%)
USE - Maintain or enhance use values	Important (22.2%)		(Σ=22.2%)
• Allow for ecologically sustainable multiple use while maintaining reef access		-Perception of access for reef use, Chapter 5	Important (4.44%)
• Minimise conflicts with other uses or other values of the area		-Perception of social condition variables, Chapter 5	Important (4.44%)
• Limit damage to the natural environment from human activities incl. anchoring, boat strikes, fishing, habitat degradation, traditional hunting, noisy and intrusive activities.		-Perception of damage from human use, Chapter 5	Important (4.44%)
• Maintain scenic integrity and quality experiences		-Perception of scenic beauty, overall reef quality, wilderness, Chapter 5	Important (4.44%)
• Provide for a range of recreational activities		-Areas of concentrated recreational use, GBRMPA 1998	Important (4.44%)

Table 7.1: Available biological and social datasets and their relative importance as defined by the management objectives in the Plan. The weighting for the three main objectives (ECOLOGY, CULTURE and USE) sum to 100%. The sub criteria within each objective are weighted according to their contribution to the overall weight of its objective.

7.2.4 Limitations of these analyses

As discussed in Chapters 5 and 6, the survey of regular reef users should represent a reasonable estimate of the preferences shown by the reef users in the Cairns Sector of the GBRMP. However, the probability of all types of reef users receiving and responding to this survey is unknown and thus this sample may not be representative of the full range of users. In addition, the survey data are not independent as each participant provided three responses, one for each reef site they frequent. Several reef locations were dominated by one or two user groups. The probability of spatial confounding with type of use is high and therefore, analyses of separate user groups were not conducted.

Comparisons between survey data (Chapter 5), biological monitoring data (Chapter 4 and 6), endangered species data (Chapter 4) and EMC data (Chapter 4) are meant to generate hypotheses and provide general indications of patterns that may exist. Information on the actual levels of use from the EMC Database is limited in that it provides data on tourism use only. There is no readily available or reliable information on actual levels of use for all use types at the management authority (Planning Staff, GBRMPA 2002).

7.3 Results

7.3.1 Management settings and perceived resource value in the Cairns Planning Area

7.3.1.1 Is there a relationship between the management settings and the primary activity of respondents to the survey?

Respondents to the survey were asked to describe the main activity in which they participated while at the reef. The percentage of respondents for each activity is provided in Chapter 5, Table 5.1.

The types of use indicated by the survey respondents differed among the proposed management settings. A correspondence analysis between the management settings and the main activity of the respondents to the survey helps to illustrate these patterns of use (Figure 7.1).

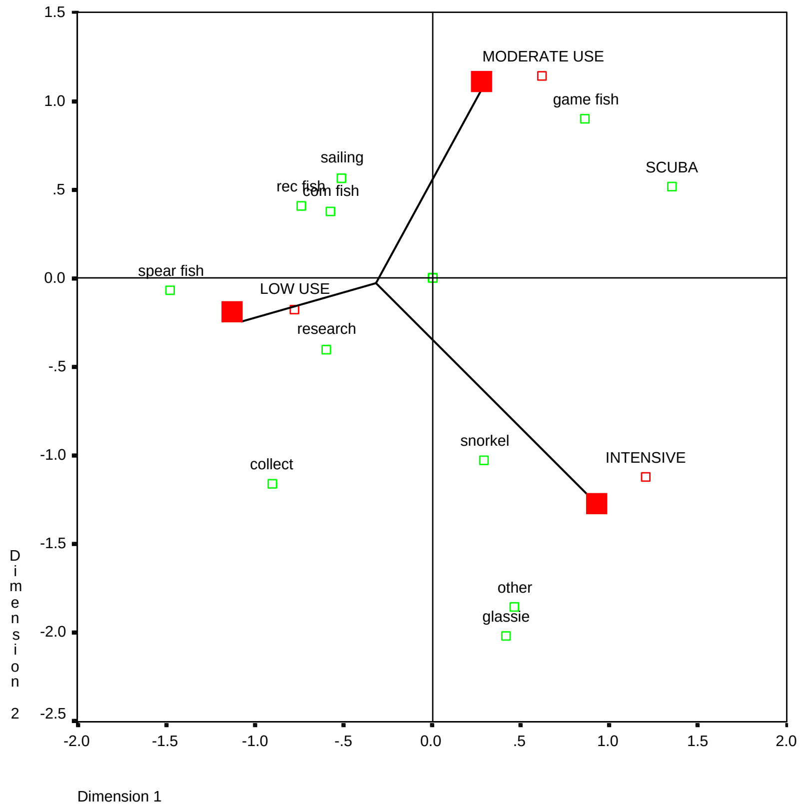

Figure 7.1: Correspondence analysis of primary activity by management setting from the Plan. Correspondence analysis describes the relationships between two variables (primary activity displayed as green open squares and management setting displayed as red filled squares) in a low-dimensional space, while simultaneously describing the relationships between the categories for each variable. For each activity type (note: activity name is shortened for displaying on the graph) and management setting, the distances between points in the plot reflects the relationships between these variables, with similar activities and management settings plotted close to each other.

Collectors, commercial fishers, recreational fishers, sailors and spear fishers primarily chose reefs in the Low Use management setting. Overall, most of the responses were from this group (325 responses). Forty one percent of Game Fishers and SCUBA divers described reefs in the Moderate Use setting and were the second largest groups of respondents (225 responses). Snorkellers and “others” mainly described reefs that were in the Intensive Use management setting. The "other" category included glass bottom boat tours, reef walking, photography, swimming and relaxing.

7.3.1.2 Is there a relationship between the proposed management settings and the variables describing reef quality?

As detailed in Chapter 5, survey respondents were asked to assess the perceived quality of sites they visited according to 17 different variables. To determine whether there were differences among the proposed management settings in perceived quality, I conducted a multivariate analysis of variance over all variables (Table 7.2). The MANOVA results provide an overall test of "no differences" for any of the variables.

Statistic	Value	F	df (hypothesis)	df (error)	P
Wilks' Lambda	0.353259	1.55457	36	82	0.05
Pillai's Trace	0.791309	1.52759	36	84	0.05
Hotelling-Lawley Trace	1.421542	1.57949	36	80	0.04
Roy's Greatest Root	1.020538	2.38126	18	42	0.01

Table 7.2: Multivariate analysis of variance (MANOVA) results comparing management settings with ratings for perceived quality of reef sites in the Cairns Sector of the Great Barrier Reef Marine Park.

As the results of the MANOVA were significant, I then conducted a Canonical Discriminate Analysis to provide a visual interpretation of which variables were most influential in separating sites into different settings.

The Canonical Discriminate Analysis explains as much variation as possible among multivariate means or centroids (for each management setting and quality variable combination) in a reduced space. Figure 7.2 displays the plots for the first two axes for the quality variables. The figure also shows the scores for centroids at each management setting and quality variable combination. Adjacent centroids have similar responses to the quality variables while those furthest apart tend to have greater differences. Figure 7.3 shows the correlations between the quality variables and two canonical variates.

Reefs in the three management settings clearly separated out on the first two canonical variates. Low use reefs included most of the islands in the planning area and several inshore and midshelf locations (Figure 7.2). These reefs tend to be rated higher for the variables ease of navigation, convenience to port, shelter from northerly winds, presence of sea turtles and scenic beauty (Figure 7.3). Moderate use reefs included most of the Ribbon Reefs and several offshore and midshelf locations throughout the planning area (Figure 7.2). These reefs were more similar in their ratings for mild currents, wilderness, underwater topography, convenience to other reef sites, coral cover and overall quality.

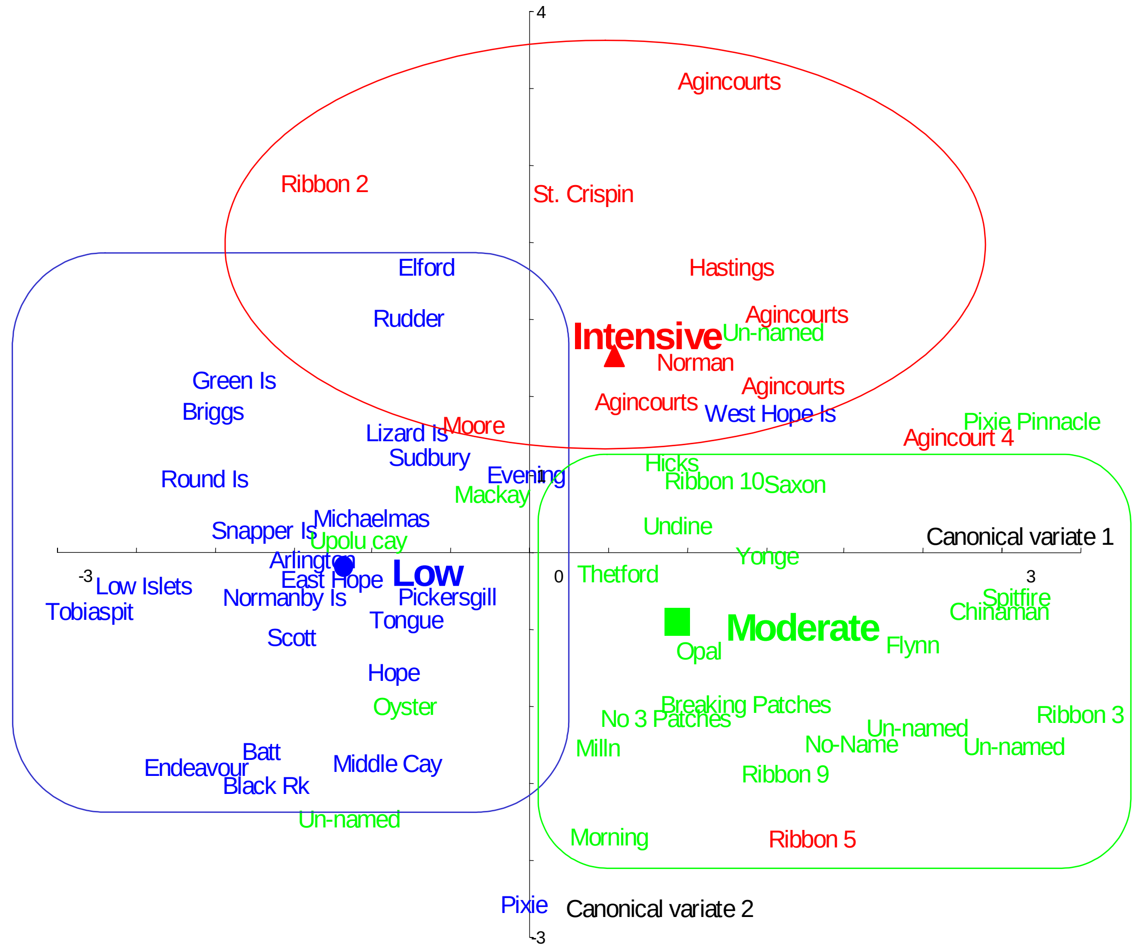

Figure 7.2. Canonical discriminant scores for mean social "quality" variables labelled by reef and coloured by the management "Setting" assigned in the Plan. Centroids for each management setting (Low, Moderate and Intensive) indicated by large coloured symbols. Data for individual survey responses were averaged for each reef before analysis. The locations of all reefs are shown in Appendix 1.

