Economic Valuation of Biodiversity Conservation. Citizens’ Non-use Value for Ningaloo Reef

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This thesis is presented for the degree of Doctor of Philosophy
Murdoch University
2009
I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary institution.

.................................

Flavio Gazzani
Abstract

This research attempts to improve a methodology for integrating environmental concerns of conservation projects in general and valuation of non-use values in particular. The study improves environmental economics analysis by accounting to assess the value of non-market goods using individuals' stated behaviour in a hypothetical setting. In particular, a new approach to Choice Modelling analysis for environmental goods is used in this case study, to obtain the value of biodiversity conservation by separately evaluating the preferences of individuals for the relevant attributes, and in doing so it also provides information that can be used in determining the preferred design for a sustainable use of marine protected areas.

This study is undertaken to explicitly assess on how Western Australian citizens value Ningaloo Marine Park by analysing their willingness to pay for its conservation. Two hypothetical conservation and protection scenarios are used: (i) to estimate the non-use value benefits of different environmental scenarios; (ii) to measure the willingness to pay for conservation; and (iii) to examine the factors that affect the Western Australians willingness to pay for conservation. The results of this study provide inputs in exploring alternative sources of financing the conservation of Ningaloo Marine Park.

A choice modelling survey was carried out in spring 2006, and it was administered to 150 Western Australians contacted on the beach and inside the camping area of Ningaloo Marine Park. The results indicate that there are positive and significant non-use values associated with the environmental, economic, and social attributes of Ningaloo Marine Park’s biodiversity conservation. The impacts of social, economic, and attitudinal characteristics of the respondents on their valuation of Ningaloo Marine Park conservation attributes are significant and conform with economic theory.
The model estimation results, highlight how the socio-attitudinal characteristics, such as higher education level and good biodiversity knowledge were able to strongly affect the willingness to pay for conservation.

In this study the trend of the respondents in favour of the introduction of entrance fee and increase of protection for Ningaloo Marine Park, was very evident. The possibility to introduce an entrance fee could be considered by policy makers in two possible options.

Option 1

Generalizing the result of this study and multiplying the average willingness to pay (WTP) per person $26.12 (the average WTP for the scenario with increased protection to 66% of sanctuary zone) for 220,000 visitors in Ningaloo Marine Park (Tourism, 2007), this option could be worth at least $5.7 million per year. The option of creating an extra 33% of sanctuary zone and an extra injection of $5.7 million per year for conservation, could be an interesting solution, and even more, protect this fragile and unique marine ecosystems for the future.

Option 2

This option reflects the present situation scenario from a biodiversity conservation and protection point of view (33% of sanctuary zone), but introduces the hypothetical entrance fee of $9 per person (the average WTP for this scenario which reflect the present situation). This amount of fee, multiplied by the 220,000 visitors could be worth almost $2.0 million per year for conservation purposes.

Introducing user fees in both options is a way to regulate access to the fragile ecosystems of Ningaloo Marine Park. It may therefore help to prevent overcrowding and other negative impacts on ecosystems due to excessive numbers of tourists, especially during the peak season (July/August). It may also be a way to capture
part of the consumers’ surplus, in order to make the protected area self-sustaining, i.e. to finance management costs and conservation. The introduction of fees will be ultimately a Government decision, but what this study shows is that there is a strong support with the community in this direction.
Acknowledgements

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I also express special thanks to the many Western Australians who responded to the Ningaloo survey and expressed an incredible attention for a future conservation and protection programme for this unique coral reef ecosystems.

Many thanks go to my wife Michela who has been taking care of my young daughter Sofia at my home in Perth.
This work is dedicated with love to my wife Michela and to my daughter Sofia, my spirit of inspiration.
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<td>ABCM</td>
<td>Attribute Based Choice Modelling</td>
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<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
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<td>AGE</td>
<td>Age</td>
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<tr>
<td>APPEA</td>
<td>Australian Petroleum and Production Exploration Association</td>
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<tr>
<td>ASC</td>
<td>Alternative Specific Constant</td>
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<tr>
<td>BIO</td>
<td>Decrease of Marine Biomass</td>
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<td>BIOK</td>
<td>Marine Biodiversity Knowledge</td>
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<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
</tr>
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<td>CM</td>
<td>Choice Modelling</td>
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<td>CVM</td>
<td>Contingent Valuation Methodology</td>
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<tr>
<td>CS</td>
<td>Compensating Surplus</td>
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<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organization</td>
</tr>
<tr>
<td>DC</td>
<td>Dichotomous Choice</td>
</tr>
<tr>
<td>DEC</td>
<td>Department of Environmental Conservation</td>
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<td>Department of Planning and Infrastructure</td>
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<td>Education</td>
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<td>ENSO</td>
<td>El Nino Southern Oscillation</td>
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<td>EPBC</td>
<td>Environment Protection and Biodiversity Conservation</td>
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<td>EVT</td>
<td>Extreme Value Theory</td>
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<td>FHPA</td>
<td>Fish Habitat Protection Areas</td>
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<td>FISH</td>
<td>Decrease of Income for Local Fisheries</td>
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<td>GBR</td>
<td>Great Barrier Reef</td>
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<td>HPM</td>
<td>Hedonic Pricing Method</td>
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<tr>
<td>HTCM</td>
<td>Hedonic Travel Cost Method</td>
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<tr>
<td>IAICNR</td>
<td>Inter American Institute for Global Change Research</td>
</tr>
<tr>
<td>IID</td>
<td>Independently and Identically Distributed</td>
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<tr>
<td>INC</td>
<td>Income</td>
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<td>ITCM</td>
<td>Individual Travel Cost Method</td>
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<td>IUCN</td>
<td>The World Conservation Union</td>
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<tr>
<td>LAC</td>
<td>Limit of Acceptable Change</td>
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<td>LR</td>
<td>Likelihood Ratio test</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>MEA</td>
<td>Millennium Ecosystem Assessment</td>
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<td>MININ</td>
<td>Loss of Income for Mining and Petroleum Companies</td>
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<td>MLE</td>
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<td>Multinominal logit</td>
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<td>Marine Protected Area</td>
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<td>NOAA</td>
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<td>Natural Resource Management Council</td>
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<tr>
<td>NRSMPA</td>
<td>National Representative System of Marine Protected Areas</td>
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<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
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<tr>
<td>OLS</td>
<td>Ordinary Least Squares</td>
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<td>REEF</td>
<td>Reduction of Coral Reef</td>
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<tr>
<td>RUM</td>
<td>Random Utility Model</td>
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<tr>
<td>SANCT</td>
<td>Percentage of Sanctuary Zone inside Ningaloo Reef</td>
</tr>
<tr>
<td>SOE</td>
<td>State of the Environment</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperature</td>
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<td>SP</td>
<td>Stated Preference</td>
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<td>Travel Cost Methodology</td>
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<tr>
<td>TEV</td>
<td>Total Economic Value</td>
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<tr>
<td>TWA</td>
<td>Tourism Western Australia</td>
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<td>WA</td>
<td>Western Australia</td>
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<tr>
<td>WAPC</td>
<td>Western Australian Planning Commission</td>
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<tr>
<td>WTP</td>
<td>Willingness to Pay</td>
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<tr>
<td>WTA</td>
<td>Willingness to Accept</td>
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<td>ZTCM</td>
<td>Zonal Travel Cost Method</td>
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Chapter I
Introduction and study coverage

1.1 Introduction

The broad aim of this study is to generate improved estimates of coral reef conservation benefits which can assist Western Australian decision makers in managing and protecting Ningaloo Marine Park. This research aims to improve the methodology for assessing public concern about conservation and development in general, and non-use values of the environment in particular.

In the last 30 years or so, valuation of environmental services has become one of the most significant and fastest evolving areas of research in environmental and ecological economics. From the outset, an important motivation for valuation studies has been to generate a better and more comprehensive informational base for the policy formulation and decision making process. Such studies can inform societal decision mechanisms trying to cope with the allocation of what are perceived as scarce resources among competing demands.

One key issue of environmental concern in Western Australia is loss of biodiversity. Policy makers have responded to concerns over declining levels of biodiversity by introducing a range of policy measures including marine conservation and wildlife management schemes. Costs for such measures are relatively easy to establish, but benefits are less easily estimated. Before such policies are implemented, it is useful to gain an appreciation of the extent of change to existing policies that would be in the best interest of society. To achieve this understanding, it is useful to gather information regarding the costs of management options and the benefits they generate. Problematic in the quest for information on the benefits of protection is that many of the benefits are not marketed. In order to compare relative costs and benefits across a range of management options, a numeral, or unit of measurement,
of value is required. In Western society, value is often measured in money terms. A challenge to economists is, therefore, the estimation, in monetary terms, of non-use values of environmental benefits.

The non-use value estimated in this study is biodiversity conservation at Ningaloo Marine Park, located in Western Australia. This coral reef supports an amazing diversity of wildlife including 600 species of shellfish and other molluscs, 500 species of fish such as whale sharks, manta rays and other tropical and subtropical fish, and a variety of other invertebrates (Department of the Premier and Cabinet, 2008). Considered one of the healthiest reef environments in the world, Ningaloo sits in a special bio-geographic zone where the distributions of tropical and temperate marine and terrestrial organisms overlap. Currently, this fringing barrier reef system and its coasts are subject to significant human pressure due to its unique proximity to the coast. Commercial and recreational fishing, as well as other human activities such as mining or tourism, have the potential for major negative impacts on the marine life of Ningaloo Marine Park waters.

The specific objectives of this study are to understand the impact of changes such as size of sanctuary zone, coral reef coverage, biomass reduction, or decreased income for local fisheries, can have on Ningaloo Marine Park, and translate these into economic value. To account this estimation, a technique for non-marketed values called choice modelling is used.

In a choice modelling application, respondents who are likely to be affected by changes in resource management are asked, in the format of a questionnaire, to select their preferred management options from a range of options. The options are described in terms of the characteristics or attributes of their outcomes. A statistical analysis of the choice made by the questionnaire respondents allows the development of a model that explains the probability of an option being selected by respondents in terms of the attributes of the option’s outcomes and the socio-economic characteristics of the respondents. So long as one of the attributes used to
describe the option’s outcomes is monetary for instance, a user’s fees to be used to fund the environmental improvements offered by the option – the model of choice can be used to estimate, in monetary terms, the values people place on different management options.

The case study of Ningaloo Marine Park, which is one of the most important ecosystems in the world from the viewpoint of global biodiversity, involves a comparison of the benefits of biodiversity conservation vis-à-vis the alternate use options of Ningaloo coast, such as commercial and recreational fishing, mining and petroleum exploration, tourism and recreation. While the research area of biodiversity valuation has grown significantly over the past decade, most research efforts dealing with valuation focus on terrestrial diversity; no methodical investigation has been made of marine biodiversity valuation issues.

Many of the non-use values are not accounted for in the decision-making process. The non-monetarisation of such benefits may mean that they are either under-valued or over-valued in the intuitive decision-making process. Thus, a failure to account for such benefits could lead to a lack of public investment to preserve the pristine natural environment of Ningaloo Marine Park. This study is not an isolated estimation of particular coral reef ecosystems, rather it presents an integrated approach to vulnerable and fragile ecosystems, and to the integration of non-use values into the decision-making process of Western Australian conservation policy.

The first part of this chapter outlines existing sustainable natural resources management in Western Australia. The second section briefly highlights previous studies applying environmental economics for non-use values in Australia. The last section focuses the attention on the aims and objectives of this study and finally the thesis structure is presented.
1.2 Institutional Framework for Sustainable Natural Resource Management in Western Australia

Western Australia’s 27,000 km coastline is largely undeveloped and relatively pristine. Some areas of the coast however are developing rapidly and in need of careful management, others are already under considerable threat or have become degraded or irreversibly damaged and require more urgent remedial action. An example is the environmental degradation caused by the Alcoa Aluminia, bauxite refinery in Wagerup (CSIRO, 2004).

In order to protect the State’s ecological environment, Western Australia has developed institutional arrangements in natural resource management over the last decade or so that have been created through community interest and Commonwealth Government support. Many of these arrangements are not legislated, and the structure has flexibility and the ability to respond to changing circumstances.

These recent approaches to Ningaloo Marine Park have focussed on bioregions or whole catchment, including the coasts, as an appropriate scale and meaningful biophysical unit for research and management. However, in addition, research and management focuses specifically on coastal environments resources.

1.2.1 Natural Resource Management “Caring for our Country”

The Commonwealth Government recognises that there is a pressing need to protect Australia’s unique natural environment and to improve the sustainable management of the country’s natural resources. The new “Caring for our Country” natural resource management programs is an initiative to better target national priorities (NRM, 2008).
“Caring for our Country” commenced on 1 July 2008 and it brings together the delivery of a raft of Commonwealth programs into an integrated package of public and private investment focus on natural resource management. The goal of this management program is to have an environment that is healthy, better-protected, well-managed, resilient, and that provides essential ecosystem services in a changing climate. “Caring for our Country” focuses on achieving strategic results and invests in six national priority areas:

1. national reserve system,
2. biodiversity and natural icons,
3. coastal environments and critical aquatic habitats,
4. sustainable farm practices,
5. natural resource management in remote and northern Australia, and
6. community skills, knowledge and engagement.

Source: NRM, 2008

The planning and implementation of these NRM initiatives are based on regional needs. Across Australia, 56 NRM regions have been identified. Each region has produced integrated regional NRM plans and investment strategies, which help identify and coordinate actions that address issues specific to a particular region (NRM, 2008).

An important issue however is the excessive fragmentation of policy making structures in Western Australian natural resource management. In fact, there is not a single body or institution responsible for the establishment processes and decision making. An effective institutional solution would require specific single body which coordinates and facilitates decision making, and would probably involve Commonwealth, state and territory organizations, possibly through a Ministerial Council.

The WA State Government has a Cabinet Standing Committee overseeing policy and
other developments in natural resource management, sustainability, the environment and associated areas (Cabinet Standing Committee on Environmental Policy). The Committee comprises the Minister for the Environment (chair), the Minister for Agriculture, Forestry and Fisheries, the Minister for Planning and Infrastructure, the Minister for Local Government and Regional Development and the Minister for Peel and the South West.

A Natural Resource Management Council (NRMC) advises the Minister for the Environment on natural resource management policy issues and provides leadership in the community on natural resource management generally. The Council comprises thirteen members, eight community members chosen through an expression of interest process based on their expertise in natural resource management matters and five Directors General of State agencies involved in natural resource management.

Six regional community-based Natural Resource Management Groups have developed over the years to cover Western Australia geographically, to focus and integrate the community input into managing natural resources. These groups are:

- The Avon Catchment Council
- The Swan Catchment Council
- The South West Catchments Council
- The South Coast Regional Initiative Planning Team
- The Northern Agricultural Catchments Council
- The Rangelands Natural Resource Management Coordinating Group

The last group includes Ningaloo Marine Park, and is of particular interest to this study. The Rangelands cover approximately 1.85 million square kilometres, which represent 90 percent of Western Australia and more than 75 percent of the coastline, and supports a dispersed population of 133,000 people. Although the region contains a large proportion of the nation’s natural assets and contributes significantly to the national economy, it has traditionally been allocated limited resources and has a
relatively low population to address and manage natural resource issues. A significant conservation estate exists involving national parks, nature reserves, conservation parks, marine parks and reserves. The Rangelands have been administered within four distinct geographical sub-regions: the Kimberley, Pilbara, Gascoyne-Murchison (includes Ningaloo Reef), and Goldfields-Nullarbor (NRM, 2008).

The State Government and these Regional Natural Resource Management Groups, along with the Natural Resource Management Council, signed in 2007 a Natural Resource Management Memorandum of Understanding to work together to better manage natural resources within the regions and the State as a whole.

Many other groups are involved in natural resource management such as Local Government, statutory authorities (e.g. the Environmental Protection Authority and Conservation Commission), non-government organizations (such as the Conservation Council of Western Australia, Greening Australia (WA), World Wide Fund for Nature), community groups (such as Friends of the Fitzgerald River National Park), production groups (such as the WA No-tillage Farmers Association, Saltland Pastures Association, Liebe Group, Environmentally Responsible Agriculture Organization) and industry (such as Oil Mallee Association, OMA).

The Natural Resource Management Council (NRMC) has recently (2007) commissioned work to better define what the term ‘natural resource management’ means and to consider how this should be interpreted in a Western Australian context. For the NRMC, the term ‘natural resources’ is used to encompass renewable resources such as forests, water, wildlife, soils, etc., and non-renewable resources such as coal, oil, and ores, all of which are natural resources. ‘Management activity’ is defined as an activity undertaken by humans for the purpose of harvesting, transporting, protecting, changing, replenishing, or otherwise using resources (NRM, 2008).

Sustainability in natural resource management is seen by the NRMC, as addressing
the triple bottom line of economic development, ecological integrity, and social and cultural wellbeing. Thus, the concept of sustainable natural resource management is defined as “using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be increased” (Department of the Premier and Cabinet, 2008). Marine biodiversity and the conservation of natural areas as well as the preservation of important ecosystem services are the priority goals for the maintenance of some fragile ecosystems, such as Ningaloo Marine Park. However, the careful management of an area for ecological, social and cultural benefits requires special status and management plans. The paragraph 1.2.4 focuses the attention on the Ningaloo marine protected area management plan.

1.2.2 Ningaloo Coastal Regional Strategy

In addition to the interests of the above agencies, the Western Australian Planning Commission (WAPC) has carriage of the Government’s vision for the Ningaloo Coast: to protect its world-class natural values while enabling sensitive development of the region as a sought after nature-based tourism destination, for local, national and international visitors (WAPC, 2008). The Ningaloo Coast Regional Strategy Carnarvon to Exmouth is an important element of the State’s Government plan, which provides a comprehensive framework for sustainable tourism development on the Ningaloo Coast. Under the Strategy, the towns of Carnarvon and Exmouth serve as the ‘gateways’ to the Ningaloo coast. Coastal development in other areas is limited to small-scale, low-impact development. High impact developments such as marinas and canals are inappropriate in areas outside Carnarvon and Exmouth and will not be permitted.

The Western Australian Planning Commission in July 2003, released the first
discussion paper related to the strategy titled *Future directions: sustainable tourism and land use scenarios for the Carnarvon-Ningaloo coast*. A series of public information sessions, community planning days, and direct consultation involving State agencies and local government, key stakeholders and the general public were undertaken in 2003.

The four key objectives of the Ningaloo Coast Strategy are still as outlined in this first paper, namely:

1) Provide state agencies, local government, community and proponents with clear guidance regarding acceptable and sustainable development on the Ningaloo coast.

2) Maintain the Ningaloo coast as an all-seasons recreation and nature-based tourism destination and limit growth with managed staged development, to ensure that the community continues to enjoy a remote and natural experience.

3) Preserve and protect the natural environment and enhance and rehabilitate degraded areas within the environment.

4) Consolidate future residential, commercial, and tourism should also provide opportunity for the development of culturally appropriate tourism through the interpretation of Aboriginal heritage.

Source: WAPC, 2008

The aim of this strategy is that all planning and development must meet the needs of current and future generations through appropriate land use and planning policies and practices which integrate environmental protection, social advancement and economic prosperity in the interests of sustainable development (WAPC, 2008).

Development must be within the limits of ‘acceptable change’. The limits of acceptable change are defined by the Ningaloo Coast Regional Strategy, as ‘the degree of change a system can accommodate or buffer while still sustaining or returning to its desired characteristics. The limits may be defined by environmental, social or economic
concerns’ (DEC, 2008b). What is acceptable or appropriate is determined by consultation with scientists, government agencies and communities, and set down in legislation and regulations. The limits of acceptable change establish the maximum level of alteration for a resource that society is prepared to accept.

The Limits of Acceptable Change (LAC) planning system was initially proposed in the early 1980’s as a means of improving recreation management of protected areas (Stankey et al., 1985). It was developed in response to growing recognition in the U.S. that attempts to define and implement recreational carrying capacities for national park and wilderness protected areas were both excessively reductionistic and failing (McCoy et al., 1995). The carrying capacity concept itself, while useful in a generic way to encourage discussion about visitor impacts, was based on biological models of the capability of resources to sustain a given number of animals over a period of time on a particular range or pasture. Such models did not transfer well into ecosystems being managed for human benefits based primarily on recreational experiences that were not themselves well understood (McCool, 1996). The LAC system assesses the probable impact of an activity, decides in advance how much change will be tolerated, monitors what’s happening systematically and regularly, and determines what actions are appropriate if agreed-upon quality standards are surpassed (Mbaiwa, 2002). The main criticism of the LAC process is that it can be costly in terms of time and staff, due to its requirement for monitoring.

The Western Australian Planning Commission’s role is based on the protection of high-conservation areas such as the Ningaloo Marine Park, Cape Range National Park and surrounds. These areas are rare and irreplaceable natural assets with outstanding scenic, recreational and scientific value, which have been identified as a potential world heritage area. Development must not adversely interfere with these values (WAPC, 2008). Biodiversity underpins the ecological processes that make life possible. Healthy ecosystems are necessary to maintain and regulate atmospheric quality, climate, fresh water, marine productivity, soil formation, cycling of
nutrients, and waste disposal. The Ningaloo Coastal Strategy is aiming to protect and conserve the ecology of this valuable part of Western Australia.

1.2.3 Fishing Sector in Western Australia

For marine biodiversity conservation in Ningaloo Marine Park, one of the most important environmental issue is the impact of commercial fishing, followed by mining and petroleum exploration, and tourism (including recreational fishing). Commercial fishing represents in Western Australia an important economic sector. In 2006-07, commercial fisheries, including aquaculture, accounted for $615 million of Western Australia’s income per annum, of which over $600 million comes from exports (DoF, 2008a). These exports represent about 25% of the national total, making Western Australia the leading Australian state in terms of fisheries. Additionally, an estimated 600,000 Western Australians contribute a further $570 million in annual economic activity from recreational fishing and aquatic eco-tourism (Tourism Western Australia, 2007). In some regional towns in the Gascoyne and Kimberley regions, fisheries activity provides the main form of employment.