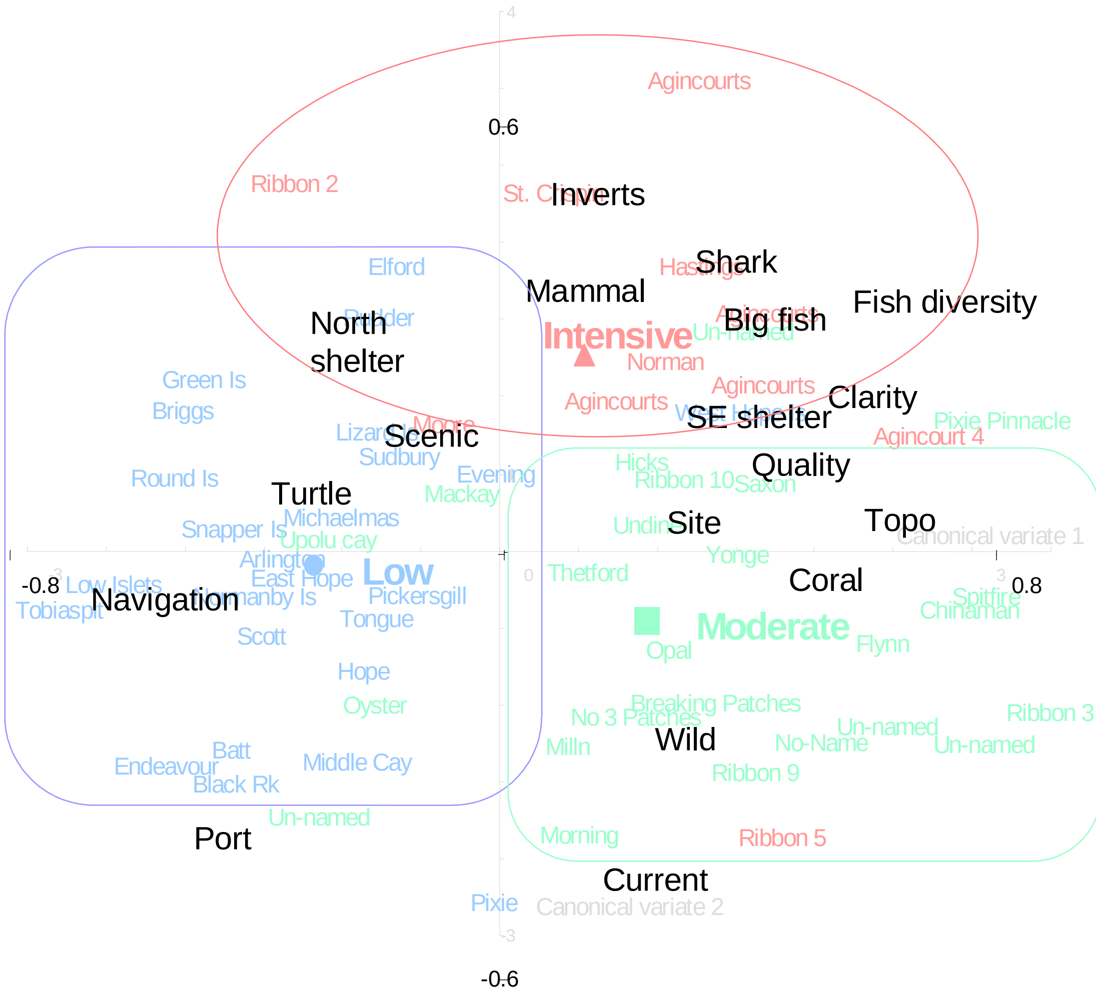

Figure 7.3. Canonical structure showing correlations between the social “quality variables measured and the first two canonical variates superimposed on Figure 7.2. The locations of all reefs are shown in Appendix 1.

While there were only a handful of intensive use reefs assessed in this analysis, they were similar over many variables (Figure 7.2 and Figure 7.3). These reefs rated highly for diversity of fish species, presence of sharks and rays, presence of big fish, water clarity, shelter from SE winds, and the presence of marine mammals. Most of these sites were well established offshore pontoon-based tourism operations. Ribbon Reef Number 5 did not separate out with the other intensive use locations and was more similar to the moderate use locations, including the other Ribbon Reefs in the Cairns Planning Area. It is not currently a major tourism location (GBRMPA planning staff, pers. comm. 1997).

7.3.1.3 Is there a relationship between management settings, frequency of damage and perceived levels of crowding at reef sites?

Survey respondents were asked to assess the frequency of damage perceived to be from natural and human impact at site of sites they regularly visited. To determine whether there were differences among the proposed management settings in perceived levels of damage, I conducted a multivariate analysis of variance over all variables (Table 7.3).

As the results of the MANOVA were significant, I then conducted a Canonical Discriminate Analysis to provide a visual interpretation of which variables were most influential in separating sites into different settings.

Statistic	Value	F	df (hypothesis)	df (error)	Pr > F
Wilks' Lambda	0.45	2.4	24	116	0.001*
Pillai's Trace	0.63	2.3	24	118	0.002*
Hotelling-Lawley Trace	1.03	2.5	24	114	0.000*
Roy's Greatest Root	0.81	4.0	12	59	0.000*

Table7.3: Multivariate analysis of variance (MANOVA) results comparing management settings (low, moderate and intensive) with ratings for “perceived damage" for reef sites in the Cairns Sector of the Great Barrier Reef Marine Park.

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Canonical Discriminant scores for mean "damage" variables from the first two axes are shown in Figure 7.4. The figure also shows the centroids for each management setting and damage variable combination. Adjacent centroids have similar responses to the damage variables while those furthest apart tend to have greater differences. Figure 7.5 shows the correlations between the damage variables and two canonical variates.

The results of the Canonical Discriminant analysis illustrate the difference between reefs in the three management settings and the perceived levels of damage from the natural and human impact variables. The reefs within each of the different management setting grouped with other reefs in the same setting (Figure 7.4). The Low Use reefs were rated higher for the frequency of damage from the variables spearfishing, overfishing, pollution, Indigenous hunting and cyclones (Figure 7.5). The moderate use reefs were locations where more damage was observed from SCUBA diving, snorkelling, anchoring and algae (Figure 7.5). The frequency of damage to reef sites from vessel groundings, crowding and crown of thorns starfish was more apparent at the intensive use locations (Figure 7.5).

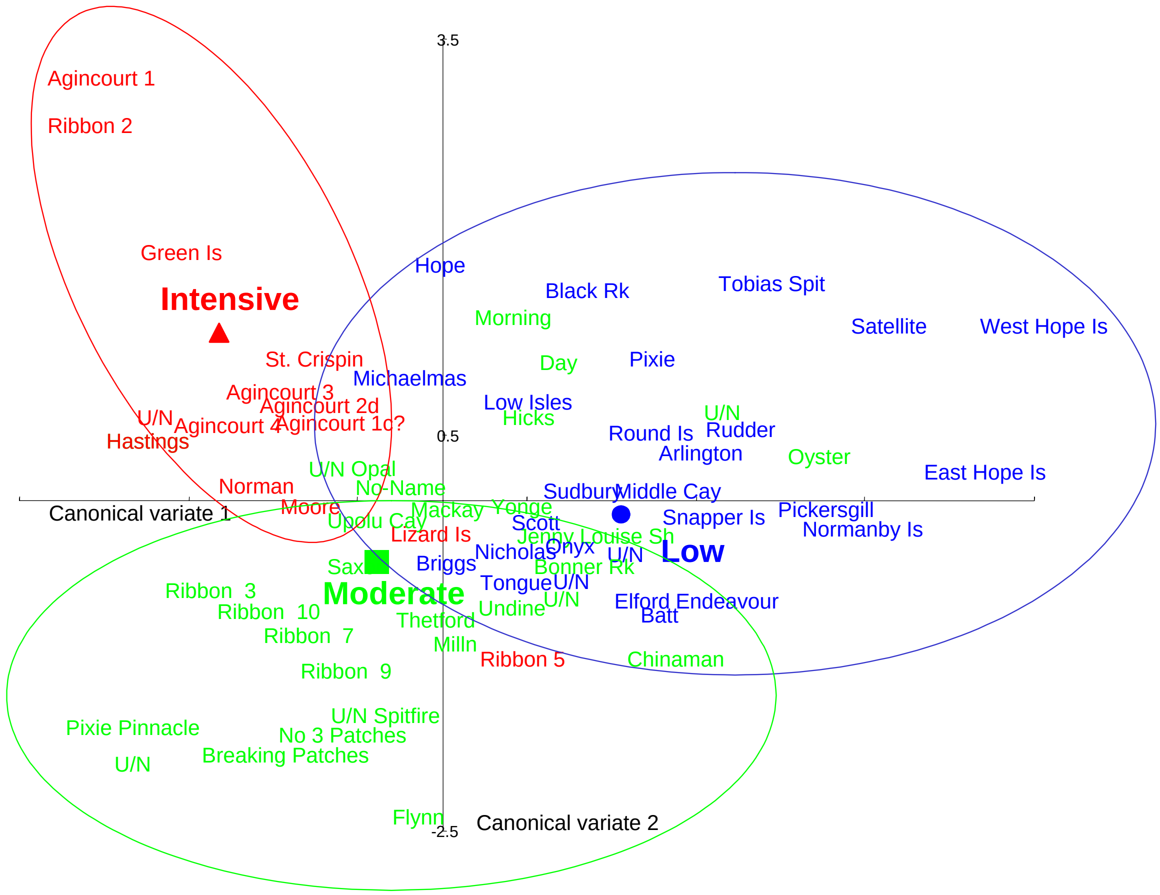

Figure 7.4 Canonical descriminant scores for mean "damage" variables from the social survey labelled by reef and coloured by the management "Setting" assigned in the Plan. Centroids for each management setting (Low, Moderate and Intensive) indicated by large coloured symbols. Data for individual survey responses were averaged for each reef before analysis. The locations of all reefs are shown in Appendix 1.