A key feature of coastal waters is the diversity of fish. This supports well-developed commercial and recreational fisheries. Within Western Australia there are thirty-four managed commercial fisheries, five licensed recreational fisheries and a number of emerging aquaculture industries (DoF, 2007). These fisheries are mainly coastal and have developed under conditions of low productivity compared to the western shores of the other continents in the southern hemisphere. Many of the target species are demersal and rely on specific habitats, for example coral reefs, mangroves or algal reefs that are limited in number and extent (DoF, 2002).

These circumstances lead to the possibility of over-exploitation that could compromise the sustainability of these fish stocks and other interdependent non-
target species and their habitats. Fish As an integral part of fisheries management plans and strategies in Western Australia, in addition to the Marine Reserves legislation, fish and their habitats have a special protection and management with the establishment of Fish Habitat Protection Areas (FHPA) controlled by the Minister for Fisheries. The purposes of these protected areas are the following: 1) the conservation and protection of fish, fish breeding areas, fish fossils or the aquatic ecosystem; 2) the culture and propagation of fish and experimental purposes related to that culture and propagation; 3) the management of fish and activities relating to the appreciation or observation of fish (DoF, 2008b). Under the FHPA fish can include a range of organisms such as fin fish, crustaceans, molluscs, corals, seagrasses and algae at all stages of their life cycles. However, it does not include mammals, birds, amphibians or reptiles - these are protected under the Wildlife Conservation Act.

Over-exploitation of natural biological resources can compromise sustainability. The sustainability of fish stocks and conservation of their habitats are desired government outcomes reflected in the Fish Resources Management Act 1994. The objects of this Act are consistent with sustainability objectives and guiding principles. It guides decision-making in relation to commercial fishing at Ningaloo. However the non-market value of fish resources to the community and the ecology are yet to be translated in economic terms.

Australia’s Commonwealth Government legislation now requires that all export fisheries undergo an assessment against guidelines for sustainability. In 2008, the government has committed $15 million to the development of a new fisheries research institute and associated community education initiatives to promote the sustainable use and management of marine resources (Department of the Premier and Cabinet, 2008).
The WA Department of Fisheries has also released a Policy for the Implementation of Ecologically Sustainable Development (ESD)\(^1\) for Fisheries and Aquaculture in Western Australia.

Ecologically Sustainable Development (ESD) is the concept that seeks to integrate short and long-term economic, social and environmental effects in all decision making. It therefore represented a fundamental shift in public policy because it affects all government departments and agencies to some degree. Whilst ESD has proven elusive to implement effectively, the current policy is an attempt to outline a practical and efficient framework to move forward. These principles are contained within the objectives of the *Fisheries Resources Management Act 1994* (FRMA) but it is yet, to demonstrate both to the government and the broader community that they are being achieved.

The ESD policy outlines how sustainability can be implemented within the fisheries sector. It focuses on the environmental components of sustainability that are necessary to complete for the export assessments that Commonwealth Government legislation now requires.

There is however increasing pressure on the marine environment on Ningaloo coast from a variety of users, including those in the aquaculture, fishing and tourism sectors, together with a growing community desire for unfettered access to the marine environment and for conservation of important areas, habitats and species.

\(^1\) The term ‘Ecologically Sustainable Development’ (ESD) was adopted in Australia in the 1980s to emphasise the importance of the environment to long-term survival and to ensure that there was a balanced approach in dealing with environmental, social and economic issues.
While the State of the Fisheries Report 2006-2007 indicates that the majority of commercial, recreational and aquaculture fisheries are being managed sustainably (DoF, 2007) there is concern about the status of the fish populations, particularly on Ningaloo coast, where some species such as the Spangled Emperor, *Lethrinus nebulosus* recently decreased in number and size, caused by recreational fishing (Westera, 2003). The implications from this decrease are yet to be scientifically examined and understood but there has not been a way to represent in economic terms the value of conserving these resources.

1.2.4 *Australian Marine Protected Areas: Ningaloo Marine Park Management Plan*

Australia's definition of a marine protected area is: an 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 other effective means. This definition was originally adopted from by the 1994 World Conservation Union's (IUCN) definition and has been used by Australian governments (DEC, 2008a).

The key points of this definition are: i) the primary objective of the establishment of marine protected areas is conservation of biological diversity; and ii) the protection has to be effective. In the case of public land, effective management means that the area is protected by an Act of Parliament, whereas in the case of privately owned or indigenous land, protection is ensured by a covenant or conservation agreement (DEC, 2008a). Depending on where they are located, marine protected areas in Australian waters are managed by State, Territory or Commonwealth (Australian)
government agencies, or a combination of government agencies. The United Nations Convention on the Law of the Sea establishes Australia’s rights and responsibilities over a vast area of the ocean - some 16 million square kilometres. Most of this area is the sole responsibility of the Australian Government.

Ningaloo Marine Park was declared a Marine Park in May 1987 and includes both Commonwealth and State waters covering a total area of 5,076 km². The Commonwealth boundaries have been extended twice, most recently in April 2004 to incorporate two relinquished petroleum exploration leases. In December 1998, the Commonwealth Government launched Australia’s Oceans Policy with a commitment to integrated and ecosystem-based planning and management. Delivery of the National Representative System of Marine Protected Areas (NRSMPA) is a major focus of the Oceans Policy. Ningaloo Marine Park is part of the NRSMPA. The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of marine protected areas, to contribute to the long-term ecological viability of marine systems, to maintain ecological processes and to protect Australia’s biological diversity at all levels. Marine protected areas within the NRSMPA have been established especially for the conservation of biodiversity and have a secure status (DEC, 2008a).

The Ningaloo Marine Park Management Plan was adopted in 1989 and it covers the Commonwealth waters and the State waters. The State waters include Sanctuary, Recreation and General Use Zones, while the Commonwealth waters are managed as a single whole with similar provisions to the Recreation Zone of the State waters. The Plan identifies the major existing and potential pressures on the ecological, social and cultural values of Ningaloo coast. These are: pollution, aspects of commercial and recreational fishing and tourism, introduced species, petroleum and mineral exploration and production, and commercial shipping (DEC, 2008b).

The Ningaloo Marine Park Management Plan specifies the management goals and
strategies for Ningaloo Marine Park (Commonwealth and State Waters). The goals relate to the strategic objectives of the Marine Park and are presented in Table 1.1.

As illustrated above, the goal of this plan is to facilitate the conservation of marine biodiversity in this area and to ensure opportunities for nature appreciation, a wide range of recreational and commercial activities, research and education are maintained and managed within an ecologically sustainable framework. The plan also provides mechanisms for the local community to participate actively in the ongoing planning and management of the reserves.

Table 1.1  The Ningaloo Marine Park Management Plan strategic objectives

Conservation
– To maintain the marine biodiversity of the Marine Park; and
– To maintain key ecological processes and life support systems.

Recreation
– To provide for and manage recreational and cultural uses to the extent compatible with the conservation objectives for the Marine Park.

Science and Education
– To promote education, nature appreciation and scientific research on the biological, geophysical and cultural values of the Marine Park.

National System
– To manage the area as part of a comprehensive, adequate and representative system of marine protected areas to contribute to the long-term ecological viability of marine and estuarine systems.

Conservation and management of State waters in WA is a complementary mechanism. The relevant authorities and their roles are set out below.

• **The Marine Parks and Reserves Authority (MPRA).** The MPRA is an independent authority, in which marine conservation reserves are vested (i.e. legally entrusted to), on behalf of all Western Australians. The Authority’s functions include the provision of advice to the Minister for the Environment in relation to marine conservation reserve proposals, and to submit management plans for areas that are vested in the Authority. In planning proposed marine conservation reserves the Authority provides broad policy direction to the advisory committee for each reserve and will generally has an observer status at meetings to facilitate information exchange and to provide advice as required.

• **The Department of Environment and Conservation (DEC).** The DEC was formed on 1 July 2006 through the amalgamation of the Department of Conservation and Land Management and the Department of Environment. The DEC has the primary responsibility for managing WA’s marine conservation reserves, and to prepare management plans for consideration by the MPRA. The department facilitates the overall planning process, and specifically supports the Advisory Committee to develop the indicative management plan. It provides technical and policy advice relating to marine conservation matters, and coordinates communications between the committee, sector reference groups, Government departments and the broader community.

• **Other Ministers.** The Minister for the Environment is responsible under the *Conservation and Land Management Act 1984* (CALM Act) for the establishment of marine conservation reserves. The Minister reviews the advice of the MPRA and, after seeking the required approvals of other Ministers, publishes a Notice of Intent.
to create the marine conservation reserve and releases the indicative management plan, for public comment.

• The Minister for Fisheries. The creation of marine conservation reserves has potential to affect the use of an area for commercial fishing, aquaculture/pearling, recreational fishing, petroleum exploration and production and mining. In recognition of this, the CALM Act requires that the Minister for the Environment must seek the approval of the Minister for Fisheries and the Minister responsible for the administration of the Mining Act 1978 before the release of an indicative management plan and Notice of Intent to establish a reserve. Following the consideration of public comment, the Minister for the Environment must obtain the concurrence of the Minister for Fisheries, and the Minister for Resources and Assisting the Minister for State Development before proceeding with the creation of the reserve. Ningaloo Marine Park legislation and management are further presented and discussed in Chapter II and in Chapter III.

1.3 Sustainable Development and Economic Valuation of Biodiversity Conservation

Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth. The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been
achieved at growing costs in the form of the degradation of many ecosystem services and increased risks of irreversible changes. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems (GreenFacts, 2008).

Yet many ecosystem services are largely unrecognised in their global importance or in the pivotal role they play in meeting needs in particular countries and regions (Daily, 1997). For example, ocean ecosystems provide a tremendous service by absorbing nearly 60 percent of the carbon that is now emitted to the atmosphere from human activities, thereby slowing the rate of global climate change.

Although major advances had been made in ecological sciences, resource economics and other fields during the 1980s and 1990s, these new findings appeared to be poorly reflected in policy discussions concerning ecosystems and their health (MEA, 2008). For this reason, in 2001, the Millennium Ecosystem Assessment (MEA) was created by the United Nations Secretary-General Kofi Annan. The objective of the MEA was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MEA involved the work of more than 1,360 experts from 32 countries (MEA, 2008).

According to the MEA, ecosystem services are the benefits people obtain from ecosystems. This definition is derived from two commonly referenced and representative definitions:

1) Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors (Daily, 1997).

2) Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from
ecosystem functions (Costanza et al., 1997).

The MEA definition follows Costanza and his colleagues in including both natural and human-modified ecosystems as sources of ecosystem services, and it follows Daily in using the term “services” to encompass both the tangible and the intangible benefits humans obtain from ecosystems, which are sometimes separated into “goods” and “services” respectively.

It is common practice in economics both to refer to goods and services separately and to include the two concepts under the term services. Although “goods,” “services,” and “cultural services” are often treated separately for ease of understanding, the MEA considers all these benefits together as “ecosystem services” because it is sometimes difficult to determine whether a benefit provided by an ecosystem is a “good” or a “service” (Costanza et al., 1997).

Many of the MEA's authors consider today that supporting and regulating ecosystem services cannot be usefully distinguished. The MEA authors also agreed that the biggest gap is between the supporting-regulating services that are essentially defined by environmental scientists and the provisioning and cultural services whose definition require input from the actual beneficiaries of those services.

According to the Millennium Ecosystem Assessment ecological services classification, at Ningaloo Marine Park such complex relation between ecosystem services and goods include fish recruitment opportunities provided by marine habitats, phytoplankton biomass production, coral reef communities for protection of coastlines through accumulation and cementation of sediments and dissipation of wave energy, shoreline intertidal reefs which provides a valuable food source for fish and shorebirds etc., and environmental amenities such as recreational opportunities, bathing water quality and attractive wilderness and remote coast line.

In Western Australia, and most other industrialized countries with coastal areas, some coastal ecosystem goods and services are subject to increasing scarcity, implying different types of conflicts. One type of conflict might be between those
who demand coastal ecosystem services, for example, between residential people in some remote coastal areas such as in the case of Ningaloo coast and the growing urban population. The former group wants to make a living and has access to a good communication infrastructure, whereas the latter group is increasingly interested in high-quality recreation facilities as incomes in this group grow (Soderqvist et al., 2005). The conflicts that such an increasing demand for coastal services might create are likely to be reinforced by the public nature of many ecosystem services, which implies difficulties for property rights holders, if any, to exclude other people from consuming the services.

These conflicts illustrate that coastal issues are in general not likely to be successfully managed without integrating not only ecological interrelationships, but also the surrounding economic, social and cultural landscape. What contributions can environmental economics, and in particular economic valuation of ecosystems goods and service, make for finding human activities consistent with sustainable development?

The purpose of measuring such values is to integrate them in judgements about what development is ecologically, socially, and economically desirable. One might view this activity as measuring the returns of natural capital in economic terms. This means that environmental aspects are not to be covered by the ecological dimension solely, but also by the economic dimension. However, while these aspects are likely to enter into the ecological dimension in physical, chemical, and biological terms, they appear in the economic dimension as their importance for human well-being expressed in economic terms (Soderqvist et al., 2005). More precisely, welfare economics theory suggests that changes in well-being can be measured as economic values as revealed by people’s trade-offs between scarce resources (Alam, 2003; Dolan and Peasgood, 2007).

As a consequence, environmental change as manifested in, for example, an increased protection of marine ecosystems, involves an economic value as soon as people are
willing to make trade-offs between such a change on the one hand, and other resources, such as income, on the other hand. These trade-offs are typically measured as people's willingness to pay (WTP) for environmental improvements or for avoiding environmental damage. Biodiversity is at the core of the provision of environmental services by marine ecosystems, CO₂ absorption, healthy food chains and recreational opportunities are just a few examples of the importance of biodiversity.

Given the complex links between marine ecosystems and human wellbeing, a prerequisite for an appropriate analysis and action is first of all the implementation of economic methodology able to estimate the biodiversity non-use values. Environmental valuation techniques can provide useful evidence to support marine ecosystem conservation by quantifying the economic non-use values associated with the protection of biological resources. Environmental economics analysis can help guide the design of biodiversity policy by eliciting public preferences on different attributes of biodiversity.

Measuring the economic value of biodiversity conservation (non-use value) can allow to identify a wide range of uses for such values, including demonstrating the value of biodiversity in targeting biodiversity protection, and in determining damages for loss of biodiversity. This can become a fundamental step in conserving this resource.

The analysis and estimation of the non-use values of a marine ecosystems, using for example the recent choice modelling methodology, are extremely important. They allow researchers to study people attitude towards conservation, we can understand their preferences for different environmental management scenarios and at the same time estimate in monetary terms, their willingness to pay to protect a fragile ecosystem for the next generation.
One important aim of this study is to analyse and as far as possible quantify the importance of marine ecosystems to Western Australians in order to make better decisions regarding the sustainable use and management of Ningaloo Reef ecosystem services. The study provides a reliable analysis of Western Australians preferences for conservation and possible alternative management options for Ningaloo Marine Park. These results are useful information for the national and regional coastal management plans and they contribute to an area where there has been a limited number of attempts to quantify the importance of biodiversity conservation.

1.4 Application of Non-use Valuation Analysis in Australia

The aim of this section is to briefly highlight some previous applications of non-use values carried out in Australia. Most of these studies were focussed on terrestrial recreational areas, forest preservation and water supply analysis and none was undertaken on coral reef biodiversity conservation.

One of the first non-use value analyses was done in 1981 by Maxwell & Newman (1981) who examined the costs and benefits of reducing water pollution in Lake Colac, Victoria. The study focused on the willingness to pay by employed individuals for improving water quality, from unsuitable for fishing and suitable only for passive recreation and stock watering, to suitable for fishing, swimming and active recreational uses. Contingent valuation was used in this study and the WTP was estimated about $19 per year per person (Maxwell and Newman, 1981).

Mattinson and Morrison (1985) conducted a cost-benefit analysis to study the alternative strategies for reducing the algae problems in the Peel-Harvey Estuary in Western Australia. They used contingent valuation to value the improved water
quality through reductions in blue-green algae. The WTP estimate for recreationalists was very low ($1.4 per person per year), possibly because of the existence of nearby substitute sites (Mattinson and Morrison, 1985).

Imber, Stevenson and Wilks (1991) estimated the dollar value Australians place on conserving of Kakadu National Park in the Northern Territory, as opposed to mining it. This study was carried out to provide information on environmental values for the Resource Assessment Commission’s Inquiry into the use of the Kakadu Conservation Zone. Contingent valuation was used to elicit willingness to pay for conservation. The results showed that Australians were willing to pay a considerable amount ($12.38 per person per year) to protect the Park from the effect of mining (Imber et al., 1991).

The first non-use valuation applied to recreational use of the Great Barrier Reef was undertaken in 1992 by Hundloe and Blamey (1992). Economic values were derived via the travel cost method (TCM) and contingent valuation method (CVM). A demand curve for the recreational site was estimated by regressing the visitation rates for different geographic zones on explanatory variables, one of which was travel costs. By examining how demand was expected to respond to the imposition of various hypothetical entry fees, the net economic benefits to consumers were estimated. This research indicated that adult visitors (in 1990-91) were willing to pay $8 to visit coral sites in good condition (Hundloe and Blamey, 1992).

By the end of the 1990s, Choice Modelling (CM) was increasingly being used to generate estimates of the value of changes in environmental quality. This is partly because of the informational efficiencies of the technique, but also because of concern about the accuracy of contingent valuation (Rolfe and Bennett, 2007). Choice modelling was applied to environmental estimations in two important case studies in Australia. The first was done by Blamey, Gordon and Chapman (1999), in
assessing the options for the Canberra water supply. The purpose of this study was to provide information to assist the policy makers in their long term water supply planning. For the first time, a different ranking of options (such as recycling water, restrictions, etc.) and different willingness to pay were presented to the respondents. The results indicated that respondents were willing to pay to achieve an increase in water quality a $22 annual increase in the cost of water per person. (Blamey et al., 1999).

The second important study was conducted by Bennett et al., (2001) to value the protection of wetlands in the Macquarie River valley in central western New South Wales. The non-use values estimated in this study are the improvement of environmental quality for wetland rehabilitation, and they provided useful information for policy makers, who were able to generate a range of data to conduct benefit-cost analysis. The willingness to pay per household for an improvement in wetland quality was equal to $36.10 per year (Bennett et al., 2001).

Following these two important studies, choice modelling was also used in Australia for non-use valuation, mainly of terrestrial recreational sites and water use analysis. Choice modelling analysis for biodiversity conservation has not been previously applied in Australia, and this research is the first time that non-use values are being estimated for a Western Australia coral reef ecosystems.

As illustrated above, only few studies were undertaken on non-use values in Australia, and in particular none was done on marine biodiversity conservation of coral reefs.

Economic valuation of biodiversity and ecosystem services is possibly the most powerful policy tool for halting the loss of biodiversity while maintaining incomes and livelihoods. Yet rarely have such approaches been applied to coral reef “hotspots”, which house the vast majority of the planet's marine biodiversity. The importance of this study is hence that it estimates for the first time the value of biodiversity conservation of an Australian coral reef. The economic valuation of
Ningaloo Marine Park can provide a means for measuring and comparing the various benefits of environmental resources like coral reefs and it serves as a powerful tool to aid and improve the wise use and management of these resources.

1.5  Scope and Aims of the Study

As one of the basic problems in the preservation and improvement of environmental attributes, resource under-valuation or the failure of either the market or government to capture all the benefits of the natural environment, can lead to the misuse, misallocation or ruin of the environmental resource. The protection and conservation of natural resources involve considerable social costs in terms of foregone direct-use benefits. Moreover, the lack of information on how citizens value conservation, particularly non-use values, can easily weaken government commitment to consistently allocating an annual budget for conservation. For various economic reasons that economists call market failure, the benefits of protection and conservation are only partly accounted for whereas the costs of protection receive thorough coverage (Dixon and Sherman, 1990). As a result, fewer and smaller areas are protected than is socially desirable. Because governments find it difficult to capture these benefits, budget allocation for the management of protected areas is frequently inadequate.

This study was undertaken to provide information on how citizens value Ningaloo Marine Park through their willingness to pay for its conservation. The results of this study can provide inputs in exploring alternative sources of financing the conservation of Ningaloo.

The substantive aim of this study is to provide policy makers with much needed information on the public benefits that Ningaloo Reef generates in terms of non-use values that accrue to the Western Australia public. The non-use value estimated in
this study is the biodiversity conservation that can be used in benefit-cost analysis of alternative marine conservation management scenarios, thereby enabling sustainable management of the Ningaloo coast. This study uses various well established theories and concepts from economics, statistics, survey research and many areas of environmental science (e.g. marine biodiversity conservation and natural resources management). The research does not try to examine the validity of these concepts and theories. Rather, the methodological aim of this study is to improve the environmental economics methodology of non-use values, using a new approach to elicit citizens’ willingness to pay for conservation.

1.6 Research Questions

The focus of this study, is then on examining the applicability of a non-market valuation method in the context of marine protected areas and the objective of the valuation is the estimation of the non-use values provided by Ningaloo Marine Park. In particular, this study seeks to identify the monetary value that Western Australians place on environmental quality of NMP in terms of biodiversity conservation and protection. Many different land uses occur in Ningaloo Marine Park and with each different land use comes a suite of threats to biodiversity. Some of the threats to NMP marine environment include over-fishing, mining, oil and gas exploration and coastal development. The increased sanctuary zones and funding for management are critical to protecting NMP for future generations. As a point of departure, this study focuses the attention on marine environmental issues on Ningaloo Marine Park, and basically asks:

• What is the role and function of Marine Protected Areas in biodiversity conservation?
• What are the main threats to marine biodiversity ecosystems in Ningaloo Marine Park?

These problems are discussed in Chapters II and III. The second part of this study is dedicated to the economic valuation of biodiversity conservation. The research questions of this section are related to how to estimate the economic values of non-market benefits of biodiversity protection so that they can be incorporated into decision-making processes. Thus it focuses particularly upon the following questions:

• What are the attitudes of Western Australians towards conservation and protection of NMP?
• Does Choice Modelling methodology generate useful information about respondents’ attitudes towards conservation and protection?
• What is the economic value of Ningaloo Marine Park for Western Australians?
• What are the main factors that affected the respondents’ willingness to pay for conservation?
• What specific advice does this study generate for marine planners and policy-makers?
• How can we create economic incentives for biodiversity conservation for NMP?
• What methodological advances does the new Choice Modelling approach offer?

1.8 Thesis structure

Following the introduction, this thesis has eight chapters.

Chapter Two present a marine biodiversity review, focussing the attention on the scientific gaps and difficulties related to coral reefs ecology knowledge. Particular attention is paid to potential benefits of marine reserves and the design of marine protected areas.
Chapter Three provides a detailed description of Ningaloo Marine Park in terms of its physical, ecological and social aspects. It discusses the problems of environmental threats caused by human activities, such as commercial and recreational fishing, petroleum and mineral exploration, tourism, pollution, introduced species, and commercial shipping. Climate change and ocean acidification are also described.

Chapter Four reviews the environmental economic valuation literature of non-use value analysis. It discusses the problems and prospects of the two most important stated preference methods namely Contingent Valuation Method and Choice Modelling. This chapter provides detailed descriptions of the points of strengths and weakness of these two methodologies for valuing environmental goods and services.

Chapter Five comprehensively reviews the international literature review on economic valuation related to biodiversity. The objective is to illustrate the techniques that have been used recently and the results that have been achieved in empirical studies relevant to marine and coral reef biodiversity valuation.

Chapter Six is concerned with the description of the methodology and the designing of survey procedures to be used to estimate the non-use values of biodiversity conservation of Ningaloo Marine Park. This chapter gives the methodological framework of Choice Modelling analysis and presents a detailed focus on the alternative approach used to the survey design in this case. The econometric analysis using the Multinominal Logit model is also described as adopted in this case study.

Chapter Seven estimates the non-use values of biodiversity conservation, using Choice Modelling analysis. A willingness to pay for conservation is derived and discussed with particular attention on the compensating surplus and the implicit prices. A
separate section analyses the main factors that affects the respondents’ willingness to pay. Based on the survey results the Chapter also provides respondents’ priorities, perceptions, preferences and options in regard to different possible conservation management scenarios for Ningaloo Marine Park.

Chapter Eight gives the concluding remarks about the study and provides some alternative policy recommendations for a future sustainable management conservation and protection of Ningaloo Marine Park. This chapter also indicates future research directions.
CHAPTER II

Marine biodiversity coral reef crisis and marine protected areas: theory and recent development

2.1 Biodiversity: Definition and Importance

Many complex and different meanings can be, and have been, ascribed to the term “biodiversity.” Its scope of meaning seems to expand daily. In the Global Overlay Program of the World Bank, for example, many recent forest biodiversity valuation exercises include values associated with carbon sequestration to abate global climate change, even though biodiversity and climate change are the subjects of two quite distinct international conventions.

One might rightfully ask then “If biodiversity valuation can include values for climate change, where does one draw the line in valuation?” The only way to answer this fully is to review the different meanings that one might attach to biodiversity and these different meanings can have different implications for valuation (Ruitenbeek and Carter, 1999). Also, there are important similarities – and differences – among marine, terrestrial and coral reef biodiversity.

Both marine and terrestrial systems are open. Organisms transport themselves across boundaries either under their own steam, or more often transport is provided by physical processes (e.g., wind, land bridges, or ocean currents.) However, marine systems are relatively more open than terrestrial systems because water provides the dispersal medium.
The majority of marine species distribute their larvae among the plankton via ocean currents. As a result, the recruitment line could cover hundreds of kilometres. In terrestrial systems, conversely, long-distance self-powered dispersal is limited; even species which rely on air for dispersal are only air-borne for a limited time. Given the differing patterns of dispersal in marine and terrestrial ecosystems, species endemism is a more common phenomenon on land than in the sea. Marine ecosystems include coral reefs, intertidal zones, lakes, estuaries, and pelagic and deep ocean systems. The relative degree of species and ecosystem biodiversity in these systems depends on the physical characteristics of the particular system. In general, marine organisms exhibit more genetic diversity than terrestrial organisms; and terrestrial ecosystems exhibit more species diversity than marine systems. Marine systems have more higher-level taxonomic diversity than terrestrial environments: among all macroscopic organisms, there are 43 marine phyla and 38 terrestrial phyla; of the 43 animal phyla, 32 live in the sea and only 11 inhabit terrestrial environments (Reaka-Kudla, 1997). However, in a coral reef, which is dominated by substrate, species and ecosystem biodiversity is relatively high; in the open pelagic ocean, where there is no substrate, diversity is relatively low. Because of the existence of substrate, coral reef ecosystems and terrestrial ecosystems share similar structuring processes. Terrestrial ecosystems are dominated by substrate, biotic interactions, and the properties of air. Coral reef systems are similarly dominated by substrate and biotic interactions; but instead of air, they have to deal with the physical properties of water. By contrast, open ocean ecosystems, having no substrate, are dominated primarily by the properties of water. In coral reefs and terrestrial ecosystems – particularly rainforests – physical complexity, high species diversity, high functional diversity, and co-evolved species associations are biologically generated.
To differing degrees, the biota control the structures of these systems. In open ocean pelagic ecosystems, with the absence of substrate, and a more diffuse ecosystem structure is more the result of abiotic forces than biotic interactions. Based on recorded species, fewer than 15 percent of currently named species are found in the ocean (Gaston, 1998) because less work has been done on the Oceans. However, coral reefs rank among the most diverse of all natural ecosystems, comparable to rainforests.

The coral reef contains thousands of species interacting among themselves and abiotic conditions in a crowded marine environment. The result is many fine subdivisions of food and space resulting in high productivity, and efficient use of space. For example, symbiotic algae with coral polyps process the polyps’ wastes thus improving recycling and nutrient retention. Also, diurnal and nocturnal fish species share their specific shelter sites (Ruitenbeek and Cartier, 1999).

The crowded and competitive conditions on coral reefs result in many types of interactions among species. One interaction well developed in the reef is antibiosis: the production by one organism of substances repulsive or fatal to another. These are the highly bioactive compounds investigated for various pharmaceutical properties: such as antiviral, antimicrobial, anti-tumour, and anticoagulant. They are used in the production of pharmaceuticals to treat viral and bacterial infections, cancers, and heart disease. Corals have also developed strategies to protect themselves from abiotic forces; for example, pigments protect the coral organism from harmful ultraviolet rays. These can be used for the production of sunscreens for humans (Ruitenbeek and Cartier, 1999).

The term biodiversity indicates a broad range of biotic phenomena ranging from the smallest unit studied – genetic diversity, to the earliest studied – species diversity, to the recently studied – ecosystem diversity. Within ecosystem diversity, both biotic and abiotic processes are studied as elements of functional, community and
landscape diversity. When discussing the value of biodiversity, one should be clear about what the term connotes.

Genetic diversity refers to diversity within species – its total variety of genes. Different populations of the same species are not genetically identical; nor are individuals within the same population. Therefore, whereas the genetic diversity of a collection of species obviously declines with the extinction of a member species, it also declines with the extinction of a population of that species – a process known as genetic impoverishment (Reaka-Kudla, 1997). In the marine environment, whereas some species extinction events have been documented, the loss of marine biodiversity comes primarily from genetic impoverishment.

Genetic diversity is important for adaptation: those species with high genetic diversity are better equipped to adapt to environmental changes. In agriculture, for example, genetic uniformity in a cultivated species renders that species vulnerable to climatic variations and disease.

Genetic resources, a category of genetic diversity, refers to the actually or potentially useful characteristics and information contained in the genes and chemical substances of microbes, insects, plants, animals, and other organisms. Extracted from these organisms, genetic resources take the form of biomolecules, germplasm, enzymes and chemical compounds to be used for innovation in agriculture, horticulture, pharmaceuticals, and other types of chemical industries producing products ranging from skin care to industrial microbes for waste degradation.

Species diversity refers to diversity among species; it is the variety of different species within a collection of species. In the hierarchical system used to classify living things, species represents the lowest of the main taxa after kingdom (the highest), phylum, class, order, family, and genus.

Estimates of the total number of species on earth range between 5 and 120 million; only about 1.8 million species have so far been described (Reaka-Kudla, 1997).
Species diversity is important for ecosystem health. Ecosystem resilience is affected by the loss of its functional diversity which occurs with the extinction of functionally important species. Some species are functionally redundant meaning that should they be removed, there exist other species within the ecosystem that can assume their function (Leis, 2006).

However, species which provide a critical structuring service in the ecosystem may not be replaceable, and their removal will change the structure of the system. For example, if a key predator is removed from an ecosystem, the dominant prey can then exclude its competitors thereby simplifying the ecosystem structure to a monoculture.

In terms of economic value, species diversity provides a breadth of consumptive opportunities in terms of current and future sources of food, nutrients, medicine, and construction materials. It also provides non-consumptive option and existence values. However, consumptive opportunities afforded by species diversity can become limited or less desirable, as a result of over-exploitation of certain species. For example, the over-harvest of top marine predators for human consumption is resulting in marine catches from lower trophic levels. Due to the over harvesting of these top predators, humans are consuming different species that are further down the food chain; but as we move down the food chain, there are fewer potential species fit for human consumption.

Ecosystem diversity refers to the constituent biotic and abiotic elements and processes of an ecosystem, defined over a particular spatial and temporal scale from days and centimeters to millennia and thousand kilometers. The term includes the concepts of community, landscape, and functional diversity. Community diversity refers to species combinations and interaction, habitat pattern, relative abundance, distribution, population age structures, and trophic structure (Hatziolos et al. 1998).

Landscape diversity refers to the variety of spatial scales and patterns of species combinations across the landscape: the patchiness of the landscape. Functional
diversity refers to the degree of niche subdivision, and the number and abundance of functionally distinct species filling the niches. The maintenance of ecosystem diversity is important for the protection of genetic and species diversity contained within the system, and for the overall resilience of the system.

Ecosystem resilience refers, in general, to the system’s ability to absorb disturbances and renew itself, returning to a healthy-normal state.

A disturbance can be defined as any phenomenon that causes organism mortality. Functional diversity is particularly important in maintaining ecosystem resilience. Research has shown that the more functionally diverse an ecosystem, the better equipped it is to recover from shocks (Walker, 1995).

The economic value of ecosystem diversity stems from its direct use values (recreation, research and education); its indirect values (biological support, physical protection); and its existence and option values. Direct use values are the most obvious because they enter the economy in some way; indirect values are generally less so because their economic value is not priced, or is hidden in production of some other good or service. The biological support provided by a coral reef, for example, can be considerable (Ruitenbeek and Cartier, 1999). For those reasons capturing the “real” economic value of coral reef biodiversity is very complex and hard. The Appendix III and IV present a wide review of coral reef ecology and marine ecology.

2.2 Coral Reef Crisis

Coral reefs have declined over the course of human history, culminating in the dramatic increase in coral mortality and reef degradation of the past 20-50 years (Pandolfi et al., 2003). This “coral reef crisis” is well documented and has stimulated numerous publications on the future of coral reefs (e.g., Hoegh-Guldberg, 1999;
Knowlton and Jackson, 2001; Cinner and McClanahan, 2006) and their vulnerability to environmental change (e.g., Bryant et al., 1998; Dornelas et al., 2006).

The causes of this crisis are a complex mixture of direct human-imposed and indirect climate-related stresses, including factors such as outbreaks of disease, which have suspected but unproven connections to both human activities and climate factors. By 1998, an estimated 11 percent of the world’s reefs had been destroyed by human activity, and an additional 16 percent were extensively damaged in 1997–98 by coral beaching (Wilkinson, 2000, 2002).

Widespread coral bleaching, unknown before the 1980s, has brought recognition that reefs are threatened by global-scale climate factors as well as by more localized threats, and that different types of stress may interact in complex ways. Although the crisis is widespread, individual reefs and even whole regions exhibit considerable variation in both health and responses to stress (Kleypas, 2004).

### 2.2.1 Climate and Environmental Change

Over the past one to two centuries, human population growth and development have greatly altered not only local environments, but also the global environment as a whole. Major systematic changes include rising atmospheric concentrations of greenhouse gases (GHGs) that influence the earth’s energy budget and climate. In addition, the global phosphorus and nitrogen cycles have accelerated because of artificial fertilizer use and massive changes in land use, the hydrologic cycle has been altered by river damming and water diversion as well as climate change, major natural ecosystems have been altered by fishing, forestry, and agriculture, and the ecological and biogeochemical implications of increased atmospheric CO2 levels go well beyond the effects on global temperature (Steffen and Tyson, 2001).
Because coral reefs occur near the junction of land, sea, and atmosphere, their natural habitats experience both the marine and terrestrial results of any climatic change and are vulnerable to human activities. The terms “acute” and “chronic” are used to classify various stress factors, discuss their interactions, and integrate their probable combined effects. Acute stresses are those short-term events that cause rapid damage on a reef (such as from tropical storms), while chronic stresses act over longer terms and are generally associated with more gradual environmental degradation (such as sediment loading). Although some stresses are not clearly either acute or chronic, this approach allows us to discuss reef decline as a combination of stresses, and highlights the need to consider chronic (and usually less apparent) stress as much as acute stress.

2.2.2 Non-Climate Stresses to Coral Reefs

A wide variety of environmental factors that are not directly related to changes in the climate system have the potential to stress coral reefs. Reef communities have been described as “disturbance-adapted” ecosystems (Connell, 1997; Bellwood et al., 2006), but that adaptation is to natural rather than human-enhanced disturbances. Cycles of damage followed by recovery are natural aspects of reef persistence, and coral reefs have been described by Done (1999) as a “shifting steady-state mosaic” a regional population of reef communities that are diverse and changing, but in which all of the important types and components are always represented.

This pattern breaks down when reef communities are lost and fail to recover (as appears to be happening worldwide), or when critical components are lost on a regional scale (e.g., the loss of Acropora species—staghorn and elkhorn corals—in the Caribbean), causing fundamental change in the larger coral reef ecosystem.
Reef decline, as opposed to change or variation, has two components: the initial damage or mortality and the failure of the ecosystem to recover.

Reefs can recover from acute stresses and tolerate chronic stresses, but chronically stressed reefs are far less likely to recover from acute stress (Leujak and Ormond, 2007). As disturbances (acute stresses) become more varied and frequent against a background of deteriorating conditions (chronic stresses), components of the original coral reef mosaic are progressively replaced by noncoral organisms. Environmental alteration and climate change need to be considered together to predict the future trajectory of coral reef ecosystems, since both can cause chronic and acute stresses; both also vary across time and space and are likely to have strong interactions. Table 2.1 and the discussion that follows consider the main human-induced stresses on reefs, whether acute or chronic, and how they interact with climate change and each other. These stresses act over different spatial scales, which is important to understanding responses and possible remedies.
### Table 2.1  Stresses on coral reef ecosystems

<table>
<thead>
<tr>
<th>STRESS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chronic Stresses</strong></td>
<td></td>
</tr>
<tr>
<td>Carbonate ion decrease and reduced calcification</td>
<td>Cooler areas will be stressed first, opposing possible warming benefit</td>
</tr>
<tr>
<td>Temperature increase</td>
<td>Gradual increase may be chronic stress in warm areas, benefit in cool</td>
</tr>
<tr>
<td>Over harvesting</td>
<td>Fishing-commercial, recreational, infish; souvenir, aquarium trade</td>
</tr>
<tr>
<td>Nutrient loading</td>
<td>Land use, agriculture, sewage treatment, biomass burning</td>
</tr>
<tr>
<td>Introduce invasive species</td>
<td>Increased competition and debilitation by parasites, predators or diseases</td>
</tr>
<tr>
<td>Ocean-atmospheric circulation change</td>
<td>Specific predictions are difficult</td>
</tr>
<tr>
<td>Coastal and watershed alteration</td>
<td>Alteration of circulation patterns, runoff, and land-ocean coupling</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Land use-agriculture, land clearing, construction, increased erosion</td>
</tr>
<tr>
<td><strong>Acute Stresses</strong></td>
<td></td>
</tr>
<tr>
<td>Temperature increase</td>
<td>Transient high temperature episodes are major stresses</td>
</tr>
<tr>
<td>Storm frequency</td>
<td>Major factors in land-ocean coupling</td>
</tr>
<tr>
<td>Urbanization, watershed modification</td>
<td>Increase in waste, alteration of land-ocean coupling</td>
</tr>
<tr>
<td>Commercial and incidental destruction</td>
<td>Transportation, tourism and recreational use, mining, dredging, destructive fishing</td>
</tr>
</tbody>
</table>

Source: PEW Centre on Global Climate Change, Kansas by Robert W. Buddemeier and Kleypas 2004
2.2.3 Overfishing and Resource Extraction

Fishing for food and recreation removes fish and other organisms (e.g., giant clams and sea cucumbers), and with them, the ecosystem functions they perform. Many organisms of all types are also taken for use as souvenirs or decorations (mostly shells, but also corals), and for the aquarium trade.

Overfishing, the unsustainable fishing or collection of particular organisms, is a global problem with a long history of impacts across the entire marine ecosystem (Jackson et al., 2001; Pandolfi et al., 2003). Removal of plant-eating organisms (herbivores) from a reef upsets the competitive balance between corals and seaweeds, often leading to a fundamental change in the community.

Coral reefs are limited by the availability of hard seafloor areas of suitable depth. Corals and calcifying algae must compete with no calcifying plants (macro algae, or seaweeds) for this space, so anything that enhances the growth of plant material on reefs can also inhibit the growth of the reef-builders. Plant-eating animals (herbivores) are important controls on seaweeds, and both experimental studies (Lirman, 2001) and field comparisons of heavily and lightly fished areas have shown that reduced herbivore populations tend to result in enhanced seaweed growth at the expense of coral cover (Littler and Littler, 1997; Rees et al., 2007).

One of the most dramatic demonstrations of the effect of herbivory resulted from a gradual loss of herbivores due to overfishing, combined with an acute disease outbreak. Prior to the 1980s, the most important reef herbivores in the Caribbean were parrotfish, surgeonfish, and the black-spined sea urchin, Diadema antillarum, but in many areas the fish populations had been greatly reduced (Hughes, 1994). When a disease outbreak destroyed most of the Diadema populations throughout the Caribbean in 1983–84 (Lessios, 1988), acute episodes of coral mortality (due to hurricanes and other factors) combined with the absence of crucial herbivores to convert coral-dominated Caribbean reefs to seaweed-dominated communities.
(Hughes, 1994; Aronson and Precht, 2006). The chronic stress of over fishing is often hard to avoid on coral reefs. Although seemingly lush and teeming with life, reef communities generate only small amounts of sustainably harvestable biomass. Further, many reef organisms are long-lived and must reach a certain size or age before they reproduce. Removal of large individuals thus has a disproportionate impact on the species’ reproduction. Fishing operations also often have acute destructive effects beyond simple removal of target species. By-catch (incidentally captured non-target species) is often wasted, and damage to other reef organisms and the reef structure itself is common (e.g., from boat anchors or nets). Blast fishing, widespread in the Southeast Asian region, destroys habitat and is extremely wasteful in terms of incidental kills. Muro-ami (“fishnet”) fishers mechanically smash shallow patch reefs and net the fish that are driven out. In areas such as the South China Sea, the shallow sea floor is trawled, and chains are dragged to destroy corals that would snag the nets (Burke et al., 2002).

### 2.2.4 Coastal Zone Modification and Mining

Human efforts to improve or maintain the coastal zone often have unintended ecological consequences. Dredging, land reclamation, shoreline protection, harbour and runway construction, and other similar activities can have direct, acute impacts by destroying coral reef habitats. The impacts of spoil dumping, sediment suspension, or local contamination may become chronic and extend well beyond the immediate site. Less apparent is the potential long-term chronic stress imposed by altering patterns of both marine and fresh water movement (Hitchcock and Bell, 2004). Reef destruction can also result from deliberate mining of nonliving resources. On atolls, reef islands, and in other coastal areas, sand and reef-rock are the only readily
and economically accessible building material. Although healthy reefs produce enough sand to supply reasonable uses, sustainable “harvesting” requires careful attention to where and how the material is removed (Sheppard, 2000).

2.2.5 Harbour Impacts

Globalization has brought increases in the exchange of products and resources around the world. This tendency will continue to grow in the coming years. To cope with such a growing trade, ports will play an indispensable role. They are required to play a more active role in the integration of logistics and to provide better terminals server with lower costs. The following stresses are associate with:

• Vessel movement
  a) Intertidal erosion: A connection between ship movement and potential impacts on the erosion of intertidal flats and salt marshes is difficult to establish. There is low information about the waves generated by the movement of the ships breaking on the intertidal (Bates, 1998).
  b) Re-suspension of sediments: Suspended sediment decreases the amount of light that penetrates the water column and therefore has an impact on plants and algae. The re-suspension of sediments may cause disturbance to sensitive marine animals, particularly due to a smothering effect as the sediments settle. Depending on the quality of the sediments, organic matter, nutrients, and contaminants may be re-released affecting water quality, by the removal of oxygen for example, with possible detrimental effects on marine animals and plants in the area (Berry et al., 2007).
• Cargo operations

a) Discharges: Several materials like grain, coal, iron, clay may cause the production of dust. Handling of liquid bulks may require its charge through pipelines, which provides the potential for leaks, emissions and spillages.

b) Noise from cargo operations: Noise can cause disturbance to animals.