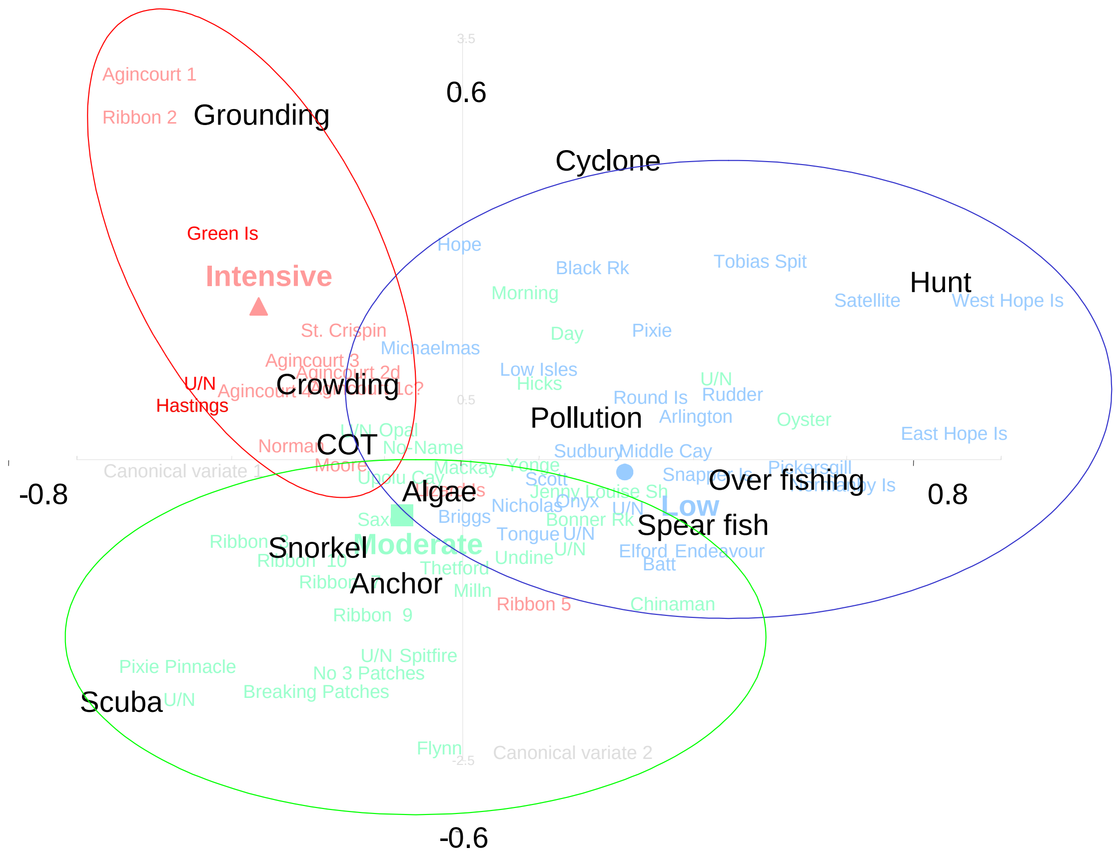

Figure 7.5 Canonical structure showing correlations between the "damage" variables from the survey and the two canonical variates superimposed on Figure 7.4. The locations of all reefs are shown in Appendix 1.

To determine whether there were differences among the proposed management settings and perceived levels of crowding, I conducted a chi-squared analysis of pooled categories (groups with values of less than five were pooled) for each variable (Table 7.4). Reefs with different management settings received significantly different proportions of ratings (on a scale ranging from never to frequently) only for the crowding variables “acceptable number of vessels”, “acceptable number of people” and “preferred distance between anchoring sites” (Table 7.4). The presence of more people and vessels is more acceptable at Intensive Use locations than at Low Use reefs. The preferred distance between anchorages is smaller at Intensive and Moderate Use locations than at Low Use locations. Other crowding variables were not significantly related to management settings.

Crowding variables	Chi-square	df	N	significance
Acceptable number of people at reef sites	23.189	4	469	0.000*
Acceptable number of vessels at reef sites	43.287	14	575	0.000*
Frequency of seeing others at reef site	17.529	10	862	0.063
Prefer to see others at reef site	8.692	10	762	0.562
Anchor distance	15.249	10	763	0.123
Preferred anchor distance to other reef users	23.544	10	859	0.009*

* indicates a significant result with $p<0.05$

Table 7.4: Pearson's Chi-Square analyses comparing management settings with ratings for perceived levels of crowding at reef sites in the Cairns Sector of the Great Barrier Reef Marine Park.

7.3.2 Management settings and biological monitoring data in the Cairns Planning Area

To determine whether there were differences among reefs in the three management settings in the abundance of various reef biota, I conducted a multivariate analysis of variance over biological (Mapstone *et al.* 1995 and AIMS monitoring data) and management setting variables (Table 7.5) between the management settings and the monitoring data variables collected by AIMS and Mapstone *et al.* (1995). The abundance of reef biota for either monitoring data set (Table 7.5) was not significantly different for reefs with different management settings.

Statistic	Value	F	df (hypothesis)	df (error)	Pr > F
Wilks' Lambda	0.016	1.95	36	10	0.130
Pillai's Trace	1.607	1.37	36	12	0.289
Hotelling-Lawley Trace	23.295	2.59	36	8	0.079
Roy's Greatest Root	21.422	7.14	18	6	0.059

Table 7.5:Multivariate analysis of variance (MANOVA) results comparing management settings (low, moderate and intensive) with biological monitoring data for reefs in the Cairns Sector of the Great Barrier Reef Marine Park.

As there were no differences detected using these analyses, I did not further explore this combination of datasets using Canonical Descriminant Analysis.

7.3.3 Evaluating management settings using Multiple Criteria Decision trees

Using the Simple Multiattribute Rating Technique (SMART) (Edwards 1977), I was able to assess the management decisions to assign particular settings to specific reefs in the Plan based on the relative weights of the following biological and social data sets:

- AIMS monitoring database - Sweatman *et al.* (1998) (Chapter 7);
- Seabird nesting and roosting locations - GBRMPA (1998) (Chapter 5);
- Biological Monitoring data - Mapstone *et al.* (1995) (Chapter 7);
- Marine Mammals database - Marsh *et al.* (1994) (Chapter 5);
- Anecdotal sightings database - GBRMPA (1998) (Chapter 5);
- Survey of Regular Reef Users - Chapter 6;
- Areas of concentrated recreational use - GBRMPA (1998) (Chapter 5); and
- Locations of cultural and heritage significance - GBRMPA (1998) and Symth (1990 and 1991) (Chapter 5).

First I assigned relative weights to each dataset on the basis of the criteria laid down in the Plan (Table 7.1), in order to determine which reefs received the highest rating. The model shown in Figure 7.6 illustrates the goal of “reef conservation” as a function of ecological, cultural and use criteria. The quantitative model estimates the relative performance of reef locations in the Cairns Planning Area in meeting the overall goal of reef conservation as a function of the combined scores for many weighted criteria. The cumulative weights for each criterion and the decision score for each reef (calculated from data scores and their relative weights) are provided in Figures 7.6 and 7.7. The reefs with the highest decision scores were more closely aligned with the overall goal, while the reefs with the lower scores were less aligned with the overall goal. As the weighting was based on my interpretation of the priorities in the Plan, one could hypothesize that reefs with higher scores require more protection, while reefs with lower scores require less protection.

Most of the reefs with high decision scores (0.5 and above) were designated as Low Use reefs, but there are a few exceptions. Moore Reef (decision score = 0.588) and Hastings Reef (decision score = 0.540) were designated as Intensive Use locations, and Green Island (decision score = 0.570) was designated as a Moderate Use location. This anomaly was partially resolved by the Marine Park Authority in the Plan by splitting Moore and Hastings Reefs into two localities and designating Moderate Use on the half requiring more protection and Intensive Use on the other. Green Island was identified in the Plan as a “Sensitive Location” which limited the number of tourist operations that could visit it to 4 vessels on a given day (GBRMPA 2005b).

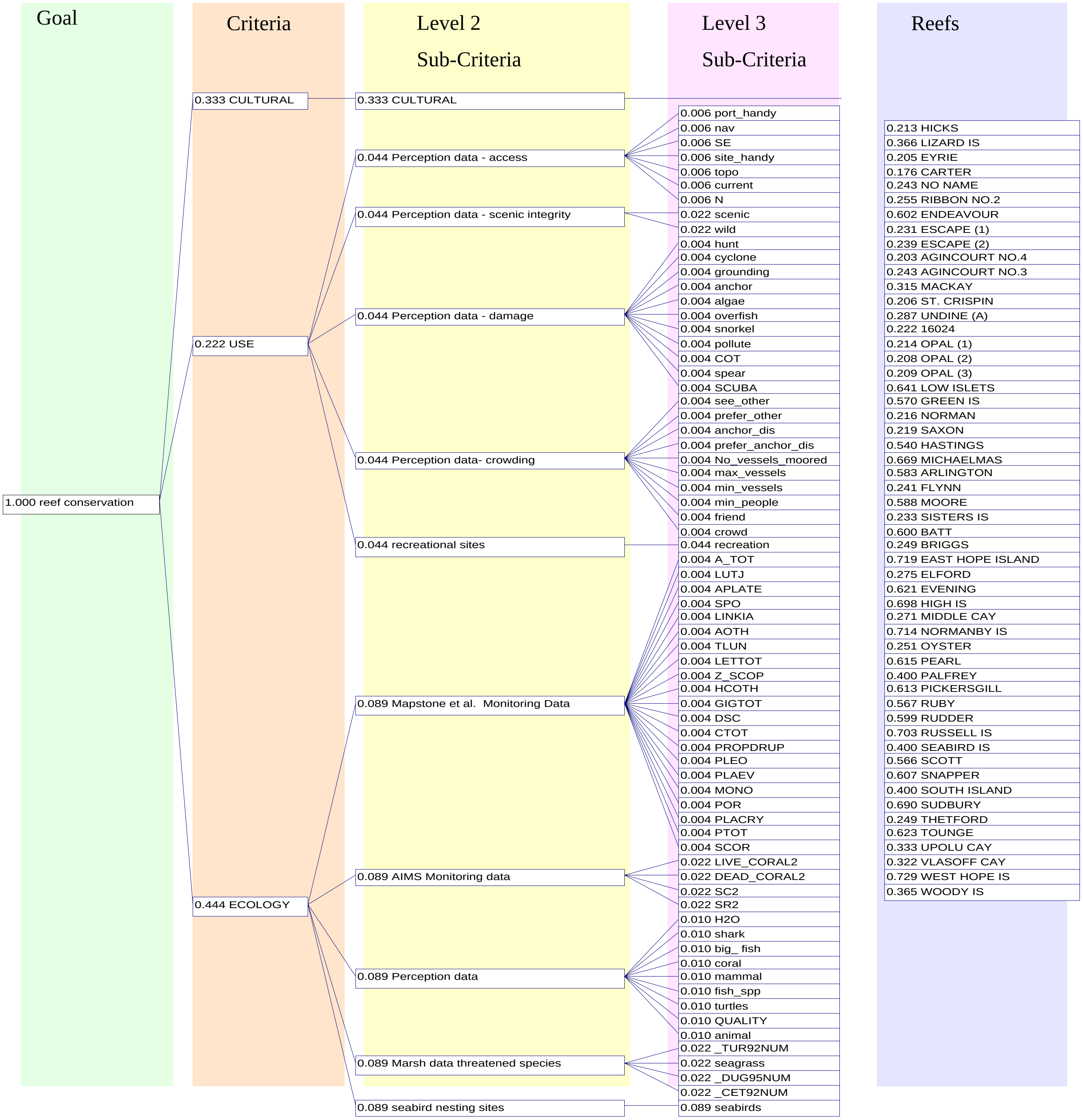

Figure 7.6: Multiple Criteria Decision model for the overall goal of reef conservation in the Cairns Planning Area. Values to the left of the criteria and sub-criteria are cumulative weights and values to the left of reefs are the decision scores calculated from the relative weights and data scores for those locations. The coloured background is used to clarify the different levels in the decision tree.

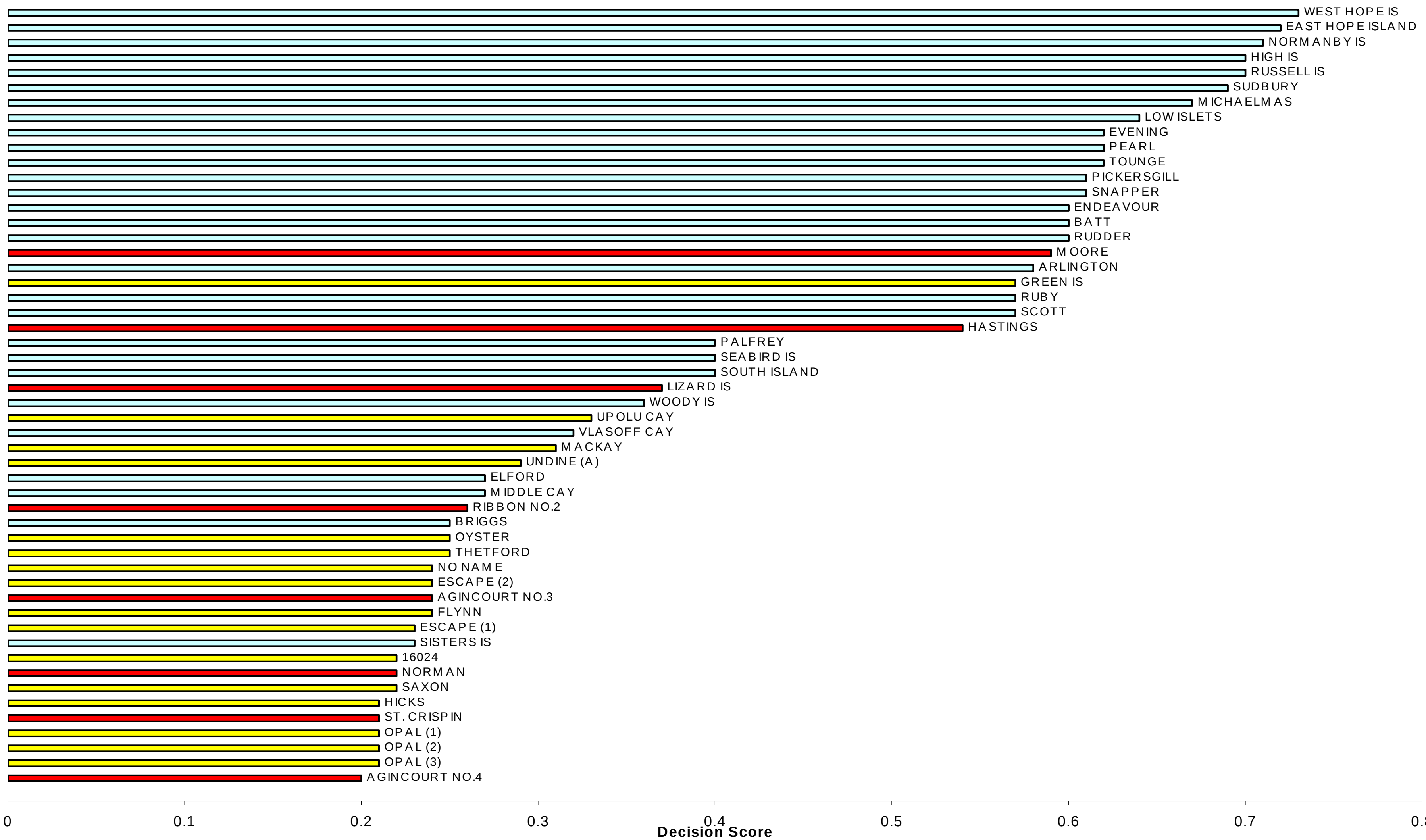

Figure 7.7: Graph of the decision scores for reefs in the Cairns Planning Area. The decision score for a reef was calculated as the sum of all ratings of the reef against the lowest criterion, weighted by the importance of that criterion to the decision. Those reefs with higher decision scores (e.g. West Hope Island, East Hope Island, etc.) are more aligned with higher priority criteria and may require more protection. The reefs with decision scores highlighted in blue have a Low Use setting, those in yellow have a Moderate Use setting while those in red have an Intensive Use setting.

Reefs with decision score of less than 0.50 were mainly designated Moderate Use (15 reefs) with some Low Use (9 reefs) and Intensive Use (6 reefs) interspersed. Lizard Island (decision score = 0.399) received an Intensive Use setting for two of its four localities; the other two localities received a Low Use setting. The Intensive Use area is associated with the use of the island by the resort and long range roving tourist operators.

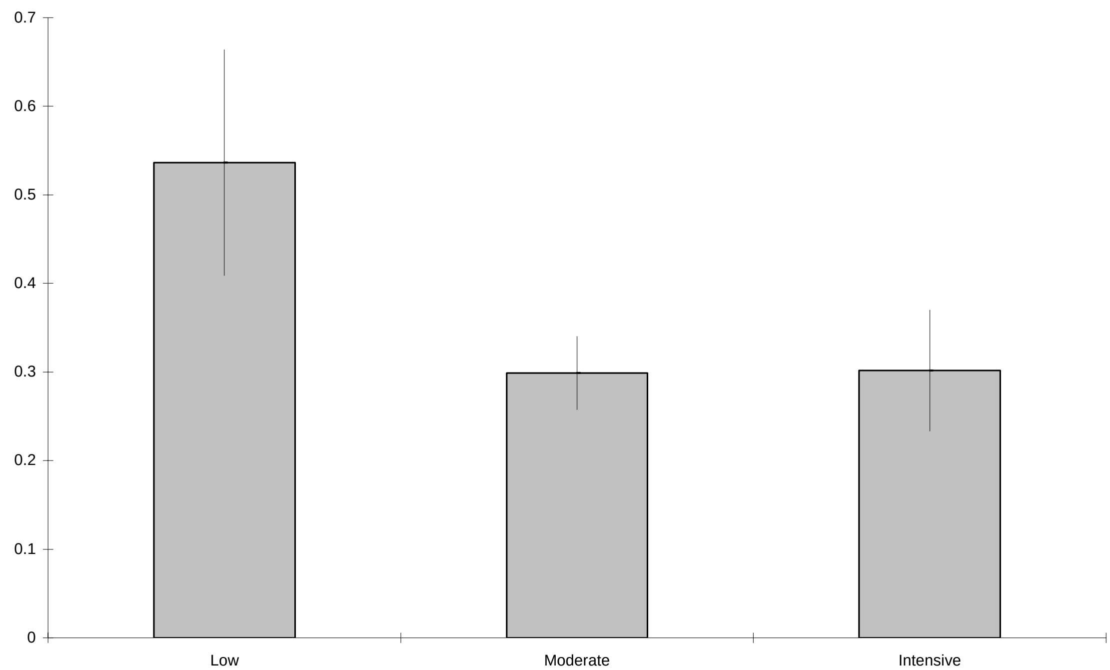

Figure 7.8: Mean Decision Score (± SD) for Cairns Planning Area reefs in each of the management settings (Low Use, Moderate Use and Intensive Use).

Figure 7.8 illustrates that reefs designated as Low Use had a higher mean decision score than either the Moderate or Intensive Use reefs. Results of a univariate ANOVA with *post hoc* multiple comparisons indicated that reefs with higher decision scores had low use settings and were more protected by the Plan than reefs in the moderate or intensive use setting (Tables 7.6 and 7.7).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.6728	2	0.3364	31.7772	0.0000
Intercept	4.8038	1	4.8038	453.7946	0.0000
Setting	0.6728	2	0.3364	31.7772	0.0000
Error	0.4869	46	0.0106		
Total	10.4283	49			
Corrected Total	1.1597	48			

Table 7.6: Univariate analysis of variance and multiple comparisons to test the difference between management settings and decision scores derived using the Simple Multiattribute Rating Technique. Analysis of Variance testing that there is no difference between settings and decision scores.
* Computed using alpha = 0.05 ** R Squared = 0.580 (Adjusted R Squared = 0.562)

(I) SETTING	(J) SETTING	Mean Difference (I-J)	Std. Error	Sig.
Intensive	low	-0.235*	0.046	0.000
	moderate	0.003	0.050	1.000
low	Intensive	0.235*	0.046	0.000
	moderate	0.238*	0.033	0.000
moderate	Intensive	-0.003	0.050	1.000
	low	-0.238*	0.033	0.000

*The mean difference is significant at the 0.05 level.