Maintenance operations

Maintenance wastes can enter a harbour as a result of a number of activities including scraping old paint from vessels, cleaning pontoons, cleaning jetties and wharves or cleaning vessels (Laist, 1997).

a) Biocides and bleach: Fouling of harbour structures, such as slipways, steps, jetties, pontoons, can result in surfaces becoming covered in layers of bacterial and algal slime that must be removed. In most cases the use of biocides attends to be the simplest and most effective means of maintaining safe harbours. The impact of chlorine on the marine environment has been monitored for many years and has been shown to be toxic to shellfish and fish as well as causing the localized lowering of species diversity. The relatively widespread use of bleach is encouraged by the fact that it works very well as an inexpensive, easily applied biocidal agent, and there are few non-polluting alternatives, which easily remove algae and prevent its occurrence for sometime (Wang et al., 2008).

b) Detergents: When detergents enter harbour waters they can cause the formation of ‘grey water’ which contains phosphate nutrients that encourage algal growth.

c) Antifouling paints: The most effective means of protecting boats from the fouling is to apply a coating of antifouling paint which contains a biocide that is designed to leach into the almost static layer of water next to the hull preventing organisms adhering to the paint by poisoning the settling organisms. The most commonly used biocides in antifouling paints for recreational vessels and larger commercial vessels have been tributyltin (TBT) and copper compounds. It became apparent that the use
of TBT was causing severe damage to non-target species in the wider marine environment, such as deformities in shellfish and mollusc communities, reduced growth of algae and toxic effects in young fish. The effects of TBT were particularly noticeable on dog whelk populations near harbours and marinas where female dog whelks developed into males (Shimasaki et al., 2006).

2.2.6 Increase in Sediments or Nutrients enhance Algal Growth Rate

Seaweeds play a pivotal role as one of the main groups of primary producers in marine ecosystems. Diversity, distribution and abundance of seaweeds are known to be influenced by both physical and biological factors (Lobban and Harrison, 1994; Choi et al., 2006). Grazing pressure, a biological factor, has been regarded as the major factor controlling the structure of macro algal communities (Anderson and Underwood, 1997). There have been various studies on inter- and intraspecific competition for nutrients and space of macro algae during the last ten years (McCook, 1997, 1999), and they are known to determine patterns of macroalgal dominance or exclusion in coral reef ecosystems. Water motion, a physical factor, has been proven to be a key determinant of macroalgal production (Lobban and Harrison, 1997), influencing a number of abiotic and biotic factors that control macroalgal zonation and community structure, including nutrient availability, temperature and rates of herbivore (Belliveau, 2002). Water motion can also influence the community structure via wave action (Lobban and Harrison, 1997), which influences propagated dispersal, fertilization, settlement and recruitment (Pulido et al., 2007).

The common observation that reefs in high sediment conditions often have high relative abundance of macro algae (McCook, 1999), suggests that increases in sediment loadings might enhance algal growth.
However, the little information available on sediment elects on coral reef algae indicates that sediments are directly deleterious to macro algae. For example, on inshore reefs of the Great Barrie Reef, sediment deposition inhibited Sargassum recruitment and growth (Umar et al. 1998), as predicted from temperate work. Given that most benthic macro algae require stable substratum for attachment, and the probable effects of suspended sediments on algal growth (reduced light due to turbidity, smothering by sediments on algal tissue), it is reasonable to assume that any benefits to the algae from sediments arise indirectly, either through nutrients associated with the sediments, or through reduced competition or herbivory. Increased nutrient concentration will increase algal growth, but only when growth is limited by supply of that nutrient, rather than by nutrient uptake, light availability or temperature (and only when growth rates are not already maximal). The limited data available for coral reef macro algae suggest that this is often but not always the case. In a comprehensive series of laboratory experiments, (Schaffelke and Klumpp, 1998) have shown that growth of Sargassum baccularia is enhanced by increased nutrient concentrations within the range of concentrations relevant to inshore fringing reefs of the Great Barrier Reef, but saturates at moderately high levels. The list of potential stresses on coral reef ecosystems can be continued but it is already clear that this fragile and highly sensitive environment is exposed to dramatic negative influence which can potentially destroy it. If not controlled, human and climate change induced impacts will result in a different, and many ways unrecognisable, coral reef ecology.
2.3 Marine Protected Areas: Theory and Practice

2.3.1 Traditional Approaches to Marine Conservation

Marine reserves have existed in one form or another for thousands of years. In Oceania, permanent reserves were traditionally designated ‘tapu’ or sacred sites (Johannes, 1978) and existed for many generations before the arrival of Europeans. I briefly describe below the sophisticated classification of waters’ use and marine reserves in Maori culture, and the particular distinction between tapu and rahui. Various concepts give an insight into the various ways that traditional concepts and practices, and the Maori world-view that they were based upon, supported the management of waters and life within them. Many Maori continue to view matters through this lens.

• Tapu

Water that had been ritually set aside was waitapu. It was subdivided into: waikino (dangerous water); waipure (water for ritual cleansing); waitohi (waters of dedication, a ceremony somewhat similar to baptism); and waiwhakaheketupapaku (water burial sites). It was essential that water set aside for one purpose not be used for another. Food would not be taken from any waitapu and it would not be appropriate to ritually cleanse in water usually used for burying the dead. Nor was it appropriate to bury the dead in a fishing ground (Williams, 2006).

Today, place-names can be indicators to the classification of waters: Pareora (correctly, Pureora) and Waitohi, both in South Canterbury, New Zealand, were places where ritual cleansing and dedication, respectively, were carried out, not altogether dissimilar activities but each requiring its own form of waitapu. They are approximately equidistant from Waiateruati, the major local traditional centre of
population, but about 10 kilometres in different directions, an indication of the distances folk would travel for the appropriate type of water with which to perform a specific ceremony (Williams, 2006).

Such sophisticated classification of waters indicates the extent to which spiritual concerns permeated traditional society. It was fundamental to any area where resources were harvested that the locality be treated with respect.

- **Rahui**

As with land, restrictions were applied to water bodies in a number of ways. Rahui were temporary restrictions, usually imposed at species level to allow the species to be reserved, or build up after being depleted (Kawharu, 2000). Tapu was a permanent or semi-permanent restriction, usually over a small locality. Wakawaka were divisions, facilitating the sharing of a resource between kin groups. Access to particular stretches of water was limited to certain descent groups, or a succession of eel weirs may be erected, each operated by a different group. Eel drains at hapua (coastal lagoons) are still operated in this traditional way and the licensing of whitebait stands on West Coast rivers is a contemporary usage consistent with the wakawaka principle (Williams, 2006).

In recent legislation in New Zealand, such as the Resource Management Act (1991), and more particularly in the settlement of Kai Tahu’s and other tribes’ treaty claims, various levels of recognition have been accorded Maori vis-a-vis the management of waterways. In some cases this involves concepts virtually unknown previously to the wider New Zealand society. In each case, new management regimes have been instituted, consistent with the Kai Tahu philosophy outlined above, and usually following traditional practice.
• **Aboriginal Australia**

In Australia, Aboriginal has strong spiritual connections with the environment, and strong beliefs about hunting, gathering and eating of foods and in particular the concept of preserve some species.

An important aspect of Aboriginal spirituality is the belief that every person has a totem. “Totemism” describes the relationship between an individual with a plant or animal species: “A totem is in the first place a thing; an entity, an event or a condition. Virtually anything perceivable can serve: plants and animals of all kinds – anything in the entire floral or faunal realms” (Stanner, 1979 pp.23).

Groups may also have a totem: a group totem is ancestral, traceable through a descent line in the language group. A totem serves as the symbol of, and companion to protect the relevant person or group. Where the totem has a physical form, harming it or killing it - sometimes even touching it - is prohibited.

Different clans are assigned different totems and in some cases individuals are given personal totems when they were born. It is custom not to eat, kill or harm their totem. Sharks are a totem of the South Australian Ramindjeri people and are forbidden to hunt them, and Stingray is also the totem emblem for some Torres Strait Islanders (Pring, 2002).

Strehlow (1970) analyse the concept of totem such as an ecological system. The structure he described is entirely characteristic of many regions of Australia. This is a structure in which a regional ritual community is also a community of social and ecological reproduction. It is a community made up of politically autonomous group, each of which is responsible for the well-being of several species and of the other groups. The system is one of interdependence — the rain people, for example, make rain for everybody, humans and non-humans, and they depend on others to fulfil their responsibilities. The kangaroo people depend on the rain people for rain, and take responsibilities for kangaroos. Their actions benefit everybody, including
kangaroos. The people with whom he studied in the north-west corner of the Northern Territory took this a step further in contending that other animals like sharks have their own rituals and law, and that they too take care of relationships of well-being.

Not only in the Northern Territory, but across the whole continent, there are similar structures of restraint, management for long-term productivity, control of sanctuaries, protection of permanent waters, refugia, breeding sites, and selective burning for the preservation of certain plant communities and other refuge areas (Rose, 1996). Contrary to conservative views of hunter-gatherer peoples, Australian Aborigines and other hunter-gatherers have a great deal of ecological knowledge at the levels of information, management, and organization of responsibilities. Totemic relationships connect people to their ecosystems in non-random relations of mutual care. Long-term interests are thus served through responsible care for 'others' as well as responsible care for 'self' (Rose, 1997). The analysis of Aboriginal systems suggests that responsible land and marine management is best accomplished through systems of interpenetrating rights and responsibilities.

Western cultures makes very little use of these traditional knowledge and practices and has created its own approaches to marine and coastal management.

2.3.2 Contemporary Approaches to Marine Conservation

A marine reserve may be defined as a spatial area where some, or all, species receive long-term protection from harvesting. Reserves may exist in certain locations because of natural or physical features, but are also imposed as part of the management of marine resources. In both cases, zero harvesting of all species within a reserve is rare. Reserves or ‘no take’ areas often form a part of larger marine protected areas (MPAs) that have less protection and may include areas that allow for some consumptive use. For example, in the US a variety of activities, but not oil or gas extraction, are
allowed within some areas of ‘marine sanctuaries’. In one of the world’s largest MPAs, the Great Barrier Reef Marine Park, only about one third of its total area is now either within no entry or ‘no-take’ zones while the rest is divided into zones where some form of access and harvesting are permitted.

In recent years marine reserves have received increased attention by both policy makers and researchers. In part, this has been driven by concerns over the need to preserve both representative marine habitat and biodiversity, and because of fears that fisheries management has, in general, failed to adequately conserve marine resources (Ludwig et al. 1993, Helvey, 2004). These issues have led some governments to include MPAs as key components within their management of fisheries and led many others to agree to the implementation of networks of MPAs within the coming decade.

Despite a burgeoning interest in marine reserves, especially in the biological literature, the bioeconomic — the integration of biological and economic — study of reserves is relatively limited. A cause for the lack of bioeconomic models is that many specialists within biology and economics are relatively uninformed about each other’s disciplines.

By contrast to the long-standing and traditional use of marine reserves, the scientific interest and study of the benefits of reserves is relatively recent. In their classic book, On the Dynamics of Exploited Fish Populations, Beverton and Holt (1957) develop a model where in part of the habitat there is no prey or fishing and predict the effects on fishing yields from reserves, or what they call ‘refuges’. They also evaluate the effectiveness of reserves within fisheries regulation and observe that if the rate of transfer of fish from a reserve to a harvested area is too low then a reserve will reduce fish yields, while if the transfer is too high a reserve would provide very few harvesting benefits (Beverton and Holt, 1957). They conclude that for a reserve to increase yields an intermediate case of fish transfer is required, and emphasise the
difficulties of using reserves to manage fisheries because of the complexity in calculating the transfer of fish.

2.3.3 Contemporary Approaches to Conservation Management

Conservation management seeks to regulate human activities to minimize direct and indirect negative impacts on valued sites and valued species, with the goal of sustaining existence of specific species or of biodiversity in general. In either case, activities managed include those that might have direct negative impacts on the target, and those that have only indirect effects, and may have these effects at some considerable distance from the location where the activity takes place. Thus conservation of a coastal marine site or species may require that industrial, agricultural, commercial, and recreational activities conducted on land be regulated, along with fishing or other activities conducted on the water. Although conservation management directed at specific valued species, such as green turtles, manatees, or the jewfish, has longer history, (Sale, 1998), the comments here are restricted to management directed at valued sites because that has been overwhelmingly the more prevalent form of conservation management applied to coral reef regions.

Central to conservation management is the concept of marine management area (MMA), a specific coastal or open ocean location to which specific management actions are directed. Marine protected areas are one of several MMA and MPSs also occur in several forms (Agardy, 1997).

Without distinguishing terrestrial and marine areas, the International Union for Conservation of Nature (IUCN, 1994) recognizes six categories of protected areas, ranging from nature reserves and wilderness areas (Category 1), to managed resource protected area (Category 6), which would include biosphere reserves and
other multiple use MPAs such as the Great Barrier Reef Marine Park (see Table 2.2). Examples of all six occurs in marine environments (Agardy, 1997).

Given the broad range of types of managed areas, and even of MPAs, let alone the fact that some MPAs are managed specifically as no-take (sanctuary zone) for fishery purpose, generalizations are difficult. In all managed areas, however, there is a formal (usually legal) declaration of boundaries of each area, and an attempt to manage one or more human impacts on it (Kelleher, 1995, Doyen and Béné, 2003).

Fish population within MPA boundaries frequently benefit from this management along with other components of the ecosystem, showing greater abundances, individual size, and longevity in MPAs where fishing activities are restricted.

Table 2.2  IUCN’s Categorization of Protected Areas, based on the Objectives of Management (1994).

| CATEGORY 1a – Strict Nature Reserve: Defined as a protected area managed mainly for science. An area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring. |
| CATEGORY 1b – Wilderness Area: Defined as 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. |
| CATEGORY II – National Park: Defined as a protected area managed mainly for ecosystem protection and recreation. A natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible. |
| CATEGORY III – Natural Monument: Defined as a protected area managed mainly for conservation of specific natural features. A region containing one or more specific natural or natural-cultural features which are of outstanding or unique value because of their inherent rarity, representative or aesthetic qualities or cultural significance. |
| CATEGORY IV – Habitat/Species Management Area: Defined as a protected area managed mainly for conservation through management intervention. 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. |
| CATEGORY V – Protected Landscape/Seascape: Defined as a protected area managed mainly for landscape/seascape conservation and recreation. An area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural 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. |
| CATEGORY VI – Managed Resource Protected Area: Defined as a protected area managed mainly for the sustainable use of natural ecosystems. |

Source: IUCN, Ecosystems, Protected Areas & People Project, 1994
Although fisheries management is based (even if not successfully) on a rich body of theory defining how harvested populations grow, conservation management is based far more on compromise and consensus among competing user groups as they reluctantly yield their “right” to use all parts of the commons comprising the reef. Underlying conservation management is a relatively thin base of ecological theory, and the understanding that overexploitation or mismanagement kills reefs.

The theory is thin for two reasons. First, the low level of participation of the ecological community has led to reliance on ecological concepts that are a decade or two out of date. For example, the competitively mediated equilibrium in relative abundances of species that is supposed to exist to unimpacted systems is a good example of a concept that is far less solid than many conservationists appear to recognize. Second, conservation has a longer history in terrestrial systems, and conservation biology is almost entirely terrestrial in focus, so that most theory derives from terrestrial examples. The substantial differences between marine and terrestrial systems mean that this theory does not transfer readily (Agardy, 1997).

The gaps in relevant ecological knowledge extend broadly. For example, there exist many studies documenting the negative impacts of sedimentation on coral survival and growth, but attempts to mitigate anthropogenic sedimentation are driven by rule-of-thumb guides to acceptable levels because the ecological research has not yet led to formulation of tolerance limits.

Similarly, artificial reef are seen as a vulnerable conservation tool in region where natural reefs are sparse but a shallow shelf that could support them exists. However, the building of such artificial reefs is usually done without ecological data on how many, how large, how close together, what shapes, what structural complexity, or what building materials will be best. Too often, they are built of whatever is at hand, and may be more useful as garbage disposal mechanisms than as conservation tools.
Studies such as that of Lindberg (Frazer and Lindberg, 1994)\(^2\) on the west Florida shelf are far too rare. The most egregious gaps in knowledge concern the scale, connectivity, and ecosystem dynamics of marine systems, because these could provide sound ecological reasons guiding management decision such as determining the sitting, sizes, and shapes of MPAs (Roberts, 2003). Instead, these important decisions are made in strongly political process, pitting those who wish to protect sites from human impacts against those who wish to impose minimal restraints on human activities.

Despite several recent, and welcome, calls for the development of integrated networks of MPAs (whether for conservation or for fisheries management), the need to develop the ecological theory necessary to help guide the detailed decisions needed in such an endeavour has scarcely been mentioned (Agardy, 1997). Indeed some argue that to suggest this subverts the urgent need to increase protection now (Ballantine and Langlois, 2007). In a strongly worked call for reserve networks, one large group including several highly regarded ecologists noted that “more information about reserve size and spacing” was needed if networks were to meet management objectives (Murray et al., 1999). They however suggested vaguely that the best way to gain this information was to implement reserve systems and then study how they function. There are more than 1300 MPAs already in existence around the world, many in a reasonable proximity to one another, so I wonder why establishing more is necessary before this neglected research can take place.

Groups of influential ecologists should be able to mount a stronger argument in favour of setting this research as a high priority (Langlois et al., 2006).

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\(^2\) Lindberg used the placement of new artificial reefs by the management agency as an opportunity to test explicit hypotheses about size and placement effects in a properly designed long-term ecological project.
We can be a little optimistic given the signs that a small but growing number of ecologists are undertaking research that will help build science of reef management. Along with targeted field studies, there must be a greater integration of these with theoretical studies if a scientific base for conservation management is to be built (Doak and Mills, 1994; Parsons et al., 2004).

2.3.4 Potential Benefits of Marine Reserves

Reserves can generate a range of potential benefits, some of which may generate spill-over in harvested areas. These benefits arise from reduced mortality and/or decreased habitat or environmental damage due to the establishment of no-take areas. The habitat benefit can be important in fisheries where, for example, evidence exists that bottom trawls used to catch demersal species and dredging for shellfish can damage marine habitats, increase mortality of fish not caught in trawls, and reduce the rate of recruitment of some species (Turner and Paavola, 2003). Kellner et al., (2007) extends earlier work of others from the US National Marine Fisheries Service to list 41 potential non-fishing benefits from reserves. He summarises these benefits under three headings: one, protect ecosystem structure, function and integrity: two, increase knowledge and understanding of marine systems and three, improve non-consumptive opportunities. In terms of non-consumptive benefits, reserves can increase aesthetic and recreational values because of higher population densities and/or larger individuals both within no-take areas and adjoining areas. In terms of ecosystem integrity, a reserve can generate two principal payoffs. First, a more desirable population structure (characterised by age, gender or individual size) within a reserve can increase breeding success and mean recruitment into the harvested population (Roberts, 2003). Second, reserves can result in a greater number (and possibly a greater level of abundance) of species, especially populations...
harvested outside of the reserve and also generate positive harvesting spill-overs for adjacent areas (Lester and Halper, 2007).

In a recent survey of 112 independent measures of marine reserves, Lester and Halper (2007) find, relative to reference sites, that reserves on average appear to double population density, nearly triple biomass and raise size and diversity by 20-30% within reserve boundaries. Where reserves generate benefits, these appear to occur in a relatively short period of time of one to three years, although some of this increase is likely due to redistribution of fish rather than exclusively natural growth within reserves (Sanchirico et al., 2006).

Empirical evidence of the benefits of reserves is also supported in various case studies synthesised by Gell and Roberts (2003), and in a meta-analysis of 19 marine reserves where abundance of targeted fish species was 28% higher within reserves. Such benefits, at least for some reserves, have spilled over to neighbouring exploited areas as evidenced by increased catches per unit of effort and increased population size in adjacent areas (Gell and Roberts, 2003), as well as harvests of larger and often more higher valued individuals.

The empirical studies suggest that the benefits of reserves will tend to be greater the more overexploited are fish populations. Given density dependent growth, however, it is conceivable that long-established reserves that are successful at generating high densities may eventually reduce growth rates and, thus, spill-overs to adjacent fishing areas (White and Kendall, 2007). For example, Béné & Tewfik (2003), in a study of a fishery reserve off the Turks and Caicos Islands in the Caribbean, show the potential for density-induced lower growth rates where a much higher density in the reserve has led to significantly smaller conches.

This suggests that if yield or spill-over benefits of paramount importance, it may be worthwhile in some fisheries to periodically harvest target species within reserves so as to raise yields and spill-overs to harvested areas (Kellner et al, 2008).
2.3.5 Fishing Spill-overs

A key factor in modelling the bioeconomics of reserves is the net spill-overs, or the net rate of transfer of larvae, juveniles and adult fish from reserves to harvested areas. Transfers represent a trade-off in the sense that the more mobile are fish between reserves and harvested area, the less protection provided by a no-take area and, thus, the lower is the spawning biomass in a reserve. In other words, the greater the net transfer out, the larger is the size of the reserve required to maintain the same level of protection from harvesting. For ‘super mobile’ species such as large pelagic fish like tuna and billfish that migrate over thousands of kilometres, the size of the reserve required to reduce fishing mortality could be very large and would also need to account for the migration routes of the fish and where the fish are targeted for harvesting (Kellner et al., 2008). Conversely, although a low transfer rate provides increased protection from fishing, for a given reserve size, it also reduces the benefits to fishers as less fish spill-over to harvested areas.

Roberts (2003) provide an informative review of the studies of spill-overs from reserves to adjacent areas. Despite the difficulties of measuring changes directly attributable to reserves, spill-over studies provide substantial evidence of the potential payoffs from reserves. These benefits come in two main forms: net larval export that can increase recruitment into the fishery in the future and net export of adults that are immediately vulnerable to harvesting (Baskett et al., 2007). Spill-overs, however, are highly dependent on reserve design especially if fish migrate on a seasonal basis and aggregate at different places and times throughout the year (Kellner et al., 2008).

Moreover, transfers from reserves to fished areas cannot be assumed to be a simple diffusion process without reference to currents or other physical factors (Gaines et al. 2003), but requires an understanding of both dispersal distance and the number of
population sources. Indeed, some suggest that the dispersal pattern of larvae is the critical issue when designing marine reserves (Lockwood et al. 2002).

### 2.3.6 Design of Marine Protected Area

The process for designating marine reserves will be more effective if it is driven by well-defined goals (Ballantine and Langlois, 2007), which could include the conservation of healthy natural ecosystems, insurance of fisheries against collapse due to management errors, or many other possibilities. The process should clearly specify how it will address public values, ecological, socio-economic, and enforcement considerations, and the input of fishing communities and other stakeholders.

Goal setting is a crucial first step. MPAs can help to achieve many societal goals, ranging from fisheries enhancements to conservation of natural environments for economic and intrinsic reasons. Since no single reserve design will satisfy all goals equally it is important to specify goals at the step in designation process (Murray et al., 1999). These goals should incorporate the desires of local people, and their enumeration is an opportunity to involve stakeholders early in the reserve creation process. When establishing goals, it should be clear to what area they apply (Roberts, 2003). It is important that these goals are communicated clearly to a group of scientific advisers in a manner that is amenable to their asking relevant questions.

Once goals are clearly defined, the science and enforcement groups can develop relevant design criteria. The criteria should state acceptable ranges for several design elements and highlight how choices of one element may affect how other element are addressed. According with Sladek and Friedlander (2004), scientific criteria will most constructively address several elements:
The total size of the reserve

The habitat types to consider

Critical areas for inclusion

The size, shape, and configuration of individual reserves within a network

Extensive communication with the public helps to inform them of the design criteria and prepare them to draft alternatives for the design of MPA. Although all members of the public deserve the opportunity to present alternatives, special attention should be paid to those stakeholders that spend the most time on the water, including fishers. Scientific and enforcement experts should provide constructive critiques of proposed alternatives, including suggestions of how to make the alternatives fit better with the general design criteria (Sladek and Friedlander, 2004).

In developing design principles, a substantial effort has gone for conservation area, and much can be learned about marine reserve design from them. These efforts have examined and illuminated a wide range of concepts, including (1) minimum viable population sizes, (2) effective population sizes, (3) biodiversity hotspots, and (4) landscape processes (Sladek and Friedlander, 2004).

The first two of these concepts are aimed at ensuring any protected area is sufficiently large to contain a viable population. The latter two concepts are aimed at identifying priority areas for protection and represent two different approaches: Under the hotspot approach, scientists map out the ranges of any and all species of interest. They then analyse those maps to identify hotspots that contain particularly large numbers of species. Ideally, areas should be chosen so that all species are represented in at least one conservation area. This approaches offers the potential to find and use complementary areas to achieve broader conservation goals, but it also raises some concerns (Lundquist and Granek, 2005). Species ranges are not static and may change with developmental stages, seasons, and ecological succession (the natural process of recovery of an area to natural or human disturbance. Moreover,
concern has been raised that areas of high species diversity may in fact be poor quality habitat for many of them (Sladek and Friedlander, 2004).

In contrast, the landscape process approach looks at systems in a more dynamic way. Including an entire watershed as a part of protected area is one simple illustration of this sort of thinking since upstream activities can impact a down-stream conservation area (Kalamandeen and Gillson, 2006).

Researchers have already identified some guiding principles for designing marine protected areas. Ballantine (2003) identified three important concepts: i) Representation of all habitats; ii) Replication of reserve units to avoid losing too much from the occasional poor quality area; iii) Networking the reserve units in a self-sustaining manner. Roberts (2003) added a few additional rules of thumb. They recommended prioritising site to most efficiently achieve the greatest result. Specially, they recommended preferentially including four site categories:

- Sites that include vulnerable habitats
- Sites that contain vulnerable life history stages
- Sites that are capable of supporting exploited species or rare species
- Sites that provide ecological services

The services include coastal barriers and water purification but might also include places that have special non-consumptive value, like a popular diving spot. These authors also recommended avoiding sites with very high threats from human or natural disasters.

Although a number of different factors can influence MPA design, two stand out as especially important: the fluidity of ecosystems involved and the extent of damaging activities outside the reserve (Sladek and Friedlander, 2004). Not coincidentally these two factors underlie our ability to rely on the sea for wild-caught food. This fluidity is a crucial factor because reserves will be more effective the better they retain adults, although some degree of export reproduction is desirable. The extent of damaging activities is important because it determines the extent to which reserves have to
accomplish all management objectives. For example, high yields can be achieved from many fisheries in the absence of MPAs if fishing is at relatively low levels, carefully controlled, or both. In contrast, very large reserves may be necessary to achieve similar fishery yields if fishing activities are high in the remaining fishing grounds (Halpern et al., 2004).

Another crucial marine reserve design factor is the degree of outside impacts. For example, models have shown consistently that maximum yields can be obtained over a range of reserve sizes depending on the intensity of fishing outside the reserve (Abesamis et al., 2006). If impacts are light and strictly controlled outside of reserve, marine reserve may not be necessary. However, experience suggests that fishing rates rarely stay light and even less frequently under strict control of managers (Myers and Worm, 2003). In addition to modelling reserve design based on the scales of outside impacts, managers may wish to reduce the magnitude of outside impacts on reserve. One way in which managers can do so is by integrating reserve with coastal zone, ecosystem, or broader ocean zoning management plans. Another way is through the creation of linked land-sea protected areas that protect adjacent terrestrial and marine areas. Reserve designations can help to protect the designed area from fishing, point-resource pollution, and other direct human impacts, but may not offer protection from non-point source runoff (Lundquist and Granek, 2005).

As a result, it may be desirable to locate marine reserve downstream from terrestrial protected areas, or at least to enact stricter controls on upstream development if a reserve is put in place. In some cases, though, it may be necessary to scale up the size of marine reserve to account for major disturbances such as oil spills (Allison et al., 2003).
Zoning Marine Protected Area

The notion of zoning is well-developed on land, but there is little experience with what adjustments might be needed to apply it effectively in an aquatic environment. One reason is that this concept is at odds with the traditional view that the ocean is “free to all” and “boundless,” able to accommodate all uses in its vast expanses (Zinn, 2005). This view, which was more widely accepted when technology to gain access to deep water resources was limited and the deep ocean was characterized as a vast and largely unknown “ocean desert,” has contributed to widespread support for treating the ocean as common property beyond territorial boundaries.

In these offshore areas, the ocean has no owners and is considered to be managed as a public trust to benefit humanity (Russ and Zeller, 2003). In recent years, however, zoning has been getting more attention. This attention is a response to technological advances that permit greater access and more uses of the marine environment, including the water column, ocean floor, and subsurface resources.

Nations have become more aware of the need to discuss how to manage uses that affect common property and open access resources, and how to distribute the benefits from exploiting those resources, and zoning is one component of these discussions (Smith and Wilen, 2003). At the same time, scientific research is developing a more accurate accounting of baseline conditions in the marine environment and effects of technologies on these conditions. Policies that recognize these finite qualities are more likely to recognize the benefits of establishing MPAs (Zinn, 2005).

As ecosystem management is more widely applied, zoning will become of greater importance. While there is much experience in making management plans, far less attention has been given to zoning, even though it is at the heart of the management of a large MPA.

It is not possible to propose a “turn-key” model for zoning which would be
appropriate, unmodified, in any country or situation. For example, the sections on public participation depend on factors such as literacy and methods of information distribution. The essential points are that the usage patterns, expectations, attitudes and local knowledge of users should be determined in the planning stage and that planning should not be allowed to become the task of remote experts with no direct contact with or understanding of local issues (Richardson et al., 2006).

A zoning plan is the means by which planners and managers define the purposes for which each part of a protected area may be used. It may be in the form of a legal document but it must be capable of being understood by those whose actions it seeks to control. Planners and managers should encourage public understanding and support for the management objectives of such plans.

The format of a zoning plan will depend on its legislative basis and on the procedures of the agencies responsible for the plan. It could be in the form of a locally adopted municipal plan for a small MPA, or a nationally endorsed legal instrument, as required for example under Australia’s Great Barrier Reef Marine Park Act.

According to Kelleher (1998) the main objectives of a zoning plan are:
- To provide protection for critical or representative habitats, ecosystems and ecological processes;
- To separate conflicting human activities;
- To protect the natural and/or cultural qualities of the MPA while allowing a spectrum of reasonable human uses;
- To reserve suitable areas for particular human uses (e.g. whale watching), while minimizing the effects of those on the MPA;
- To preserve some areas of the MPA in their natural state undisturbed by humans except for the purposes of scientific research or education.

Such a zoning approach would enable managers to address a broad range of threats to and conflicts about protection and use of marine resources. Conservationists and
fishers do not monopolize conflict about use of the ocean (Sladek and Friedlander, 2004). There are also rifts between commercial, recreational and subsistence fishing; between motorized and non-motorized water sports; and between fishing and oil drilling, just to name a few. Zoning provides an opportunity to reduce all these conflicts by designating areas where each activity is allowed.

2.3.7 Networks of Marine Protected Areas

In this paragraph I describe a process that aims to develop reserve networks which conserve biodiversity, support fishery production and management, and provide other ecological services of value to people. Those criteria are fully grounded in what we currently know about marine ecological processes and this approach is explicitly directed toward development of reserve networks that will simultaneously fulfill multiple goals (Monk et al., 2008).

To design functional marine-reserve networks that fulfill multiple goals, we must bring together the objectives of different stakeholder groups. In the past, fragmentation of management objectives among different interest groups has led to the establishment of reserves based upon too narrow a set of criteria (Roberts, 2003). This has resulted in wasted effort, higher costs, and a false sense of protection. For example, fishery agencies have often created numerous single-species closures in an attempt to manage species one by one. However, the costs of implementing such closures, in terms of selection, demarcation, and enforcement, may be similar to the costs of establishing fully protected reserves that could achieve a far broader range of objectives, including the protection of commercially important species (Leslie, 2008). While individual reserves can provide multiple benefits, not every reserve will serve all objectives equally well. Goals can be viewed at the level of individual reserves or at network level. Networks will include reserves that, through their placement, may
perform different primary roles. However, overall goals for the network are achieved through the combined effects of those reserves (Roberts, 2003). The development of multi-functional reserve networks can serve as a means of coordinating the activities of agencies that have different primary goals. The establishment of marine reserves almost invariably attracts controversy, arising from the proposed restriction of existing activities (Lester and Halpern, 2008).

A major impediment to the acceptance of reserve proposals is that often only a single candidate site is under consideration. The process of reserve establishment would be made much easier if there were biologically suitable alternative candidate sites, identified by scientists together with other stakeholders, that could be fed into the socio-economic stages of selection (Roberts, 2003). Therefore a guiding principle in the development of reserve networks should be to seek multiple alternative network designs that will all perform satisfactorily on biological grounds. Choices can then be made among them according to socio-economic concerns, without the sacrifice of ecological functionality.

Reserve establishment can also be approached at many scales including local, regional, and national levels. At the largest scale, planners seek to create networks of reserves that will be sustainable over the longest time scales. However, networks are often built at the national or sub-national levels initially, and this scale may be smaller than the scale at which ecological processes operate. It is important for large-scale processes to be considered, whatever the scale of reserve selection.

The criteria can also be applied to local scale problems such as the zoning of multiple-use marine management areas (Airamé et al., 2003) or defining the boundaries of a single proposed reserve. At these different scales, some criteria assume greater importance than others. For example, in zoning a small reserve, biogeographic representation is probably irrelevant because the entire area lies within a single region. In establishing the boundaries of a single reserve, connectivity with others may also have little influence on design, whereas maximizing the
inclusion of viable habitats, and assuring linkages among them, may be of much greater concern (Airamé et al. 2003).

Roberts (2003) suggests that there is a logical sequence in which the criteria should be considered, and the first two criteria are of prime importance whether conservation, fisheries management, or other human benefits are the primary goals of the reserve network.

They are “biogeographic representation” and “habitat representation and heterogeneity.” These criteria aim to capture the full spectrum of biodiversity in reserve networks. Next, candidate sites are screened according to human threats and the likelihood of natural catastrophes. Sites where risks are too great are rejected.

Following this, the relative values of sites as reserves can be gauged with a series of modifying criteria. They can be applied in any sequence, and the order in which they are used depends largely on the objectives envisaged for reserves (Size, Connectivity Ecosystems Linkage and Ecological services for humans).

**Biogeographic Representation**

The objective in applying this criterion is to ensure representative coverage of all biogeographic regions in protected areas, including transition zones. This is fundamental for the protection of biodiversity. To apply this criterion, it is first necessary to determine what biogeographic regions exist within the overall target area. As a first step, the distribution patterns of the fauna and flora should be analyzed to determine if there are distinctive biogeographic provinces within the region. For example, Bustamante et al. (1999) defined different biogeographic regions of the Galapagos Islands based on composition of fish, invertebrate, and seaweed assemblages. They used this information to help select sites for fully protected zones within the Galapagos Marine Reserve. Day and Roff (2000) set out a detailed scheme
for classifying marine habitats and biogeographic regions in Canada as a basis for
designing a representative system of marine protected areas for the country.
Ballantine and Langlois (2007) also emphasized the need for replication of reserves
within biogeographic regions. Isolated reserves may provide little long-term
protection for species or habitats.
Conserving the functioning of an ecosystem, i.e., maintaining the ecological
processes of that system, requires attention not only to species but also to functional
groups of species. In a species-poor ecosystem, each primary process (primary
production, decomposition, nitrogen fixation, capture of water, habitat creation,
recycling of nutrients, etc.) may be provided by many fewer species than in a species-
rich ecosystem. Hence, from a functional standpoint, maintaining species-poor
systems may be as important as the more traditional focus on species-rich systems. In
a species-rich system, many species are likely to coexist with others that perform
similar roles (Caliman et al., 2007). Therefore, removal of any particular species may
not result in serious disruption of the process because other functionally similar
species may be able to compensate for the lost species. However, species loss in a
low-diversity system may lead to complete loss of a process. For example, the
devastating El Niño of 1982–1983 destroyed 95% of corals throughout large areas of
the eastern Pacific, a low diversity area where only 4-8 genera of corals were
responsible for reef growth (Wellington and Glynn, 2007). Coral reefs in the eastern
Pacific have declined further since this El Niño, whereas recovery may have been
possible from a similar event in the western Pacific where 50 genera are reef builders
(Nanette and Furman, 2006).
This question can now be tested empirically in diverse areas of the Indo-West Pacific
where reefs were devastated by extensive El Niño related coral bleaching in 1998
(Wellington and Glynn, 2007).
The traditional emphasis on targeting highly diverse areas for protection is
appropriate if the focus is on species. However, low-diversity areas must not be over-
looked because they may be in greater need of protection to maintain ecosystem functioning. A focus on species richness alone ignores the vulnerability of low-diversity systems (Roberts, 2003).

**Habitat representation and heterogeneity**

This criterion seeks to achieve protection of the full range of habitats present in a biogeographic region. Habitats should first be defined (e.g., mangrove swamps, sandy beaches, coral reefs) and agreement reached on the overall list of habitats that occur in a region. Candidate sites can then be compared on this basis. Several general rules guide the selection of habitats (Scopelitis et al., 2007): (1) All habitats must receive protection. (2) Each habitat should be protected in more than one area, as a guard against local catastrophes, to support exchange of propagules among sites, and to provide replicate sites for monitoring and research. (3) The total area set aside for the protection of each habitat should be approximately related to its relative prevalence in the region. If there is a global target to protect, say, 20% of the marine environment, then 20% of the area of each habitat should fall within reserves (Roberts, 2003). For example, if a habitat covers 50% of a region, then one fifth of that 50% would be incorporated into reserves. (4) Special care should be taken to guarantee inclusion of rare habitats.

Habitat heterogeneity provides an important means of evaluating and comparing rival candidate sites. Ideally, all chosen reserves should contain a mix of habitats. The desirability of an area for conservation will increase in proportion to the diversity of viably sized habitat it encompasses viable habitat is one which supports populations capable of long-term persistence (Jones, 2007). Habitat heterogeneity in a given area can be quantified as the number of habitats present, divided by the possible total number within the biogeographic region. A second and complementary measure
takes into account whether those habitats are already conserved elsewhere (Roberts, 2003). This can be quantified as the number of habitats in the area that are not protected elsewhere (expressed as a proportion of the total possible number of habitats). These quantitative measures can be used as such, or they can be converted into a score or rank for the area.

**Human threats**

Ideally, marine reserves should not be placed where they will be subjected to damaging human impacts, for example in areas close to known sources of contaminants such as outfalls, dumps, or their plumes. A measure that incorporates distance from a source of impact and prevailing currents may help to estimate relative threats from point-source pollution. Non-point source pollution is less easily quantified, but proximity to centers of urban, industrial, or agricultural development may serve as a starting point. However, this is not to say that reserves should never be placed in areas of high risk. Their presence might help mitigate threats, and such areas may be in greatest need of some of the ecological services they could perform, such as water filtration (Daily, 1997).

Catastrophic human impacts are often accidents, such as shipwrecks and chemical and oil spills (Suchanek, 1993; Pineira et al., 2008). These occur on a variety of scales depending on the magnitude and duration of the event. Increased risks are associated with proximity to major ports, shipping lanes, oil pipelines, oil production platforms and refineries, power-generating plants, and chemical production facilities. These are often non-mitigatable threats (Gonzalez et al., 2006). An understanding of the spatial dynamics of such catastrophes will allow reserves to be placed in relatively low risk areas. Replication of reserves should insure that some reserves in a network always remain unaffected (Allison et al., 2003).
In addition, establishing a marine reserve may increase recreational and educational use to the point of generating negative impacts on the protected resources. For example, reserves may incur trampling of vegetation and sessile animals, damage to the benthos from anchoring (Dinsdale and Harriott, 2004), increased turbidity from swimmers and boats, and increased contact with and breakage of sensitive species, such as branching corals, by snorkellers and divers (Hawkins et al., 2005). Reserves may also attract commercial and recreational fishers to their boundaries which may reduce populations of mobile species in small reserves. Poaching may also become a problem as stocks build up.

Reserve sites must be evaluated as to the relative level of threats, both current and anticipated, and the potential for mitigation and/or recovery. In practice, this may often involve a qualitative rating as many areas will have multiple and often overlapping levels of human threats (Aramé et al., 2003). Sites where the overall level of human threat is too great or for which there is almost no potential for recovery should generally be excluded from consideration. Where human threat levels are moderate, the relative recovery potential of sites and need for replication of site types should be considered. Sites for which overall human threat is low should be rated highly on that basis, especially if protection will reduce anticipated future threats. Protected areas whose presence will mitigate existing threats are of especially high value.

**Natural catastrophes**

Areas that are focal points for episodic catastrophes, if they can be identified, should be avoided as sites for reserves since species will have to re-colonize from elsewhere following disturbances. The more frequent and widespread the catastrophe, the less desirable a site will be (Allison et al., 2003). If natural catastrophes are present region
wide, there will be a need for a greater proportion of the area to be protected, and more replication of reserves. One important caveat in applying this criterion is that natural ecosystems may be resilient to catastrophes, such as hurricanes, and damage may be relatively minor. Catastrophes that cause mass mortalities of organisms over large areas, such as severe anoxic events, place the greatest restrictions on candidate reserve sites.

Series of criteria that modify the value of sites as reserves

1) Size

Reserves must be large enough to be viable and fulfill the desired goals. There are no upper limits on size that are relevant to conservation goals, but to achieve an export of fishable stocks they should not be too large (National Research Council, 2000). It is difficult to be precise about what constitutes “too large” because it depends on the species involved and local oceanographic conditions. In general, upper limits are more likely to be set by practical considerations, cost, or user conflict than by biological considerations. Most studies suggest that spill-over of juvenile and adult fish from reserves will be localized (Russ and Alcala, 1996; Murawski et al., 2000; Tewfik and Béné, 2008). The probability of fish leaving a given reserve will decrease as the area of the reserve grows (Chapman and Kramer, 2000). Smaller reserves spread over a management area will thus be better than fewer, larger reserves, but only up to the point when reserves become too small to provide effective protection to species. The safest option will be to have a range of reserve sizes in the network, and it is rare that this is not a natural outcome of selecting and combining areas to cover all habitats representatively (Roberts, 2003).
2) Connectivity

Connectivity, defined here as the transfer of offspring between places, is critical to the function of reserves. Reserves in a network must be close enough to allow organisms to transfer among them. Our understanding of connectivity is rapidly growing but we are far from the stage where a simple and robust decision-making process can be defined for networking reserves (Shanks et al., 2003). However, some rules of thumb might be applied to achieve sufficient connectivity among sites.