Table 7.7: Univariate analysis of variance and multiple comparisons to test the difference between management settings and decision scores derived using the Simple Multiattribute Rating Technique. Post Hoc Multiple Comparisons using the Bonferroni Test. Based on observed means.

7.4 Discussion

In this chapter I explore the relationship between the perception data provided in the survey of regular reef users (Chapter 5), biological monitoring data (Chapters 4 and 6) and the management settings provided in the Plan. The results of these analyses are separated into two sections. First, I explore the relationships between the management settings and the social and biological datasets. Then, using Multiple Criteria Decision trees, I assess the management settings in the Plan in terms of their ability to further the goal of reef conservation.

The main findings of this chapter suggest that the settings determined in the Plan should be an effective framework for capping levels of use and maintaining the existing quality of reef locations.

7.4.1 Management settings and perceived resource value in the Cairns Planning Area

7.4.1.1 Activities of Reef users and Management Settings

While the patterns of use in the Cairns Sector were partly dictated by existing zoning, permit and other management restrictions (Chapter 5), analyses of the relationship between management settings and activities of regular reef users suggest that the settings support existing use patterns and maintain the *status quo*. For example, low use settings were established at reefs frequented by recreational and commercial fishers, researchers and recreational boaters. These groups prefer less crowded reefs that are away from the high use tourism locations while still relatively close to Cairns (Chapter 5, Section 5.3.3.6).

Moderate use settings were established at reefs frequented by game fishers and SCUBA divers, while Intensive Use settings were designated at reefs frequented by large scale tourism operations where snorkelling and glass bottom boat tours were common. Intensive Use settings may have been deemed appropriate for these locations as larger numbers of people were more acceptable to regular reef users at sites that historically had high numbers of tourism visitors. In addition, maintaining existing patterns of reef use and access rights through the Plan potentially allowed for a more politically acceptable management process while limiting further growth and development of the area.

There were reefs that had high level of tourism and recreation use, but were identified in the Plan as sensitive locations and thus required additional protection. In these areas (including islands such as Low Island, Michaelmas Cay and Green Island) settings were used in conjunction with other management mechanisms to cut back or limit use.

7.4.1.2 Quality of Reefs and Management Settings

Perceived quality with regard to the diversity of fish species and the convenience and shelter variables: e.g. water clarity, convenience to port, ease of navigation and underwater topography (Chapter 5, Section 5.3.3) varied significantly for reefs with different management settings. Low use reefs were perceived to provide the most shelter and convenience as they were located close to shore and within easy travelling distance of a port (Figures 7.2 and 7.3). These reefs were predominantly frequented by small groups of recreational and commercial fishers, researchers and collectors (Figure 7.1), and thus the Low Use setting would not interfere with their types of use, group size and access to these locations. In addition, the existing pattern of small groups of people was perceived as being more acceptable at low use reefs than at moderate and intensive use location (Table 7.4).

The damage seen at Low Use locations related mainly to the types of users who frequented these sites. For instance, at Low Use reefs more damage was perceived to occur from spearfishing, overfishing and Indigenous hunting than from tourism related impacts. In addition, the Low Use reefs appeared to be more damaged from pollution (possibly related to river run off) and cyclones than the Moderate and Intensive Use reefs.

Moderate and Intensive Use locations, however, were rated higher for their ecological landscape variables (Chapter 5). While these locations were not as convenient and did not provide as much shelter, they provided much better conditions for viewing the diverse coral and fish assemblages on the reefs. These locations were more accessible to the larger tourism vessels which catered for larger group sizes. Larger groups and more vessels were perceived as more acceptable at Intensive Use locations. This result indicates that regular reef users may have experienced a product shift in these high use locations during the past decade (Chapter 5). Shafer *et al.* (1998) proposed that reef visitors with more experience may have "shifted" their perception regarding an acceptable number of people to better match the current social conditions on the reef. The results in this chapter also suggest that marine park managers may have also adapted to that shift in perception by designating these areas with higher use settings and thus maintaining the *status quo*.

Interestingly, when compared with biological monitoring data (Section 7.3.2), reefs with different management settings did not have different abundances of reef biota (Table 7.5).

This result implies that the management settings in the Plan maintained current levels of use and did not necessarily reflect diversity in abundance of reef biota at different locations.

Future research should investigate whether there is a relationship between the biological monitoring data and different management settings after the settings have been in place for several years. As an adaptive management process, it will be essential to test the effectiveness of management settings by determining whether or not settings have an effect on the reef biota at a local scale over a longer time frame.

7.4.2 Evaluating management settings using Multiple Criteria Decision trees

The GBRMP is an example of a large multiple-use ecosystem-based management system. The underlying ecology of the reef system defines the outer boundaries of the area of the marine park. The overall goal of the marine park is to provide for “protection, wise use, understanding and enjoyment of the Great Barrier Reef World Heritage Area in perpetuity" (see Chapter 1) within this boundary.

Management tools such as zoning and, on a more localised scale, settings, can be used to achieve this goal while accommodating a wide variety of user groups, assisting with dispute resolution between conflicting marine resource users and conserving the natural resource (Agardy 2000). Marine protected areas such as the GBRMP must cater for common property ownership of the coastal and marine habitats with wide ranging rights of access and use of the resources.

Management settings were developed by the GBRMPA for the Plan to manage the rapid growth in use in the Cairns Planning Area. The settings were intended to reduce conflict and provide for a range of opportunities and access rights consistent with nature conservation, scientific, cultural and world heritage values (GBRMPA 1998).

Development of specific objectives about what a protected area is to achieve is largely societal and should be done by the managers in consultation with stakeholders (Agardy 2000). The three main objectives of the Plan were to 1) maintain natural conservation values to aid in the protection and recovery of threatened species and ecological communities; 2) maintain or enhance cultural values; and 3) manage human activities according to the principles of ecologically sustainable use (GBRPMA 1998). These objectives were identified by planners in consultation with user groups and stakeholders within the confines of the legislative requirements.

While the objectives of the plan were clearly defined, the decisions on where to designate different settings were largely *ad hoc* and often based on unverifiable assumptions and information (GBRMPA Staff, pers. comm. 1997). Using more rigorous scientific data (see Table 7.1), most of which were not used in the development of the Plan, and a multicriteria decision tree, I modelled the decision problem of designating settings at reefs in the Cairns Planning Area. With the goal of "reef conservation" at the top level, followed by the second level of criteria (or the Plan's objectives), the subsequent subcriteria, and finally the choice of alternative reef locations, I was able to develop a hierarchical decomposition of a very complex decision (Figure 7.6 and Figure 7.7). Using this modeling approach I determined how closely the actual settings met the goal and objectives of the Plan.

My results indicated that the reefs requiring the most protection had the highest decision scores and were mainly designated by planners as Low Use reefs. On the other hand, the reefs requiring less protection had lower scores and were mainly designated Moderate and Intensive Use reefs. These results suggest that the decision of where to designate different settings was largely successful in meeting the objectives of the Plan.

7.4.3 Implications for GBRMP and MPAs

Very clear and specific objectives about what a particular marine protected area is to achieve should be developed prior to the application of different management tools (e.g. settings). The choice of objectives is largely societal and should be developed by managers in consultation with stakeholders. The success of any marine protected area is closely related to how well user groups and stakeholders are identified and brought into the planning and management process (Agardy 2000).

After the objectives are determined, scientists should help identify what needs to be protected, in what manner and identify specific information requirements to meet the objectives.

In the case of the Cairns Planning Area, managers could have determined the relative weight of each objective to the overall goal of “reef conservation”, while the contribution of each dataset to that objective could have been determined by scientists. This hierarchical process could have been modelled during the development of the Plan and would have provided a clear and transparent decision process for the allocation of use in the area while involving user groups, stakeholders and scientists in the process.

In addition, by modeling this process, when new information becomes available, or new management priorities emerge, the entire decision on where to allocate different settings can be easily re-examined, remodelled, decisions modified and clearly justified.

7.5 Conclusion

Comparisons between the management settings, information from my survey of regular reef users (Chapter 5) and data from biological monitoring programs (Chapters 4 and 6) suggest that the Plan maintained current levels of use and did not necessarily reflect diversity in abundance of reef biota at different locations. The results of this chapter suggest that the settings were largely successful in meeting the objectives of the Plan.

Chapter 8.General Discussion and Conclusion

8.1 Introduction

Management of human activities in marine protected areas (MPAs) is a challenging task due to the diversity of user groups and ways they interact with the complex natural environment. Human relationships with the marine environment are described by Agardy (1993) as:

> *"…many things to many people. To commercial and artisanal fisherman and their customers they are a seemingly limitless breadbasket for the taking. For anglers, yachtsmen, surfers, swimmers, etc. they represent boundless opportunities for recreation. To energy and shipping technologies the seas represent an invaluable industrial resource. For some, the shoreline and oceans have some unquantifiable yet important spiritual value. Additionally, the oceans and coastal margins play a vital role in maintaining the biosphere itself. Thus, the value of the coastal zone is more than the sum of its calculable parts."*

Many conservation principles for protected areas were developed for terrestrial areas (e.g. Hockings *et al.* 2000, Jones 2000) but have been adapted and revised for marine protected areas. While there are similarities between the two environments, there are also fundamental differences (Kenchington 1990; Slocombe 1992). These differences can make management and evaluation challenging for marine areas. Day et al. (2003) noted that these differences include:

- The diversity of habitats across vertical and horizontal spatial scales in the marine environment makes monitoring more difficult
- The degree of interconnectedness and variability at different spatial and temporal scales in marine systems poses unique challenges

- The logistic difficulties of surveying marine environments
- The mobility of marine species as adult and larvae
- The lack of knowledge and understanding of marine systems.

As a conservation strategy however, MPAs can address many of these difficulties by targeting many different species, habitats, processes and human activities within a functional and interrelated system that includes both social and ecological components.

The goals of MPAs are, however, often ecologically and socially complex. Objectives vary from location to location and through time, in response to environmental and social change. The range of information needed to assess alternative strategies and ultimately the outcomes of management decisions can be extremely diverse. Interpretation and assessment of this information can be difficult for managers, scientists, stakeholders and especially the broader community. There is a need for adequate guidelines and processes. There is also a need for techniques that can be used to explore alternative decisions, using the best available information and in a way that is understandable and repeatable.

Conservation responsibilities at the ecosystem level extend beyond one program, institution, industry, community or even government. As a result, goals, information and processes must be sufficiently generic to bridge gaps and address overlapping situations, interests and jurisdictions. "*As far as possible, goals and objectives should be as widely applicable as possible for simplicity's sake, for consistency, and as some rough measure of their robustness.*" (Slocombe 1998).

At the same time, individual criteria must be flexible enough to address specific issues at a local level. They need to be explicit enough to be objectively and rigorously assessed, yet be comparable among different areas and situations and still reflect basic, fundamental values and ethics (Slocombe 1998).

These requirements are particularly critical for multiple use areas that aim to achieve a variety of outcomes (Agardy *et al.* 2003). Within multiple use MPAs, and particularly in a MPA as large and diverse as the Great Barrier Reef Marine Park, management must, by the very nature of the MPA, have multiple objectives. A comprehensive, clearly documented and systematic approach to defining goals, objectives and criteria is fundamental in ensuring that all aspects of management are considered.

For complex ecosystems that include diverse social impacts and interactions, the level of knowledge available to managers at appropriate scales is often very low. Where there is uncertainty an adaptive management approach that improves performance is all the more important. Adaptive management processes provide a means to correct mistakes and develop better strategies for learning *in situ* what strategies are effective and what improvements can be made.

The fundamental first steps to achieving an adaptive system are well thought out, comprehensive objectives, which can be explicitly and directly linked to specific criteria for both initial and ongoing data collection and assessment.

This thesis has explored the challenge for marine protected area managers of making cost-effective use of biological and social information to plan for reasonable use of a marine protected area, using the 1998 Cairns Area Plan of Management of the Great Barrier Reef Marine Park as a case study.

The main objectives of this study were to:

1. assess the criteria and methods used by government agencies to allocate resource use in the Great Barrier Reef Region (GBRR) at regional and local scales;

2. identify ways in which existing information on reef resources can be integrated into a format which is easy to access and use;

3. develop methods to assist managers to map the locations of various types of use;

4. develop methods to assess the relationships between information on marine ecosystems and patterns in human use, perceptions and values;

5. apply a decision support system to review the site-based management settings in the 1998 Cairns Area Plan of Management from the perspective of the plan's objectives and information base.

8.2 Main findings

In order to assess information requirements for management of the Great Barrier Reef Marine Park (GBRMP), I reviewed the current use of marine protected area (MPA) planning frameworks, methods and information available to managers (Chapters 2 and 3).

During this review it became apparent that comprehensive guidelines for MPA management and a wide variety of decision support tools allowing systematic application of these guidelines had been developed for other terrestrial and marine applications (Chapter 3). However these were under-utilised in planning for the GBMP at the time of this study.

It also became apparent that the Great Barrier Reef Marine Park Authority (GBRMPA) had some of the most extensive information resources and data collection programs available for any MPA (Chapter 4). However, these resources were not readily available to managers and their direct use in marine park planning, permitting, environmental impact assessment, research and day to day management was extremely limited (Chapter 4). My survey of GBRMPA managers (Chapter 4, Appendix 2) indicated that planning decisions were often based on personal experience and anecdotal evidence, a common practice in conservation management around the world.

For example, while the volume of information available for conservation management has increased enormously over the past 20 years (Pullin *et al*. 2004), Pullin and Knight (2001, 2003) found that most conservation actions are based on "*anecdote, personal experience and interpretations of traditional land management practices*". They proposed that this was not because conservation organisations did not want to use the information, but mainly because they did not have time to access it or the supporting framework to readily absorb and use it. Pullin *et al.* (2004) suggested that managers should be able to model the outcomes of alternative actions using the best available information using decision support systems similar to those in use in the field of medicine.

In this thesis, I presented several decision support modeling methods that can assist managers to systematically use a range of information sources to select marine protected areas and assign varying levels of protection. This integrated approach is demonstrated in Chapters 5, 6 and 7, using the Cairns Area Plan of Management as a case study and should have broader application in both the GBRMP and other marine parks.

For most MPAs, including the GBRMP, there is still a need to develop socio-economic indicators (Day *et al*. 2003) and gather relevant social data. Most monitoring in the GBRMP has focused on ecological conditions in a few selected areas, with less attention focused on management effectiveness and social and economic values. In July 2005, the GBRMPA identified 21 critical research needs, five of which were socio-economic in nature (GBRMPA 2005c). Day *et al.* (2003) also identified a need to work closely with local people who are out in the marine environment regularly such as commercial fishers, tourism operators and local volunteers.

Using ecological perception theory and spatial analyses, I conducted a survey of local reef users that provided insight into the social conditions, perceptions of reef quality and levels of acceptable use at specific locations (Chapter 5). This type of information should be collected as an integral part of planning, decision making and evaluation in marine protected areas. In fact, the GBRMPA recently identified the need for this kind of information for the entire GBRMP as *critical* in its list of research priorities (GBRMPA 2005).

The techniques used in Chapter 5, including the mapping of perceptions across broad spatial scales, represent progress in a relatively new field of social science referred to as public participation GIS (geographic information system). Researchers have only just begun to explore the use of GIS to examine social and political values by using spatial analyses to map community values and social perceptions (Craig and Elwood 1998, Elwood and Leitner 1998, Harris and Weiner 1998, Talen 1999, 2000).

The results of the survey of local reef users in Chapter 5 indicated that the reefs in the Cairns Planning Area were perceived to be of high quality, with offshore reefs on the edge of the continental shelf receiving higher ratings than reefs located closer to shore. The perceived quality of coral cover and diversity of fish species were found to be the best indicators of overall reef quality (Chapter 5, Section 5.3.3.2). High quality sites were those with excellent coral cover and high diversity of fish species, while low quality sites had poor coral cover and poor underwater topography (Chapter 5, Section 5.3.3.3).

Overfishing, anchoring and cyclones were perceived to cause the most damage to reefs (Chapter 5, Section 5.3.3.4). Overcrowding was an issue at most reefs within the Cairns Planning Area, particularly those reefs near the major port of Cairns. The number of vessels at a reef location was considered to make more of a visual impact than the number of people, and thus may be a better indicator of social impacts or conflicts (Chapter 5, Section 5.3.3.6).

Using multivariate statistics and spatial models, I then compared biological monitoring data with local reef users' perceptions of reef quality (Chapter 6). Comparisons between biological monitoring data and the quality variables "coral cover" and "diversity of fish species" suggested that sites perceived as higher quality have more hard coral, less soft coral and fish species commonly associated with branching corals in back reef locations (Chapter 6, Sections 6.3.1 and 6.3.2).

In Chapter 6, I demonstrated that scientific information (biological monitoring data) could be used to predict areas that could be considered of high quality by marine park users (Chapter 6, Section 6.3.2). The ability to predict where people might go if access or future development were to make the remote areas of the GBRMP more accessible, was identified as being of *critical* importance to marine park managers planning for future use (GBRMPA 2005).

I then used decision support software and other statistical techniques to demonstrate how marine protected area managers could integrate social, cultural and biophysical data to assist and evaluate marine protected area planning at a local scale (Chapter 7, Section 7.3.3). Multiple criteria decision support systems allow managers to model the outcomes different management decisions using explicit and unambiguous objectives.

Many difficulties arise in gaining stakeholder support for MPAs because of a lack of understanding of how existing marine reserves have performed, ignorance of what we don't yet know about MPAs, lack of clarity in defining objectives and poor understanding of how objectives can be met with the MPA. As Halpern and Warner (2003) state:

"*reasonable goals, appropriate design criteria, … and the success of marine reserves can only be achieved if stakeholders are armed with information about the reserve performance relative to their needs*".

Stakeholders, including management agencies, often have different objectives (e.g. ecosystem management, ecotourism, fisheries enhancement) which can lead to conflicts about the size of the MPA, the application of different management tools, restrictions, permitted uses, and so on. Allowing managers to model the implications of their decisions from a given set of clearly defined objectives and criteria, can help them predict and interpret the consequences of alternative MPA designs and other management tools (Badalamenti *et al.* 2000).

The process of developing a multiple criteria decision support system and exploring management scenarios also assists in the development of mechanisms for evaluation. Despite the inherent difficulties in assessing the effectiveness of marine protected areas, the principal measure of effectiveness must be the extent to which the management objectives are achieved. As in the case of modeling management decisions, clear, explicit, unambiguous objectives are essential.

MPAs that meet objectives can also encourage the creation of new MPAs (Agardy *et al.* 2003). For example, in New Zealand, a MPA Fisheries Reserve introduced at Goat Island in 1977 was vehemently opposed by many stakeholders, however, 10 years later, 78% of fishers surveyed were in support of the marine reserve and in favour of further marine protection as the marine reserve was perceived to have met and even exceeded the objectives and expectations (Ballantine 1989). The main objective for the reserve was to have a place with minimal human disturbance where scientists and students could carry out research into the way a marine ecosystem functions in its natural state. After a several years of closure, researchers found an increase in populations and sizes of commercially important species, including rock lobster (*Jasus edwardsii*) and snapper (*Pagrus auratus*) (Kelly *et al.* 2000, Willis *et al*. 2000). As this scientific information was regularly communicated to the local community, local fishers began setting their lobster traps along the boundary of the marine sanctuary as they discovered that this was the best place to catch lobster (Ballantine 1989). They felt the presence of the marine reserve had actually enhanced their fishery.

Management strategies, plans and policies should be reviewed periodically for their effectiveness. An evaluation process should include the public, managers, scientists, policy makers and stakeholders and should provide an indication of how well the stated objectives of the MPA are being met. Evaluation should be a part of the normal management process (Hockings et al. 2000). An adaptive management approach should be taken to allow shifts in the focus of the management technique in response to lessons learned from past experiences. All management approaches should be reviewed and updated where appropriate (Agardy *et al.* 2003). Most management actions should be in place for a reasonable period of time to be effective and allow for a meaningful evaluation to be carried out (Day 2002). It is essential to use information on how current MPAs perform to obtain better information about effective design, minimum sizes, amount of no-take area (Agardy *et al.* 2003) and their impact on the ecological and social values of marine ecosystems.