Larger reserves will maximize the probability of self-recruitment within reserves for short-distance dispersers while for long-distance dispersers, smaller reserves spaced at broader intervals may have greater connectivity. Attwood and Bennett (1995) demonstrated how reserve networks can be designed to benefit suites of species with different dispersal characteristics. The likelihood of populations in different reserves interacting will grow as the distance between reserves falls. Thus, in spacing reserves, locations that lie mid-way between existing reserves might be favoured because they reduce inter-reserve distance and provide a stepping stone for recruitment. Ballantine and Langlois (2007) have shown how the mean distance between reserves rapidly falls as more reserves are added to a network. Dividing up the total area to be protected into smaller units rather than placing it all in one big unit will bring connectivity benefits (Edward and Codling, 2008). However, since the probability of a reserve providing effective protection to an exploited species is likely to fall with the size of the reserve (Baskett et al., 2007), it is important to be cautious in attempting to maximize connectivity by the establishment of many small reserves.

The process of selecting reserve locations according to some of the other criteria outlined here, such as biogeographic and habitat representation may in itself lead automatically to the development of a network of highly connected reserves (Leslie et al., 2003).

The application of the connectivity criterion for fishery management might also be guided by rules of thumb. For example, in places where currents are strongly
directional, reserves sited in upstream locations will be more likely to supply recruits to the rest of a management area than those in downstream locations (Siegel et al., 2008). Where currents are complex or reversing, a more even spread of reserve locations would be better.

Connectivity represents one of the great challenges to reserve science. Qualitatively, scientists know it is important but are not yet able to quantify it sufficiently to make precise recommendations about spacing and distances between reserves. “Safe” distances, those that provide sufficient connectivity to support populations in reserves, increase with reserve size and the size of reproductive stocks between reserves (Almany et al., 2007).

Thus there is no absolute figure as to how close reserves should be. If fishing depletes populations between the reserves, or if the habitat there is unsuitable for some of the species, then the distance between reserves must be smaller. For this reason, any habitat that is widely separated from other areas with comparable habitat is unlikely to contain the full potential complement of species, and may be a poor candidate as a reserve. Areas extremely isolated from other parental stocks are also more dangerously prone to recruitment failure (Maitland and Lyle, 2006).

Conversely, reserves should not be positioned too close to one another. This will reduce the chance that a local catastrophe will strike more than one of them. There are too many variables for precise limits to be set for what constitutes “too far” or “too close” and it will be safest to have a range of distances among reserves.

3) Ecosystem linkages

Maintenance of ecosystem functioning is a vital goal influencing the placement of reserves. Areas that support other habitats have a high value for meeting both conservation and fisheries objectives (Alcazar-Segura et al., 2008). Conversely, those dependent on other habitats are vulnerable unless adjacent support habitats are also
protected (Polis et al., 1997). Important links among habitats must not be overlooked in assessment of candidate reserve sites.

Here I define such linkages as the flow, or prevention of flow, of materials from one habitat to another that allows, modifies, or modulates the functioning of a given marine and coastal area. For example, protecting bird colonies without protecting their feeding grounds may be a waste of effort (Polis et al., 1997). Protecting rocky shores without protecting the adjacent kelp forests (that dampen wave action and contribute most of the carbon and nitrogen for benthic suspension feeders) may also fail to conserve the rocky-shore communities. To evaluate sites under this criterion we ask: (1) is the area dependent on linkages from elsewhere and are those linkages secure, (2) to what extent does the area serve as a link to other areas, and (3) does the overall network of conserved areas incorporate links necessary for the survival of the ecosystems represented?

4) Ecological services for humans

Services such as coastal protection or water purification, arising from the natural properties of ecosystems, add conservation value to areas (Daily, 1997). Evaluation of reserve sites according to the ecosystem services they provide should be guided by the extent to which such services will depend on protection. If the service will be provided irrespective of protection then it should not influence site selection. Where protection will help guarantee a service or services, then the demand for them (both local and remote from the site if there are linkages) should be used to help prioritize sites. Ecological–economic valuation may be a useful tool in as signing relative values to different sites although the methods are still under development (Armstrong, 2007; Samonte-Tan et al., 2007).
Conclusion

In this section I have described a process that aims to develop reserve networks that conserve biodiversity, support fishery production and management, and provide other ecological services of value to people. Those criteria are fully grounded in what we currently know about marine ecological processes and our approach is explicitly directed toward development of reserve networks that will simultaneously fulfill multiple goals.

A central objective for reserve networks is the maintenance of intact functional ecosystems at regional scales. There is still considerable uncertainty about how to safeguard critical ecological processes, and even what some of those processes are. However, I believe that piecemeal efforts to manage marine resources based on a profusion of reserves with narrow objectives and varying levels of protection will fail to account for essential processes. By contrast, representative, replicated, and fully protected reserves within well-connected networks are much more likely to lead to persistence and resilience of these processes in a changing world. Even so, it will be critical to monitor and assess the performance of reserve networks over time to verify the continued viability of key ecosystem processes (Roberts, 2003).

Fully protected marine reserves have tremendous advantages over other tools for solving management problems in the marine environment. They can achieve so much more than many other piecemeal measures that proliferate, confuse users, and sometimes conflict. However, it must be remembered that reserves form one of a series of tools available to managers and will be most successful when embedded within integrated management structures, and employed in a complementary manner with the full gamut of tools available to fisheries and coastal-zone managers.
MPAs will only be successful if we set them up in the right way and for the right reasons. Only 31% of MPAs currently meet their management goals, because too many are set up in the wrong places or with unrealistic expectations (Jameson *et al.*, 2002). We do not advocate delay in the efforts to improve the sustainability of fisheries, but we believe that we must recognize the serious gaps in our knowledge and take steps to fill them. The best way to do this is to use the existing science in deliberately adaptive management approaches for the design and implementation of networks of no-take reserves (Cowen *et al.*, 2005).

There is a need for targeted funding of research to gain the missing biological information for target species (e.g. mobility, life-history, rates and patterns of settlement and recruitment, connectivity among neighboring populations, and the status of these populations as either sources or sinks); as well as physical information about bathymetry, habitat and hydrodynamics at locations being considered for reserves.

Research is also needed into effective ways of using no-take reserves in combination with established methods for controlling fishing effort. Particularly useful will be cost–benefit approaches to determine the situations under which particular management tools are most effective. Simultaneously, we need to identify information bottlenecks and weaknesses in foundation principles (if they exist). For example, reproduction is often assumed paramount in determining demographics of populations, yet stock–recruit relationships are uncertain in fish, and other ecological factors, such as limits on available nursery habitat, or patterns of connectivity, might be demographically limiting for particular populations (Polunin, 2002). Above all, there is a need for research manipulations that will empirically test the efficacy of no-take reserves as fishery management tools.

Because these experiments must be performed at appropriate spatial and temporal
scales, this research should be done in the context of adaptive management, where
the management intervention is deliberately varied in space or time, so that the
results can be used as an experimental test of stated hypotheses, and where the
intervention is intended to be modified on the basis of the results obtained (Byers
and Noonburg, 2007).

Such research should be carefully planned, using an appropriate design, so that the
results are explicit and powerful tests of hypotheses (Hilborn et al., 2004). This is not
the time to waste opportunities with unreplicated, confounded, or other inadequate
experimental designs. We already know something of the scales of movement of
adults of target species and can investigate how these lead to spill-over from no-take
reserves. The key issue needing attention is to specify the larval dispersal envelopes
of target species, and how these determine connectivity among populations. New
techniques to investigate this crucial issue are rapidly being developed (Thorrold et
al., 2002; Sanchirico, 2005). With explicit data on larval dispersal, it should be
possible to adjust reserve size, placement and spacing to achieve particular
management objectives. For example, if reserves are established at a scale that is
larger than average dispersal distances, they should function as marine sanctuaries
for biodiversity conservation. No-take fishery reserves, however, should be sized
and spaced within dispersal envelopes for selected fishery species as part of the
management of surrounding fisheries. It should eventually be possible to specify
optimal number, sizes and specific locations of a network of no-take reserves to
achieve enhancement of specific fisheries, while ensuring the sustainability of the
network through self-recruitment (Evans and Russ, 2004).

This will require information about local geography, bathymetry and
hydrodynamics in addition to the data on dispersal patterns (Bell, 2008). We are not
yet close to achieving this, and deliberate use of adaptive management approaches
using networks of no-take reserves to test hypotheses will be essential if advances are
to be made. Adaptive management requires the building of a much stronger
collaboration between scientists, fishery managers and the fishing community, with all three groups recognizing that an effective management intervention will be of benefit to all.

Research funding agencies, management agencies, and donor NGOs must recognize that adaptive management done to gain new scientific knowledge is a legitimate activity for funding. Another significant issue is how the broader society perceives the importance and value of marine protected areas as this will in many ways determine the availability of funding for conservation and research. As this is not a straightforward question, the next Chapter examines the suite of methods that we have available for valuation of non-use values.
Chapter III

Ningaloo Marine Park: physical, ecological and social aspects

3.1 Introduction

Ningaloo Marine Park is located along the coast of Western Australia, stretching for about 270 km northwards, from just below the Tropic of Capricorn. The Marine Park includes both State and Commonwealth waters. It encompasses representative habitats of a large marine ecosystem from the shoreline to the edge of the continental slope. Ningaloo Reef, in the State waters, is one of the longest fringing barrier reefs in the world. The aim of this chapter is to present an overview of Ningaloo Marine Park, coral reef ecology description, and socio-cultural and economic aspects of the Park. This chapter is structured as follows: Section 1 describes location and boundaries of the Park, Section 2 is dedicated to the description of the physical environment such as geology and geomorphology, climate, oceanography and ecology. Section 3 describes the social settings that include indigenous and maritime heritage. In Section 4 the major issues related to the national and international management context and zoning scheme of the Park are discussed. The last section is dedicated to the threats from human activities and the potential environmental impacts.
3.2 Location and Boundaries

The Ningaloo Marine Park is located on the north-west coast of Western Australia between latitudes 21°40’ S and 23°34’ S. The Park extends northward from Amherst Point along the western coastline of the Cape Range peninsula, encompassing Ningaloo Reef, and then eastward around North West Cape and southward past Point Murat to include a small portion of the western side of Exmouth Gulf encompassing Bundegi Reef, a coastline length of approximately 270 km. The State Waters portion also includes a narrow, 40 m wide strip of land extending northward from Amherst Point to Winderabandi Point (NMPMP, 2005) and extends three nautical miles (3 nm = approximately 5.5 km) seaward of the Baseline, which follows approximately the line of the reef crest (outer edge of the reef). The State Waters portion of the Park thus comprises the narrow terrestrial strip from Amherst Point to Winderabandi Point, the reef and back reef lagoon which lie adjacent to the land, and extends approximately 3 nm seaward of the reef crest to the State Territorial Waters boundary (see Map 2.1 for references).

Beyond this lies the Commonwealth Waters portion of the Marine Park which extends seaward of the State Territorial Waters boundary a further 6 to 15 km, becoming wider to the south of Point Cloates (see Map 2.1). The two portions of the Marine Park are generally complementary and parallel, with the Park averaging approximately 18.5 km (10 nm) in width. However, there are two areas that are presently excluded from the Commonwealth Waters portion of the Park. These areas, each bounded on two sides by Commonwealth Waters and on the third by State Waters, are located to the north of Winderabandi Point. One area creates a complete break in the Commonwealth Waters portion of the Park opposite Milyering (WA 24-P Parts 2 and 3, see Map 3.1). These excisions are due to the prior presence of petroleum exploration permits which under Commonwealth legislation could not be proclaimed part of the Marine Park. It is intended that, on relinquishment, the
relevant parts of the affected permits be included within the Marine Park. A third area, comprising part of petroleum lease, originally excluded for the same reason, was proclaimed part of the Park on 21 July 1992 following its relinquishment.

The present area of the Marine Park (State and Commonwealth Waters) is 4,566 km$^2$. The Commonwealth Waters portion occupies an area of 2,326 km$^2$ while the State Waters component has an area of 2,240 km$^2$. The terrestrial strip has an area of 5.6 km$^2$ (NMPMP, 2005).

**Map 3.1 Boundaries of Ningaloo Marine Park (Commonwealth Waters).**
3.3 Description of the physical environment

3.3.1 Geology and Geomorphology

The Ningaloo Reef is the largest fringing coral reef in Australia and is over 300 km in length, forming a discontinuous barrier enclosing a lagoon. The lagoon varies in width from 200 m to about 7 km, with an average of about 2.5 km. Gaps regularly intercept the main reef line producing a series of individual elongated reef segments. The lagoonal areas backing the reef are interspersed with occasional patch reefs and near shore platform reefs (Collins, 2002). At the extreme northern end of the Park (north of Jurabi Point) the barrier reef becomes discontinuous and eventually disappears. From here around the tip of the peninsula to Bundegi Reef there are intertidal shoreline reefs and some offshore banks. The southern end of the reef is closer to shore and less continuous and becomes a shoreline fringing reef at Gnaraloo (Figure 3.1). The Park is located on the northern extremity of the Dirk Hartog Shelf (Carrigy & Fairbridge, 1954; Le Provost Dames and Moore, 2000) and can be broadly described as having the following geomorphic features:

- an inner continental shelf section; a reef slope seaward of the reef crest, (characterised by a steep slope in the north of Ningaloo Reef shifting to a gentle slope south of Point Edgar);
- a reef flat (less than 150 m wide) which consists of a discontinuous basement platform of Pleistocene marine or aolian (windblown) sediments or older tertiary limestone bedrock (Collins et al., 2003);
- a gradually sloping back reef which may be several hundred metres wide with either an abrupt shoreward edge or a gentle gradation into the lagoon;
- a lagoonal area landward of the reef, which varies in width throughout the reserves but has an average depth of 2-4 m, characterised by coarse calcareous sands in the shallows and fine calcareous sand and silt in the deeper basins and gutters;
• a shoreline characterised by either sandy beach, rocky benches or low limestone cliffs, sometimes with a sloping beach rock platform or a narrow fringing reef.

Figure 3.1 Gnaraloo shoreline fringing reef

Photo F. Gazzani

3.3.2 Climate

The climate is arid with an annual evaporation of about 2700 mm, far exceeding the annual rainfall along the coast of between 200-300 mm. Rainfall can occur in summer and winter, with summer rainfall from cyclones being irregular but sometimes heavy. There is little freshwater discharge into the lagoon (Kuhnert et al., 2000). Lighter more regular falls occur in winter with June the wettest month of the year.
The proximity of the reef system to shore is in part the result of the region’s characteristically arid climate with low average annual rainfall and extremely low levels of run-off. Although arid, there is considerable variation in the climate both within the region and from year to year. The daytime air temperature on the western side of Cape Range Peninsula in winter ranges between the low to high 20°C. In summer, average daytime temperatures range from the low 20°C to low 30°C. On the eastern side of the Cape temperatures vary more widely. An average minimum of 23°C occurs in January and 14°C in July, with average maximum of 37°C and 24°C respectively (Bureau of Meteorology, 2007). The dominant wind conditions throughout most of the year are the south-east trade winds (Osborne et al., 2000). On the western coast of the Cape the winds are predominantly from the south-west with velocities ranging from 1-3 m/sec to over 10 m/sec with a sea breeze developing in the late morning. Brisk breezes from the south occur around 70% of afternoons. Cyclonic winds although infrequent may be severe, exceeding speeds of 150 km/hr. Winds during Cyclone Vance (1998) were recorded in excess of 250 km/hr (Crowder, 2000; Fieux et al., 2005).

3.3.3 Oceanography

Water movement in the reef system is dominated by both waves pumping over the reef crest and direct wind-driven circulation, with tides serving to modulate the general circulation patterns throughout (D’Adamo and Simpson, 2001). Wave pumping causes oceanic water to flow into the lagoon over the reef crest and fan out laterally within the lagoon proper. Prevailing winds (generally from the south-southwest) cause regular vertical mixing throughout the system and drive relatively strong near shore currents northwards. Flushing of lagoonal waters to the ocean occurs mainly in confined currents via gaps in the reef. Once in the ocean, flushed lagoonal waters are then entrained in either the southward flowing Leeuwin Current
(strongest in autumn/winter) or northward flowing Ningaloo Current (strongest in spring/summer). The Leeuwin Current is a narrow (~100 km wide), poleward-directed surface flow of warm, tropical water located largely along the shelf edge (Feng et al., 2003). The Leeuwin Current (see Figure 3.2) is also driven by an alongshore gradient in steric height which depends on the transfer of water and heat from the Western Pacific Warm Pool (WPWP) (Hanson et al., 2005). The current’s strength depends on the El Nino-Southern Oscillation (ENSO), which is evident in local sea level as a measure of the onshore geostrophic flow (Waite et al., 2007).

This process is locally complicated by the structure of the mainland at Point Cloates, which disrupts near shore lagoonal water movement leading to the formation of eddy currents running counter clockwise to the south of the headland, thereby disrupting linear water movement along the reef (D’Adamo & Simpson, 2001). This process may be a contributory factor in determining the dispersal of larvae within the lagoon and could account for the higher number of temperate species to the south of Point Cloates and tropical species to the north (D’Adamo & Simpson, 2001).

**Figure 3.2 The Australian Currents**

Although the tidal regime determines the timing of spawning for the larvae, a cyclone-mediated disturbance plays a significant role in reducing the egg production and the duration of the spawning season (McIlwain, 2002). Very few studies have examined how and why extreme environmental conditions like cyclones and storms suppress spawning in reef fish. A study on the spawning periodicity of temperate species showed that high-intensity, low-frequency storms in New Zealand and the east coast of Australia lead to a short-term disruption in egg production (Tzioumis and Kingsford, 1995). Recent studies have shown that the physical factors created by strong wind from cyclones and storms can have a negative effect on reproduction in coral reef fish. Increased wave action, currents and turbidity reduce feeding efficiency and food availability (Stoner, 2004). At the moment there is no significant study that examines how the Leeuwin Current and the waves activities suppress spawning in reef fish in Ningaloo Marine Park.

The water movement associated with the northern sector of the Park and the Muiron and Sunday islands is more strongly influenced by the tidal flow of water in and out of Exmouth Gulf. The reef is located just north of the west coast’s major tidal transition zone, which is centred around Carnarvon and which separates the South Western Australian tidal zone (diurnal and micro-tidal) and the North Western tidal zone (semi-diurnal and macro-tidal). The tides in the area are mixed, predominantly semi-diurnal and with a maximum range at springs of about 2 m. Changes in meteorological conditions (such as strong offshore or onshore winds, changes in barometric pressure and cyclones) can also affect water levels (D’Adamo & Simpson, 2001).

The deepwater wave climate off the North West Cape is dominated by perennial long period south-west swell, having a mean annual height of about 1.5 m and seasonally being slightly larger in winter than in summer. Wind-driven waves have a mean annual height of about 1.2 m and seasonally are significantly larger in summer than in winter. The total waves (combined sea and swell) off the North West Cape
are significantly more severe than those experienced anywhere else along the North West Shelf. The total waves have a mean annual height of about 2 m (with little seasonal variation) and will regularly reach 3.5 – 4.0 m in the winter months and 3 m in the summer months (due to non-cyclonic conditions). The predominant wave direction is from the south-west throughout the year (D’Adamo & Simpson, 2001).

Studies of water temperature within the lagoons and in an outer reef channel location over a six-month period showed water temperatures in the lagoon ranged from a minimum of 17.8°C in August (August mean of 20.5°C) to a maximum of 29.8°C in December (mean in December 25.6°C). Mean water temperature in the channel in August 2001 was 24.1°C. Salinities in the Park are generally close to oceanic values (approximately 35 parts per thousand) (Waite et al., 2007). There are subtle differences in salinities within the lagoonal waters, as well as between lagoonal and offshore waters. This is due to local evaporation and the presence of occasionally varying regional currents such as the Leeuwin currents (Hanson et al., 2005).

3.3.4 Marine Biodiversity

The scientific understanding of the ecological values of the Ningaloo Reef has increased significantly since Ningaloo Marine Park was established. However, like most coral reefs, the Ningaloo Reef is a complex ecosystem with high species diversity. A taxonomic census of soft coral and sponge biodiversity, based on specimen collections, has never been undertaken for either State or Commonwealth waters of Ningaloo Marine Park. Most of the reef lies within the tropical belt of the Indo-Pacific Faunal Region with the Tropic of Capricorn crossing the southern end of the Park. The majority of species occurring in the Park are widespread throughout this vast region. Within the southern end of the Park, the Western Australian
Overlap zone begins, ie. a biogeographic transitional zone between the tropical fauna and the highly endemic temperate fauna of the Southern Australian Faunal Region (Greenstein and Pandolfi, 2004). Large proportions of the tropical species are at the southern limit of their geographic range within the reserves. Conversely, a few temperate Southern Australian or endemic West Coast species are at the northern limit of their range within the reserves (eg. the Western Rock lobster, Panulirus cygnus), (NMPMP, 2005). A recent review of literature (Le Provost Dames and Moore, 2000) on the Ningaloo Marine Park noted that the ecosystems represented within the Marine Park may be categorised into:

- *open ocean*, supporting planktonic and pelagic sea creatures including species of fish such as tunas and billfish, whales and whale sharks;
- *the seabed* of the continental slope and shelf, supporting demersal (bottom-living fish, mollusc and crustacean) species, epibenthic plants (algae) and animals (sponges, soft corals) and infauna (burrowing bivalves, crustaceans);
- *coral reef*, comprising the reef and lagoon; and
- *intertidal systems* formed at the point of contact between the land and the sea, including rocky shores, sandy beaches and mangroves.

However, these definitions are arbitrary, as there is difficulty in defining separate ecosystems within the marine environment due to the level of physical interaction between them and the movement of species across the artificially defined boundaries. Thus there is regular exchange between the pelagic and demersal systems for feeding and reproduction, and continuous movement of water and animals between the deep ocean and the reef and lagoon inshore (Le Provost Dames and Moore, 2000). For the purpose of this study the ecosystems categories are briefly described as follows.

- *Open Ocean*

Off the Ningaloo coast the open water habitat is characterised by warm, relatively low salinity and low nutrient water. It supports populations of mainly migratory
species of fish (e.g. mackerel, tuna, marlin and sailfish) and other large marine fauna (e.g. whales shark, dolphins, turtles) (see Figure 3.3). Demersal fish species include snappers, sea perches, emperors, lizardfish and goatfish, among others. These populations are supported by food chains based on phytoplankton, which are the basis of primary production in this environment. The phytoplankton in turn supports zooplankton, which are frequently the juvenile stages of species found in other habitats such as fish and coral larvae, and these directly or indirectly support the higher order predators (Taylor and Pearce, 1999).

- Continental Slope

The continental slope occurs at depths between 170m and 800m. Little is known about the benthic (bottom dwelling) communities that inhabit these deep waters. The limited information from surveys in the Commonwealth waters and the North West Shelf (to the north) suggests that the benthic fauna is dominated by sponge garden habitats, with burrowing worms and crustaceans in the soft sediments of mud, sand and fine ooze (Heyward et al., 2000). A number of shelled molluscs and a diversity of polychaete worms have been recorded (Le Provost Dames and Moore, 2000).

- Continental Shelf

In the northern part of the Marine Park, the continental shelf, which in this area is termed the Dirk Hartog Shelf (Carrigy & Fairbridge 1954), is very narrow, ranging from 5 to 6km. From Point Cloates southward, the shelf becomes wider, reaching more than 30km in width at the southern boundary of the Marine Park. The substrate generally consists of a variable thickness veneer of sand overlying limestone. The predominant sessile flora and fauna are algae and sponges with some soft coral, and there is a diverse mobile crustacean and mollusc fauna. While the benthic communities of the Commonwealth waters component of the Marine Park remain largely unstudied, from the small number of surveys carried out it has been suggested that the benthic fauna in waters deeper than about 40m is dominated by sponges (DoF, 2002). This is consistent with findings in other areas of the west coast.
of Western Australia. Thirty species of echinoderms have been recorded. The high diversity of bottom-living decapod crustaceans recorded from the North West Shelf is expected to occur in the Commonwealth waters with some differences in species between the two areas (Le Provost Dames and Moore, 2000).

**Figure 3.3:** Manta Ray and Whale Shark, north of Coral Bay Photo P. Greco

The North West Shelf of Australia has been identified as a sponge biodiversity hotspot, from the few surveys that have been conducted in the region (Hooper et al. 2002), all to the north of Ningaloo. As these species may have a restricted range, their biology and ecology are very poorly understood. A recent study of Ningaloo Reef
(Rees et al., 2004) could not identify a clear trend in abundance or diversity of the filter feeding communities with latitude. However, sponge density when estimated against total biomass increased with depth particularly at Point Cloates and Mandu Mandu. The soft corals (octocorals) became less prevalent as depth increased beyond the 80m zones (Cassata and Collins, 2007). Scleractinia (e.g. hard corals) were dominant in the shallow zones <40m, which is to be expected due to its long distance dispersal larvae capacity (Whitaker, 2004). Communities of low-density filter feeders are likely to be widespread throughout Commonwealth waters of the Marine Park as they were observed in most locations although their presence at Point Maud was very low. The distribution of medium to high-density communities is patchier and may relate to presence/absence of consolidated substrate, such as low outcropping ledges or exposed and near-surface pavement areas (Rees et al., 2004).

Commercially and recreationally important species are observed in the Commonwealth waters according to a 2004 biodiversity survey (Rees et al., 2004), the Ningaloo densities of red-throat emperor (Figure 3.4) were exceptionally high in comparison to the east coast, where the species is found mainly in shallower waters, and the abundance of members of the tropical snapper genus Lutjanus were less diverse and abundant than expected from the east coast work. Fish diversity was associated with habitats of greater structural complexity and, while these areas will be targeted by recreational and charter fishermen, the depths do not lend themselves to anchoring to the same extent as fishing spots in State waters. It cannot be determined how representative the communities found are for the whole marine park. It seems highly likely, given the spatial variation observed and the high diversity and endemism of the region for some invertebrates such as sponges, that additional notable benthic communities exist in Commonwealth waters at Ningaloo (Rees et al., 2004).
A much more comprehensive survey, which also includes the collection of voucher specimens, will be required before the gradients of diversity for the dominant filter feeding taxa can be established and any hotspots mapped. Variation in abundance and composition of the benthos observed at Ningaloo, while not unexpected, does appear to happen over both large and small spatial scales. On the Great Barrier Reef it has been shown that benthos can vary by an appreciable amount over relatively short distances -tens of kilometres - both along and across the shelf (Burridge, et al. 2003). A key driver of benthic communities in the mid and outer shelf waters at Ningaloo may be nutrient inputs from the waters beyond the shelf. Direct observation of sand waves, even in depths of 150m, suggest very strong internal currents are occurring in places along the reef (Rees et al., 2004). The fact that the bulk of Ningaloo Marine Park lies in depths greater than 20m has created a significant impediment to sampling the benthos adequately, and for this reason, scientific expeditions to the area assessing benthic habitats and biota have tended to be sporadic.

It is clear that the Ningaloo Reef ecological and physical environment is very rich and in many ways unexplored but it is also very fragile and exposed to the human activities in the area.
3.4 The Social Setting and Aboriginal Heritage

3.4.1 Pre-History

Although a full survey of the Western Australian western coastline has not been undertaken, numerous sites of Aboriginal occupancy have been recorded on the Cape Range peninsula. Most sites have been located in the coastal dunes and beneath rock overhangs and in caves in the foothills, rather than in the more inhospitable country inland. Numerous shell middens of varying sizes and camp sites have been located among the coastal dunes, together with a number of burial sites. The age of shell material in the coastal dunes has indicated dates of between 6,000 and 7,000 years Before Present (CALM, 1987).

Several rock shelter sites have also been located in the western fringe of the ranges, overlooking the Marine Park. The most intensively studied of these rock shelter sites are the Mandu Mandu Creek rock shelter, Pilgonaman Creek rock shelter and Yardie Well rock shelter (Morse, 1988, 1993a, 1993b). Radiocarbon dating suggests initial occupancy of the Cape Range peninsula occurred some 32,000 years ago with subsequent intermittent use or abandonment in response to climatic change (Morse 1993a). Materials collected from the sites indicate that both terrestrial and marine resources were exploited for food (Morse 1988) and decorative ornaments (Morse 1993b). These sites represent some of the oldest known exploitation of marine resources in Australia.

Occupancy of the peninsula is reported as sporadic in response to long-term climate-driven sea level change and also shorter-term sequences of adverse (dry) seasons. The unique topography of the area, particularly the central portion of the Park, results in the edge of the continental slope lying very close to shore. Even during the major glaciation some 20,000 years ago, the sea retreated no more than 10-12 km from its present position (Le Provost Dames and Moore, 2000). Consequently the rock shelters remained accessible throughout this and subsequent periods and,
combined with the carbonate composition of the rock, has resulted in the shell and bone fossils being preserved. In other parts of Australia, fringing lands exposed during the major glacial periods are now mostly inundated and records of human occupation have not been preserved (Morse, 1993b).

### 3.4.2 Aboriginal Heritage

During the middle part of the twentieth century, anthropologist Norman Tindale undertook a project to describe the tribal territories of the Aboriginal peoples of Australia (Tindale, 1974). Tindale mapped the northern part of the Cape Range peninsula comprising Cape Range and the eastern coast of Exmouth Gulf and coastal waters as the tribal territory of the ‘Jinigudira’. To the south of the present settlement of Coral Bay and extending south to Quobba Point is mapped as the territory of the ‘Baijunju’ (spelling of tribal names after Tindale, 1974). The ‘Jinigudira’ were located on the North West Cape and its peninsula (the Cape Range peninsula) to a line between the bottom of Exmouth Gulf and Whaleback Hills.

The people were described as coast frequenting who used rafts made of sticks. Most of their food is said to have come from fish traps set in the tidal estuaries. Their language was described as close to that of the ‘Talandji, the neighbouring tribal group to the east. Tindale describes the ‘Baijunju’ as being located “on Lower Lyndon and Minilya rivers. Southwest of the salt marshes to Quobba: east to Winning Pool; north to Giralia and Bullara but not to the seacoast and Exmouth peninsula” (Tindale, 1974 pp128). The coastal portions of the area described by Tindale comprise the present day Ningaloo (southern portion only), Cardabia and Warroora Stations.
3.4.3 Recent Occupation

The Jinigudira people are variously reported to have abandoned the peninsula either prior to European settlement or shortly thereafter, possibly due to a series of adverse seasons which resulted in insufficient food and water to support the population to the incidence of introduced diseases (by whalers or early settlers). Turner (1985) reports that the Jinigudira people were wiped out in the later part of the nineteenth century by an epidemic which also affected the Baiyungu people to the south. The Baiyungu people, however, continued to live in the region and were employed in the pastoral industry and wild pearl shell industries until these became uneconomic (pearl shell), or were affected by industry restructuring (pastoral industry) which lead to great reduction in the workforce on stations and the gradual drift of people toward the major town of Carnarvon.

People living in the Carnarvon area are reported to have regarded Point Maud as a favourite camping area of recent times (Morse and Wright, 1989). At the time of the 1996 census there were about 30 persons who identified themselves as being of Aboriginal descent living in the Shire of Exmouth which includes the northern part of the Cape Range peninsula (Le Provost Dames and Moore, 2000) and many more in the Shire of Carnarvon.

Despite the fact that human population numbers in the area of Ningaloo are relatively low, special efforts have been made to preserve the natural environment by putting a zoning scheme in place.
3.5 Zoning scheme for Ningaloo Marine Park

For administrative purposes, the Department of Environment and Conservation (DEC), divides Western Australia into regions, which are divided into districts. The Ningaloo Marine Park and the Muiron Islands Marine Management Area are located within the Exmouth District of the Pilbara Region, and the day to day operational management of the reserves is the responsibility of the District Manager and staff based in Exmouth. The District staff is supported by the Marine Conservation Branch, which has a central role in providing strategic guidance and assistance to Regional and District offices throughout the State with respect to marine conservation. A several other specialist branches provide support in relation to areas such as enforcement, wildlife interaction management and licensing of nature-based tourism operations (NMPMP, 2005).

The implementation of the zoning scheme is an important strategy for the conservation of marine biodiversity and the management of human use in marine conservation reserves. The zoning scheme may also assist in separating conflicting uses and provide priority for specific activities such as commercial and recreational uses, scientific study and nature appreciation. The partial or total restriction of extractive activities in representative habitats is a key strategy in the long-term maintenance of marine biodiversity values in marine conservation reserves (NMPMP, 2005). In Ningaloo Marine Park, the establishment and maintenance of sanctuary zones in which extractive activities are not permitted has played and will continue to play a key role in the protection of representative areas of important habitat such as mangrove communities, coral reef communities, macroalgal and seagrass communities and soft bottom communities (DEC, 2007). In the Marine Management Area, conservation areas, which are also no-take areas, perform a similar function.

The development of the zoning scheme for the Park and the Marine Management
Area was based on a number of key principles. These principles included:

• the zoning scheme should include adequate and representative sanctuary zones for the primary purpose of marine biodiversity conservation;

• the zoning scheme should include adequate and representative sanctuary zones for the purpose of providing ecological “insurance” via increased resilience to natural and human disturbance;

• the zoning scheme should provide areas free of significant human impact for research and monitoring, nature appreciation via recreation and tourism opportunities and for public education;

• operational principles from the Great Barrier Reef Marine Park Authority’s Representative Areas Program on the design of no-take areas, including having, where possible, no-take areas for which 10 km is the minimum dimension (for coastal bioregions);

• having larger versus smaller no-take areas;

• having only whole reefs in no take areas; and including biophysically special/unique places (eg. spawning areas);

• the application of the precautionary principle which, in this case, means that a lack of scientific certainty about the location, size or number of no-take areas should not prevent the establishment of no-take areas;

• that zoning is one in a suite of management mechanisms for the reserves;

• where possible, the placement of zones to achieve the management objectives should be done so as to minimise impacts on the existing social values.

Source: NMPMP, 2005.
The zoning scheme comprises:

- **Sanctuary Zones** totalling approximately 88,365 ha, which represents 33% of the Park.

Sanctuary zones in marine parks provide for the maintenance of environmental values and are managed for nature conservation by excluding human activities that are likely to affect adversely the environment. The primary purpose of sanctuary zones is for the protection and conservation of marine biodiversity. They are used to provide the highest level of protection for vulnerable or specially protected species, and to protect representative habitats from human disturbance so that marine life can be seen and studied in an undisturbed state (NMPMP, 2005). These zones also provide the opportunity to improve understanding of the key ecological processes of the Marine Park and to obtain critical comparative data with areas of the Park where extractive activities are permitted and/or where environmental impacts may be occurring. These zones also provide other ecological benefits such as refugia for exploited species, replenishment areas, education and nature appreciation sites (via passive recreation and tourism opportunities), ecological ‘insurance’ and resilience against the failure of the adaptive management approach adopted for the rest of the Park, and enhanced resilience to natural and human induced disturbance (Figure 3.5 shows the new delimitation sign of sanctuary zone in Gnaraloo Bay).

- **Recreation Zones** totalling approximately 36,460 ha, which represents 14% of the Park.

Recreation zones have the primary purpose of providing opportunities for recreational activities, including fishing, for visitors and for commercial tourism operators, where these activities are compatible with the maintenance of the values of the zone. Petroleum drilling and production, commercial fishing, pearling and aquaculture are not permitted in recreation zones. *Recreation* zones in marine parks provide for conservation and recreation, including recreational fishing (see Figure
3.6) where this is compatible with the conservation values.

- **Special Purpose** (benthic protection) zones totalling approximately 5,488 ha, which represents 2% of the Park.

The area seaward of the Mandu Sanctuary Zone has been classified as a special purpose (benthic protection) zone. This zone has the priority purpose of conservation of benthic habitat. Trolling by recreational fishers is permitted in this zone, however all other extractive activities are not.

![Gnaraloo Bay sanctuary zone delimitation](Photo. F. Gazzani)

- **Special Purpose** (shore-based activities) zones totalling approximately 687 ha of the coastline, which represents <0.3% of the coastline of the Park.

Special purpose zones in marine parks are managed for a particular priority purpose or use, such as a seasonal event (e.g. wildlife breeding, whale watching) or a particular type of commercial activity (e.g. pearling and rock lobster). Uses that are incompatible with the specified priority purpose are not allowed in these zones. Many areas of the coastline have been classified as special purpose (shore-based activities) zones. These zones are adjacent to sanctuary zones (in which case the
landward boundary of the sanctuary zone has been placed 100 m offshore) to allow recreational shore-based angling to continue. Special purpose (shore-based activities) zones are located adjacent to Murat, Lighthouse, Jurabi, Osprey, Winderabandi, Cloates, Maud and Pelican sanctuary zones.

**Figure 3.6** Recreational fishing sign with the map that describes all the recreational zones

![Recreational Fishing Sign with Map](Photo. F. Gazzani)

- **General Use** zone totalling approximately 132,343 ha, which represents 50% of the Park.

General use zones in marine parks are those areas of the marine park not included in sanctuary, special purpose or recreation zones. Conservation of natural values seems to be the priority of general use zones, but activities such as sustainable commercial and recreational fishing, aquaculture, pearling and petroleum exploration and production may be permitted with the risks of compromising the ecological values of
the marine park. At the moment any sort of petroleum exploration is not permitted inside the Park. All areas not zoned as sanctuary or recreation zones are classified as general use zones at Ningaloo Marine Park (see Map.3.2).

The zoning of the Park in many ways influences the types of the activities that can be supported there. Despite of this, further attention needs to be given to the threats that they may pose to Ningaloo which together with climate change can have serious implications on its ecological health.

3.6 The uses of Ningaloo Marine Park

The uses of Ningaloo Marine Park include indigenous and maritime heritage, commercial and recreational usage, aesthetic and cultural values, science and education. There is a wealth of Aboriginal history in the region associated with the extended occupation of the region. All Aboriginal sites, registered or otherwise, are protected under the Aboriginal Heritage Act 1972. There is also an extensive maritime history in the region associated with early explorers and the trading activities that prevailed along the coast following early European settlement. The reserves represent a very important area for nature-based tourism activities and usage has been shown to have shifted from extractive activities towards non-extractive nature-based activities (Wood & Dowling, 2002). The appeal of the area for visitors includes spectacular coral reefs, a wide variety of large marine fauna, the remote and wild nature of the land and seascapes and the rich maritime heritage. The area’s varying accessibility, via roads and tracks, satisfies a variety of recreation and tourism interests from basic bush camping to established accommodation and facilities at development nodes and population centres.

Recreational fishing is a popular activity in the area and the number of fishers is
expected to increase. Recreational fishers target a variety of species, the most highly regarded being emperor (Lethrinidae), seaperch (Lutjanidae) and cod (Serranidae) species. However, several other finfish and mollusc species is also caught. Recreational fishers employ a variety of methods including line, spear, net fishing and hand collection (Sumner et al., 2002). Commercial fishing activity in Ningaloo Marine Park (State waters) is limited to the waters of the general use zone north of Tantabiddi Creek and south of Point Maud. The unclassified waters of the Muiron Islands Marine Management area are also open to commercial fishing.

The waters surrounding the Muiron and Sunday Islands are highly prospective for hydrocarbons and exploration is anticipated to increase in this region over the next decade. Government policy prohibits drilling for petroleum and production within Ningaloo Marine Park but not within the Muiron Islands Marine Management Area. The next section discusses all the recreational and industrial activities inside and outside the Park and their potential impacts on the environment.
Map. 3.2  Ningaloo Reef Present Situation, 2008
3.7 Pressures from Human Activities

Any natural area subject to human visitation and use is exposed to actual or potential pressures. This section summarises the main human-induced pressures on the key values of Ningaloo Marine Park (Commonwealth Waters). There are also potential pressures from natural disasters, such as tropical cyclones and natural predators, as well as global phenomena such as increased sea water temperatures, but in absence of reliable data are not discussed in this section. The major potential or current human-induced pressures identified as affecting the physical, ecological, social and cultural values of Ningaloo Marine Park (Commonwealth Waters) include: pollution, impacts on target and non-target species from commercial and recreational fishing, and impacts from tourism, introduced species, operations for the exploration and production of petroleum products or minerals, and commercial shipping.

3.7.1 Commercial and Recreational Fishing

Commercial and recreational fishing have the potential for major negative impacts on the marine life of the Commonwealth waters (Chesson and Clayton, 1998; Harris and Ward, 1999; Moran et al., 1995). Some of these include:

- significantly reducing the distribution and abundance of target species thus changing the population structure;
- reducing population levels of non-target species through bycatch;
- major impacts on benthic communities including destruction of flora and fauna, and loss of demersal fish and other fauna through habitat modification (e.g. from trawling);
- bycatch of sea birds, turtles, dolphins and sharks;
• interruption of natural ecological balance through large-scale removal of particular species; and

• increased levels and types of litter which can impact on marine fauna (e.g. through entanglement).

Most of these impacts are more likely to be associated with commercial fishing due to the scale and nature of activities and, in some cases, the number and types of fish and other species which may be affected. However, very high levels of recreational fishing also have the potential to significantly impact on fish populations and increase levels of litter. Potential impacts of both recreational and commercial fishing are reduced through legislative regulation, educational programs and the implementation of government policies such as the Commonwealth Bycatch Policy (Commonwealth of Australia, 2000). Commercial fishing trawler are also potential treats for the coral bottom coverage (Figure 3.7 shows coral damage caused by fishing trawlers south of Coral Bay).

Figure 3.7  Broken corals caused by fishing trawler, south of Coral Bay.

Photo F.Gazzani
While the petroleum industry in Australia generally has a good environmental record, there is still the potential for damage to the sensitive marine communities from exploration and extraction activities. Some of the potential negative impacts from these activities result from:

- accidental discharge of substances (for example, oil, gas or fuel) caused by leakage, spillage, ruptures or blow out;
- emission of high-energy, low-frequency noise during seismic surveys;
- discharge of drilling fluids and cuttings; and
- rig and supply vessel anchors which may disturb bottom sediment or reef structures (Swan et al., 1994).

There is evidence that seismic operations which emit high energy, low frequency noise have the potential to cause stress and possible mortality to marine fauna in certain circumstances. Species of particular concern include cetaceans and large migratory fish (McCauley et al., 2000). All petroleum industry activities are subject to assessment and management under Commonwealth and State legislation. A wide range of technical and procedural measures is in place to ensure that activities are conducted in an environmentally responsible manner.

The proposed salt mine development near Exmouth is at the moment an important environmental issue. This salt mine is very large, some 70 kilometres long and only set a few kilometres back from the coast line. The mine will affect a marine nursery area which produces species that live on Ningaloo Reef and will create a massive toxic waste (Conservation Council WA, 2007). *Halt The Salt* is a campaign dedicated to stopping the construction of the world’s biggest salt mine on the shores of Exmouth Gulf. At the moment there is one salt mine in Lake MacLeod, just 50 km south of Red Bluff, south border of Ningaloo Marine Park (see Figures 3.8 and 3.9).
Figure 3.8  Satellite photo of Dampier Salt Mine in Lake MacLeod. *Courtesy of NASA.*

Figure 3.9  Satellite photo of Lake MacLeod including the salt mine (left-bottom side of the photo) *Courtesy of NASA.*
A total of 1,650 hectares of evaporators have been constructed on Lake MacLeod in 1997 and over twenty crystallisers averaging 20 hectares each are used for salt production with a production of 2 million tonnes of salt per year (Dampier Salt Ltd, 2004). Considering that the 2 million tonnes of salt produced by the Dampier Salt Ltd in Lake MacLeod are transported with commercial ships very close to the south border of Ningaloo Marine Park, this represents an important potential threats for the entire ecosystem, even if we don’t have at the moment any evidence of contamination.