8.3 Implications for the GBRMPA:

Although conservation goals are the main priority of the GBRMPA, the most contentious issues raised by the GBRMPA's decisions are often social and economic in nature. Therefore, social values, requirements and perceptions of the resource should be an integral part of the planning and evaluation process. Information required to support GBRMP management includes public attitudes towards management programmes, the social and cultural values and perceptions of the GBRMP and community expectations for management (GBRMPA 2005c).

I recommend that the GBRMPA use ecological and social data with GIS and a range of decision support tools in planning for future use of the marine park. There is a need for spatially explicit social data (Chapter 5) to be collected across the entire GBRMP (see Section 8.5) to assist in future planning and evaluation. Using these tools with an adaptive management approach will help provide a more transparent process for decision making and will assist in exploring a greater range of options and opportunities for effective conservation and sustainable use.

In evaluating the use of scientific data and analyses in conservation plans, Watchman *et al.* (2001) found that management plans using new information, new technology and adapting to environmental conditions tended to minimise uncertainty and increase effectiveness.

Finally, I recommend that the GBRMPA adapt and develop the spatial and statistical analyses I have used to explore, in greater detail, the relationships between social values and ecological characteristics of the GBRMP and the likely effects of increased use, faster transport and changing impacts on the more remote areas of the marine park. Up to date biological monitoring data are available for all Sectors of the GBRMP and can be used for these analyses to provide better insight into human use of the reef resources.

8.4 Implications for the other MPAs:

Planning for MPAs often involves many social and ecological objectives. Multiple use MPAs and other forms of ecosystem management aim to manage different species, ecosystem processes and human use. An open and accountable planning process for each MPA should use the best available scientific information as well as the knowledge and input of the local community. Combining social perceptions and local knowledge with scientific information provides a more holistic view of the natural environment (Roberston *et al.* 2000, Huntington *et al.* 2002, Dinsdale and Fenton 2006). In addition, feelings of stewardship for the environment and the empowerment of the community can be achieved where government and local communities work together (Webb *et al*. 2004).

Studies have shown that repeat visitors are able to detect changes in the condition of the underwater environment (Davis et al 1995, Dixon et al. 1993, Dinsdale and Fenton 2006, see also Chapter 5). These stakeholders may have an enormous depth of knowledge about the condition and extent of natural resources, their ecology and the effects of management (Neis *et al*. 1999, Berkes 2000, Johannes *et al.* 2000, Webb *et al.* 2004). Their perceptions of the environment can be used as a tool for evaluating general trends in resource condition over time and to provide insight into the community's assessment of how well the protected area management is working (Webb *et al.* 2004). By using community perceptions, MPA managers can make better informed decisions and in turn, the community makes important contributions to environmental knowledge and the management decision-making process.

8.5 Future Research Directions

Special meanings are often attributed to physical locations, ranging from sites with special religious or historical meaning to entire national or transnational boundaries (Darian-Smith 1999, Friedland and Hecht 1996, Hancock 1999). Often this can result in the development of politics and social actions built around place–based identities, (Goodchild *et al.* 2000).

The development of global perceptions, loyalties and legislation protecting the iconic Great Barrier Reef Marine Park is a prime example of this. However, there is a great deal of research yet to be done on the symbolic meaning of space using spatial analysis across different locations and times investigating different patterns of use, meanings and values.

There is also a wide range of interest in and potential for the application of a spatial perspective in the social sciences (Goodchild *et al.* 2000). This interest in using a spatial approach is stimulated by technical factors (e.g. geocoded data, existing technology) as well as by theoretical questions raised by social scientists concerning the theory of place and space. Scientific research in general is increasingly interdisciplinary and cross disciplinary. Spatial analysis methods are required to develop cross disciplinary modeling frameworks (Goodchild *et al.* 2000).

There is a growing range of research questions where location and spatial interation (e.g. space-time) are increasingly required. There is also a need for decision support systems to incorporate spatially integrated social science with other management information (e.g. biological, physical, managerial and geographical information).

Historically, scientific thought works on a reductionist tradition in which different processes are studied in isolation, in distinct disciplines and often without specific attention to space and time. In the real world, these separate processes interact in a spatiotemporal context and cannot be dealt with in isolation. The application of scientific knowledge in policy and subsequently protected area management requires explicit attention to spatial location as the basis of policy and management at a local scale.

While this thesis has explored spatially integrated information on social values and perceptions for the Cairns Section, further studies are needed to determine which reef attributes are most important to specific user groups and how their experiences are influenced by the different conditions present at reef sites throughout the GBRMP.

Research is also needed to assess and address sampling biases associated with community input to planning decisions. Scientists have often expressed doubt about the competency of the community to have equitable and direct input into management (Chuenpagdee *et al.* 2004, Dinsdale and Fenton 2006). Unlike scientific information, local ecological knowledge is gained by continual observations, can be a mix of scientific and practical knowledge, is constructed by community values and beliefs and may have a strong cultural component (McNeely 1995, Berkes and Folkes 2000, Olsson and Folke 2001, Dinsdale in review). However, the use of local knowledge integrated with scientific information in management planning has the potential to develop better management outcomes and a much stronger sense of community ownership.

One bias associated with using local ecological knowledge is that associated with shifting baselines as described by Pauly (2001). I have demonstrated that this may already be occurring in some areas of the Cairns Sector (Chapter 5, Section 5.4.3). More research is needed to investigate the possibility of continuing product shift in high use sections of the GBRMP.

In addition, future studies should investigate the relationship between ecological and social information at a variety of spatial scales. For example, researchers should assess available ecological and social data for sites within and among reefs, shelf positions, bioregions and on a reef wide basis to determine their suitability for use in different planning and research applications. Existing and new monitoring programmes should aim to incorporate the use of ecological and social data in planning and adaptive management for the GBRMP and other marine protected areas.

Finally, future research should investigate whether the effects of different management settings are reflected in the time series of data collected by biological and socio-economic monitoring after the settings have been in place for several years. As an adaptive management process, it will be essential to test the effectiveness of management settings by determining whether or not settings have an effect on the reef biota and local communities at a local scale over a longer time frame. In order to undertake such studies, robust baseline data are essential. It is also essential that such monitoring programmes are designed to measure whether the management intervention is achieving its desired objectives.

Only when ecological and social goals, information use, planning and rigorous assessment become a part of one integrated conservation management process, will this be possible.

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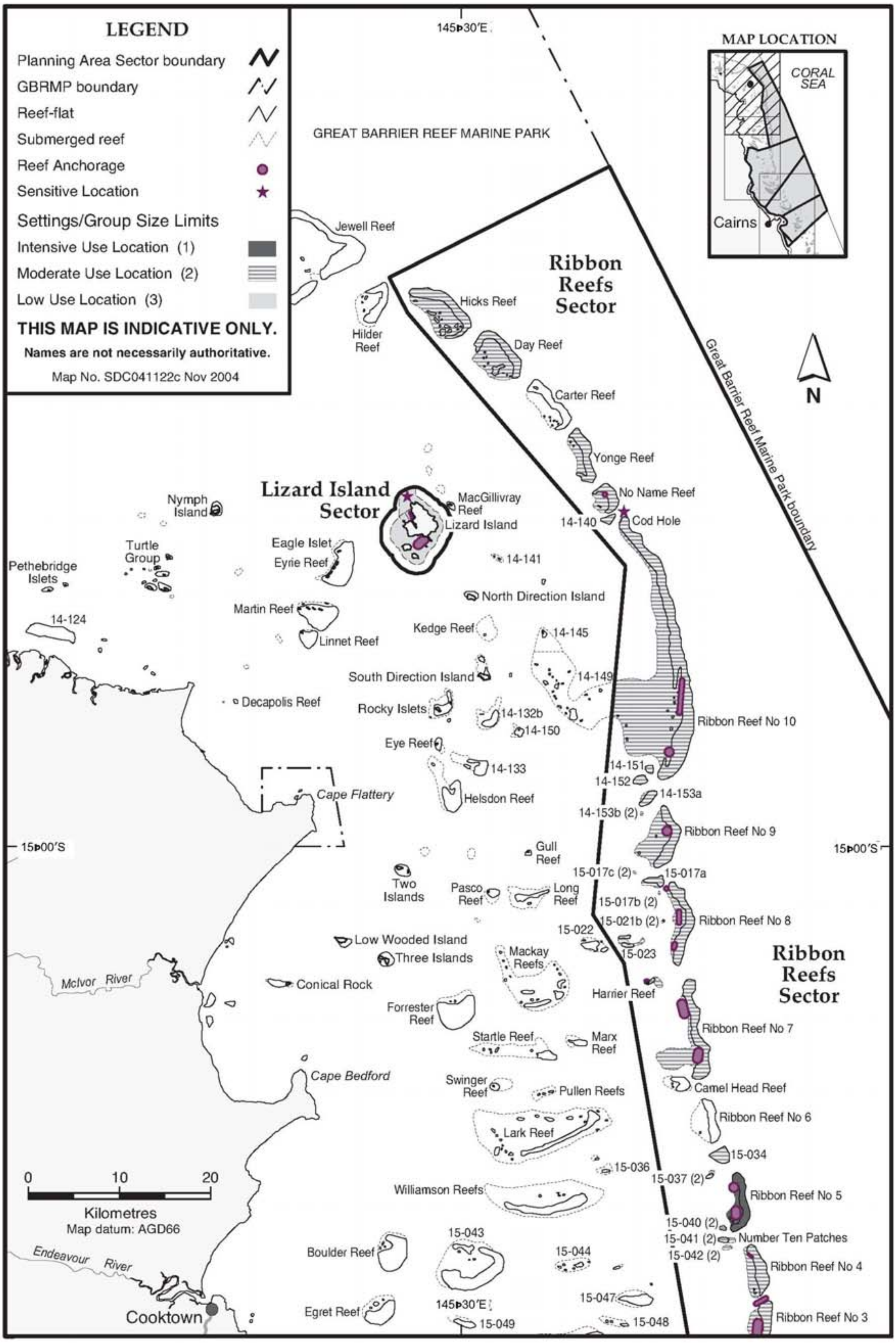
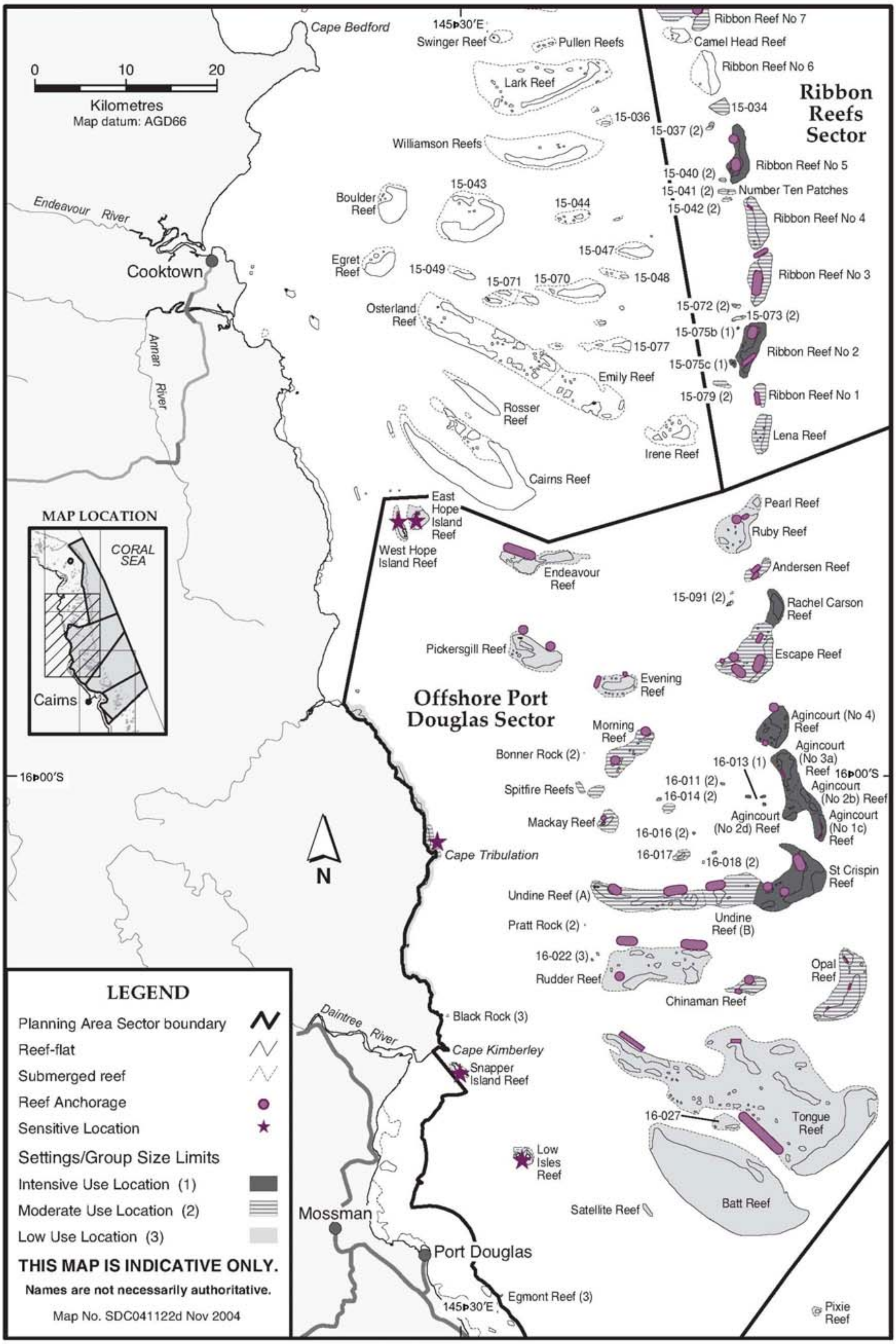
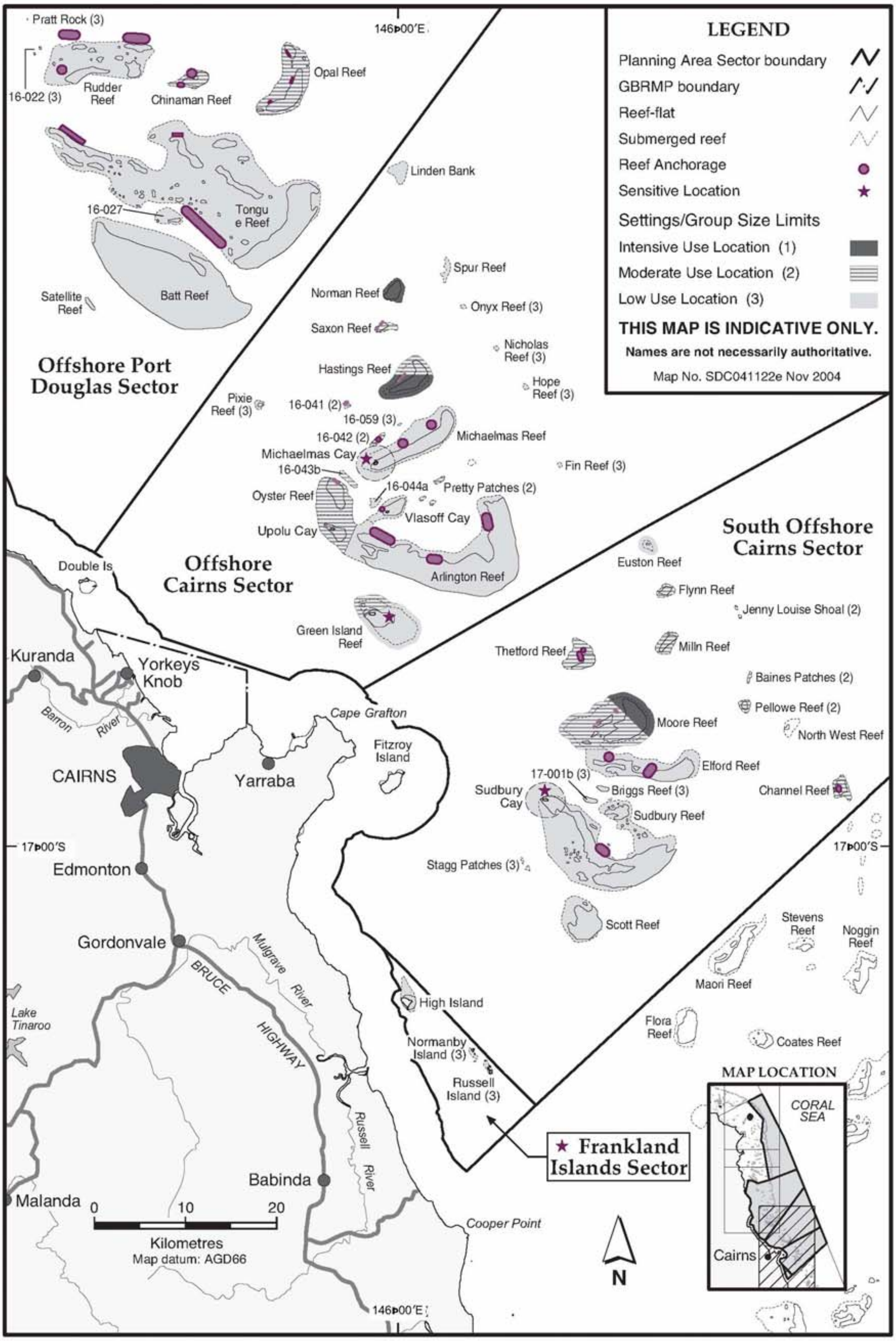
Appendix 1: The Cairns Planning Area including reef names, management settings and reef anchorages. Map 1 of 3 provided by the Great Barrier Reef Marine Park Authority.



Appendix 1: The Cairns Planning Area including reef names, management settings and reef anchorages. Map 2 of 3 provided by the Great Barrier Reef Marine Park Authority.



Appendix 1: The Cairns Planning Area including reef names, management settings and reef anchorages. Map 3 of 3 provided by the Great Barrier Reef Marine Park Authority.



To the Participant

I am a PhD student with the CRC Reef Research Centre at James Cook University. I am presently working with the GBRMPA and QDEH (Cairns Region) to assess information use in decision making and planning.

In order for you to participate in this assessment, I have enclosed the following questionnaire. You have been chosen by Ian McPhail, Chairperson GBRMPA, as a key person to receive this survey. This questionnaire will be used as a guide to prompt further discussion and to focus the scope of my PhD project.

During the next two weeks I will be contacting each of you to discuss your responses. The distribution of this survey has been limited to 22 staff members at both the GBRMPA and QDEH who are involved in making decisions about the use of reefs and islands in the Cairns Section of the Great Barrier Reef Marine Park. This involvement ranges from strategic planning to permit assessment. Your contribution to this study is highly valued.

If you have any questions or comments, please contact me at:

Barbara Breen
Tropical Environment Studies and Geography
James Cook University
Townsville, 4811

Ph: [redacted]
Email: [redacted]

Thank you for your participation.

1. **What is your area of expertise (e.g. strategic plans, zoning plans, management area plans, site specific plans, permit assessment, permit administration, other)**

___

2. **What kinds of decisions are made in your area of expertise?**

___

___

___

3. **What kinds of decisions in your area of expertise have a standard format?**

___

___

___

4. **How many people in your office make decisions of the same type and who are they?**

___

___

___

5. **In what areas of your job are decisions generally most successful?**

___

___

___

6. **In what areas of your job are decisions least successful?**

___

___

___

7. **What is the duration of problems addressed in your area of expertise?**

___

___

___

8. **Other Comments?**

___

___

___

9. **In your area of expertise, what data do you currently use to assist in making decisions concerning the use of islands and reefs in the GBRMP? (circle yes or no)**

Information type	
Aerial survelliance data	yes/no
ATSI information	yes/no
Biological Survey Information	yes/no
Commercial Fishing Information	yes/no
Distance from population centers	yes/no
Input from public meetings	yes/no
Permit information	yes/no
Physical factors: aspect, bathymetry, latitude, cross-shelf location	yes/no
Precedence from past decisions	yes/no
Recreational fishing information	yes/no
Specific lobby groups	yes/no
Tourism use	yes/no
Zoning plan requirements	yes/no
Social economic values	yes/no
Other (please list)	

10. **What data do you use when making decisions about zoning?**

____

____

____

11. **What data do you use when making decisions about site specific use?**

____

____

____

12. **What amount of accuracy do you require from the data?**

____

____

____

13. **What spatial scale of information do you use for making decisions?**

____

____

____

14. **How much data is needed to support your decisions?**

____

____

____

Appendix 3: Survey of natural resource use, 1995

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SURVEY OF NATURAL RESOURCE USE

IN THE

CAIRNS REGION OF THE GREAT BARRIER REEF MARINE PARK

1995