During mining, lakes are further disturbed by using them as rock waste dumps. More pervasive is the disposal of groundwater from the mines onto the lakes. Such water is often very saline (>200 g/l), and is thought to have no effect on the lake (Bowen, 2000). The argument is that the extra water added to a lake mimics the natural environment of minor fillings following episodic rain and that the limited fauna (brine shrimps Parartemia spp. and ostracods, and copepods) is extremely salt tolerant. This may be so, but there is no peer-reviewed scientific research to prove it, just private consultant reports to each mining venture expressing their considered opinions (Timms, 2005).

Salt mining can cause leakage of heavy metals into the environment (Boulton & Brock, 1999); however there is no published evidence of contamination from heavy metals of Australian salt lakes, even in the Western Australian goldfields with their extensive addition of water to the salinas. In some cases (e.g., Lake Carey, WA), monitoring of effluent for heavy metals suggests no problems, but mining operations at other lakes may not be so fortunate. Also secrecy between mining companies and their consultants prevents a true assessment of possible contamination (Halse et al., 2000).
3.7.3 Tourism

While tourism can have a positive influences on the Marine Park in the form of increased awareness among visitors and the community, unless it is managed appropriately it can also have damaging effects. Tourism activities have a potential for negative impacts on the ecological, social and cultural heritage values of the Marine Park. For example, disturbance from inappropriate interactions between tourists and certain large marine fauna may stress the animals (NMPMP, 2005). Low flying aircrafts may also disturb large marine fauna such as whales. At Ningaloo Marine Park, these impacts are minimised by providing guidelines to commercial operators and individuals for interactions with certain fauna such as whales (ANZECC, 2000), whale sharks and turtles (at nesting sites). The Regulations contain provisions for interactions with cetaceans which are consistent with the ANZECC guidelines. While currently there are no commercial wildlife interaction tours in Commonwealth waters, many of the fauna targeted for these tours inhabit the Commonwealth waters as well as the State waters and there is the potential for commercial tourism.

Anchor damage is a common disturbance to coral reefs (Rogers and Beets, 2001) (see Figure 2.10). Increases in the number of injured coral colonies occurred on the intensely anchored sites, similar to results reported from coral reefs that are associated with high levels of human activities elsewhere (Muthiga and McClanahan, 1997, Schleyer and Tomalin, 2000). Anchors cause damage to coral reefs during setting, retrieval, and while at anchor (see Figure 3.10). Corals are broken, fragmented, or overturned as the anchor drops to the substratum. Once set, further damage occurs by the chain dragging across the substratum or wrapping around reef structures. If the anchor lodges under a coral colony, overturning occurs during the retrieval process, particularly if an electronic winch is used. Coral reefs that experience high intensities of boating activities have higher levels of broken corals.
Anchor damage has been identified as a management problem on the Great Barrier Reef at sites that receive high levels of boating activity (Dinsdale and Harriot, 2004). Direct physical damage from snorkeling and diving has been the subject of extensive study and is well documented. The damage inflicted by divers and snorkelers consists mostly of breaking fragile, branched corals or causing lesions to massive corals. Most divers and snorkelers cause little damage in Ningaloo Marine Park; only a few cause more serious or severe damage. Research indicates that reef degradation and change of reef community structure occurs once a certain level of use by divers and snorkelers is exceeded. Repeated injury to colonies and partial colony mortality caused by diver impacts may, over the long term, affect the ability of corals to withstand other environmental stresses (Hawkins et al. 1999, Oren et al. 2001).

Training and briefing of divers and snorkelers will greatly help to reduce negative impacts.

Vehicles travelling along nesting beaches can impact on marine turtle hatchling success. They can damage marine turtle nests and nesting habitat by compacting sand, crushing nests and creating wheel ruts that impede or trap hatchlings on their
way to the ocean. The turtles tend to follow wheel ruts along the beach which increases predation by crabs, birds and other animals. Mauds Landing has been identified as being a hot-spot for intensive four wheel drive traffic (Wilson and Tisdell, 2000).

### 3.7.4 Pollution

Pollution from a variety of sources presents one of the major threats to the values of Ningaloo Marine Park. Sources may be either land-based or sea-based. Sources from the land are limited by a number of factors including the low level of run off from the hinterland due to the generally low rainfall and high evaporation rates, and the limited development of the hinterland. Nevertheless, silt laden run off and contaminants from coastal developments such as townships can be significant after periods of heavy rainfall.

The impacts are greatest on the State waters. A major oil spill, particularly from shipping, would negatively affect water quality and may cause large-scale mortality of some marine life, depending on the location, dispersal and volatility of the oil product. Based on recent history, the risks of such an event in Ningaloo Marine Park are low, but need to be minimised as the consequences could be great, in terms of negative impacts on the social, cultural and recreational values of both State and Commonwealth waters (EPA, 2000).

Pollution which may impact on Ningaloo Commonwealth waters includes:

- flotsam and jetsam from recreational and commercial uses including fishing (e.g. plastic bags, bait straps and fishing lines) and petroleum related activities;
- pollution from shore based activities (e.g. sewage);
- fuel and oil discharges or spills e.g. from vessels (small or large scale); and
• sewage and other wastes from vessels including commercial shipping and waste associated with petroleum activities.

The potential impacts of pollution include:
• reduction in the water quality which may negatively impact on marine species and communities in the Marine Park, especially the coral reefs and associated flora and fauna;
• entanglement of birds, fish and marine mammals and ingestion of marine debris, e.g. plastics, possibly causing death;
• collision of marine fauna with large flotsam; and
• mortality of fauna and flora and damage to habitats from an oil or chemical spill.

Australia has the capability to respond to spills of oil and chemicals, known as the National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances. This plan provides a national framework for responding promptly and efficiently to marine pollution incidents. Nevertheless, the sparse population and limited access of the coastline mean that it would be difficult to quickly put in place oil containment or dispersal measures in the event of a large oil spill out to sea (WestPlan, 2007).

3.7.5 Introduced and other ‘Pest’ Species

The European red fox Vulpes vulpes (Figure 3.11), deliberately introduced to Australia for recreational hunting in 1855, is known to prey on the eggs and juveniles of green and loggerhead turtles which nest on some of the beaches of Ningaloo Marine Park. While the nesting areas are in the State component of the Marine Park, the fox predation impacts on the populations of turtles that forage in the Commonwealth waters. The turtles were mainly disturbed during the camouflage phase of the
nesting process, which could possibly have further implications relating to fox predation (Lutz and Muscick, 1997). Other introduced fauna are known to prey upon marine turtle eggs and hatchlings (Morris, 1997).

Introduced marine pests pose a potential threat to the marine communities. One of the main sources of introduced marine pests, the deliberate release of ballast water, is unlikely to occur in the Commonwealth waters. There is also the potential for the introduction of exotic organisms that may become detached from the hull of a cruising yacht while at port or in a lagoon such as Ningaloo. Nationally, there is a range of activities being undertaken to minimise the risk of marine pest incursions through the National Taskforce on the Prevention and Management of Marine Pest Incursions, and the development of mandatory requirements for ships to manage their ballast water to avoid the introduction of marine pests.

**Figure 3.11** Red Fox (*vulpes vulpes*) in Jurabi Point, Ningaloo Marine Park

![Red Fox in Jurabi Point, Ningaloo Marine Park](image)

Courtesy of Menkhorst

Because Australia is an island continent, it depends on maritime transport; over 95% of its imports and exports are transported by ship. While Australia has taken steps to reduce pest introductions, for example through border controls, incursions continue to occur. Pest species are a threat to marine biodiversity as well as marine industries
such as fishing and aquaculture. For example ships’ ballast water may have the potential to transport cholera organisms (Desmarchelier and Wong, 1998), although an outbreak of cholera would depend on the breakdown of effective public health measures.

In an alarming parallel with the crown-of-thorns outbreaks on the Great Barrier Reef, millions of small coral-eating Drupella snails (Figure 3.12) devastated approximately 100 kilometres of Ningaloo fringing reef in the 1980s. Similar concerns to the crown-of-thorns starfish have been raised on the causes of the outbreaks, possible human causes and on the feasibility of controls. It has been suggested that human influences such as overfishing of natural fish predators, e.g. sweetlips and wrasses and the heavily targeted spangled emperor, may be responsible. As with the crown-of-thorns starfish, further research on the biology and ecology of Drupella is necessary (Zann, 1995). Saueracker (1997) described how the population of Drupella at Ningaloo reef, increased from 100-200 / km2 in the 1970s to 1-2 million/km2, and stated that it had destroyed 90% of corals in parts of the northern reef. Drupella has a thick shell that only large fishes could crack, so overfishing (predator removal hypothesis) may have allowed their population to increase (Hill and Wilkinson, 2004).

The fish population of Ningaloo has declined under fishing pressure. Since Ningaloo is isolated from human development, it is unlikely that extraneous human impact is responsible for the abnormal numbers. Cumming (1999) rightly argues that research is needed to identify the variation in Drupella density to distinguish normal from outbreak populations, and to quantify the impact of Drupella on coral reefs.
2.7.6 Commercial shipping

The Commonwealth waters of Ningaloo Marine Park are used by commercial shipping carrying predominantly domestic freight. There is some international traffic. The main potential impacts from commercial shipping include low level discharge of oil and fuel and possibly sewage and other wastes and noise impacts. The release of flotsam, such as large shipping containers and fuel drums, e.g. during storms, is a potential hazard to large marine fauna and small vessels. A large-scale oil spill from a fuel tanker could result in a significant impact on the marine communities of Ningaloo Marine Park. Under Commonwealth law, all shipping is regulated to minimise impacts from the discharge of wastes, flotsam and oil spills. Nevertheless, the potential threats remain.

Another significant environmental issue is the use of organotins such as tributyl tin (TBT) as biocides in antifouling paints used on vessels to prevent the build up of organisms on the ship’s hulls. Its use has been of critical importance to efficient commerce and to impeding the spread of marine pests, parasites and diseases into ports, harbours and coastal waters (Alzieu, 2000). There is international pressure to
phase out TBT-based antifouling paints because of its extreme toxicity to marine life and its persistence in the environment. The grounding of a Malaysian container ship on Sudbury Reef in the Great Barrier Reef Marine Park in late 2000 resulted in levels of TBT on the Reef that were 100 times the safe level. In the largest cleanup operation of its kind in the world, divers removed flakes of antifouling paint from a 1500 square metre section of the Reef in January 2001 (CSIRO, 2001). The International Maritime Organisation (IMO) is finalising an international convention that would ban the use of organotins in antifouling systems. Under Australia's Oceans Policy, the Commonwealth Government is committed to banning the use of TBT from 1 January 2003 and its presents on vessels is expected to disappear by 2008. Recreational vessels can also contribute wastes to the marine environment.

3.8 Potential Threats to Ningaloo Marine Park

The aim of this section is to present the environmental threats to the coral reef ecosystems resulting from climate change, ocean acidification and coral bleaching. Unfortunately, at our current stage of limited knowledge, it is unclear to what extent Australia's marine and coastal zones will be impacted by climate change, and ocean acidification, specially in the fragile coral reef ecosystems of Ningaloo Marine Park. What is clear is the need to improve our knowledge, data and modelling capacities to help better predict and prepare for the likely challenges of climate change on Australia's coasts and oceans. The ocean acidification issue highlights a wide variety of mechanisms which have been identified that could alter ocean carbon uptake, but in many cases the magnitude, is uncertain.
2.8.1 Climate Change

Despite the presence of the Leeuwin Current, a unique oceanographic feature, the subtropical Indian Ocean has received much less attention from paleoceanographic studies than the tropics. An understanding of the recent climate history of the subtropical Indian Ocean is largely impeded by the sparsity of oceanographic data coverage and the insufficient lengths of many climatic records (Kuhnert et al., 2000). The extensive reef growth of the region provides the potential for sclerochronology, which can overcome this sparsity of data.

As the result of the accompanying increase in sea-surface temperature (SST), the distribution of coral reef communities extends well down the Western Australian coast (Hatcher, 1991). The Leeuwin Current is driven by an along shore gradient in steric height which depends on the transfer of water and heat from the Western Pacific Warm Pool (Godfrey, 1996). The current’s strength depends on the El Nino-Southern Oscillation (ENSO), which is evident in local sea level as a measure of the onshore geostrophic flow (Pearce and Phillips, 1988). Sea-surface temperatures are also influenced by climatic events such as cooling following volcanic eruptions. Gagan et al., (1994) and Crowley et al. (1997) showed that these events may be detected in coral skeletal records. Using a high-resolution record from northern Ningaloo Reef, Gagan and Chivas (1995) identified a cooling event which appears to be linked to the eruption of Mt. Pinatubo in 1991. The event was most pronounced in reconstructed SST anomalies on time scales of several months up to a few years. These authors showed that SST anomalies at Ningaloo Reef correlate with those of the WPWP region, but lag behind by approximately 30 months. Of note is that the anomalies at Ningaloo Reef appear to be amplified by a factor of more than 3 (Kuhnert et al., 2000).

The past 116 years, if entirely related to temperature, suggest a long-term increase in SST with an uncertain magnitude of approximately 1.5°C. The overall warming is not
coupled to a change in the seasonality of the Leeuwin Current, which is apparent in the lack of a trend in annual skeletal amplitudes (Kuhnert et al., 2000). Australia’s iconic coral reefs, the Great Barrier Reef in the east and Ningaloo Reef in the west, are now highly vulnerable to coral bleaching from increased sea surface temperature. It is currently predicted that a warming of $1^\circ$ to $2^\circ$ C will lead to annual bleaching events and large-scale mortality (Hobday et al., 2006).

### 2.8.2 Ocean Acidification

Carbon dioxide (CO$_2$) is one of the most important gases in the atmosphere, affecting the radiative heat balance of the earth as well as the calcium carbonate (CaCO$_3$) equilibrium of the oceans. For 650,000 years prior to the Industrial Revolution, atmospheric CO$_2$ concentrations remained between 180 to 300 parts per million by volume (ppmv) (Petit, 1999; Siegenthaler, 2005). Increased fossil fuel burning associated with industrialization, cement production, and land use changes associated with agricultural activities are causing atmospheric CO$_2$ concentrations to rise, and at increasing rates (rates of increase have risen from 0.25% y$^{-1}$ in the 1960s to 0.75% y$^{-1}$ in the last five years) (Kleypas et al., 2006). The current atmospheric CO$_2$ concentration is about 380 ppmv and is expected to continue to rise by about 1% y$^{-1}$ over the next few decades (Houghton et al., 2001). The rate of current and projected CO$_2$ increase is about 100x faster than has occurred over the past 650,000 years and the rising atmospheric CO$_2$ levels are irreversible on human timescales (Siegenthaler, 2005).

Over the two decades of the 1980s and 1990s only about half of the CO$_2$ released by human activity has remained in the atmosphere, with the oceans having taken up about 30% and the terrestrial biosphere 20% (Sabine, 2004). Similar partitioning of anthropogenic CO$_2$ is expected to continue with the result that the partial pressure of
CO₂ (pCO₂) dissolved in the surface ocean is likely to double its pre-industrial value within the next 50 years. Over the next millennium, the ocean will absorb about 90% of the anthropogenic CO₂ released to the atmosphere (Archer, 1996).

Increasing the amount of CO₂ dissolved in the ocean lowers the pH, and decreases the availability of carbonate ions and lowers the saturation state of the major shell-forming carbonate minerals (Kleypas et al., 2006). Tripling the pre-industrial atmospheric CO₂ concentration will cause a reduction in surface ocean pH that is almost three times greater than that experienced during transitions from glacial to interglacial periods (Sabine, 2004). This is often termed “ocean acidification” because it describes the process of decreasing pH.

Current projections of ocean acidification suggest that the pH of surface ocean waters will continue to decline. However, the term can also lead to confusion when it is wrongly assumed that the oceans will become acidic, when in reality, ocean pH is never expected to fall below 7.0; i.e., the oceans are becoming less basic, but not acidic (Kleypas et al., 2006). Such a phenomenon could only occur in the unlikely event that CO₂ emissions reach more than 10,000 Pg C (Caldeira and Wickett, 2005). In this case, I use the term “ocean acidification” to conform with current terminology, with the recognition that it refers to the process rather than an end state.

Recent field and laboratory studies reveal that the carbonate chemistry of seawater has a significant effect on the calcification rates of individual species and communities in both planktonic and benthic habitats (Gehlen et al., 2005). The calcification rates of most calcifying organisms studied to date decrease in response to decreased carbonate ion concentration. This response has been observed in multiple taxonomic groups— from reef-building corals to single-celled protists. Experimental evidence points to a 5–50% reduction in calcification rate under a CO₂ level twice that of the pre-industrial (Jansen and Ahrens, 2004). The decreased carbonate ion concentration significantly reduces the ability of reef building corals to produce their CaCO₃ skeletons, affecting growth of individual corals and the ability
of the larger reef to maintain a positive balance between reef building and reef erosion (Langdon and Atkinson, 2005).

The effects of reduced calcification on individual organisms and on ecosystems have not been investigated, however, and have only been inferred from knowledge about the role of calcification in organism and ecosystem functioning (Kleypas et al., 2006). This knowledge is limited because calcification rates have only recently been considered vulnerable to increased atmospheric CO$_2$. Coral reef organisms have not demonstrated an ability to adapt to decreasing carbonate saturation state, but experiments so far have been relatively short-term (hours to months) (Delille, 2005).

The effects of changing calcification and dissolution on reef ecosystem functioning are unknown. This includes (1) the interactions of organisms, (2) food web dynamics, (3) basic cycling of carbon and nutrients through the ecosystem, and (4) the services that these ecosystems provide (Kleypas et al., 2006). The role of inorganic cementation in stabilization of organisms, communities, and reef structures has not been quantified; nor has the extent to which inorganic cementation may be affected by a lowered saturation state. Inorganic cementation is considered another component of ecosystem development, as it plays a role in the resilience of coral skeletons and reef structures (Feely, 2004). A wide variety of mechanisms have been identified that could alter ocean carbon uptake, but in many cases even the sign of the biogeochemical response, let alone the magnitude, is uncertain (Denman et al., 1996; Dornelas et al., 2006).

### 2.8.3 Coral Bleaching

Bleaching, or the paling of zooxanthellate invertebrates, occurs when (i) the densities of zooxanthellae decline and/or (ii) the concentration of photosynthetic pigments within the zooxanthellae fall (Kleppel et al. 1989). Most reef-building corals normally
contain around $1.5 \times 10^6$ zooxanthellae cm$^{-2}$ of live surface tissue and 2-10 pg of chlorophyll a per zooxanthella. When corals bleach they commonly lose 60-90% of their zooxanthellae and each zooxanthella may lose 50-80% of its photosynthetic pigments (Glynn, 1996). The pale appearance of bleached scleractinian corals and hydrocorals is due to the cnidarian’s calcareous skeleton showing through the translucent tissues (that are nearly devoid of pigmented zooxanthellae, see Figure 3.13). If the stress-causing bleaching is not too severe and if it decreases in time, the affected corals usually regain their symbiotic algae within several weeks or a few months. If zooxanthellae loss is prolonged, i.e. if the stress continues and depleted zooxanthellae populations do not recover, the coral host eventually dies (Buchheim, 1998). Three hypotheses have been advanced to explain the cellular mechanism of bleaching, and all are based on extreme sea temperatures as one of the causative factors (Buchheim, 1998). High temperature and irradiance stressors have been implicated in the disruption of enzyme systems in zooxanthellae that offer protection against oxygen toxicity.

The first major coral bleaching event ever recorded for Ningaloo Reef occurred in winter (July) of 2006. The combination of cold air temperatures and aerial exposure of corals due to a low spring tide and a high pressure system appeared to cause bleaching of exposed corals. Submerged corals appeared to remain unbleached. Observations made during an aerial survey indicated that bleaching had occurred along most of the Ningaloo Reef. The most severe bleaching was recorded at Pelican Point, where approximately 81% of live hard coral was bleached. Bleaching was restricted to shallow-water corals of back-reef and patch reef environments dominated by plate and corymbose acroporids (Armstrong et al., 2008).
Photosynthesis pathways in zooxanthallae are impaired at temperatures above 30 degrees C, this effect could activate the disassociation of coral / algal symbiosis (Dubinsky and Stambler, 1996) Low- or high-temperature shocks results in zooxanthellae low as a result of cell adhesion dysfunction. This involves the detachment of cnidarian endodermal cells with their zooxanthellae and the eventual expulsion of both cell types.

It has been hypothesized that bleaching is an adaptive mechanism which allows the coral to be repopulated with a different type of zooxanthellae, possibly conferring greater stress resistance. Different strains of zooxanthellae exist both between and within different species of coral hosts, and the different strains of algae show varied physiological responses to both temperature and irradiance exposure (Gleason and Wellignton, 1993). The coral/algal association may have the scope to adapt within a coral’s lifetime. Such adaptations could be either genetic or phenotypic. As coral reef bleaching is a general response to stress, it can be induced by a variety of factors,
alone or in combination. It is therefore difficult to unequivocally identify the causes for bleaching events.

A major trigger for coral bleaching is an extended period of excessively hot, calm and clear conditions that damages the photosynthetic pathways of the zooxanthellae and causes their expulsion *en masse*. The bleached coral’s capacity to build new skeleton is compromised, its tissues are damaged, and its reproduction is reduced, if not suspended (Michalek-Wagner and Willis 2000; Ward *et al.* 2002). A bleached coral may die, in part, or entirely (Baird and Marshall, 2002). Alternatively, a bleached coral may fully recover its colour and the energy contribution of its zooxanthellae within months.

Recent increases in the incidence of coral bleaching on the Great Barrier Reef have been correlated with warming sea temperatures (Done *et al.*, 2003).

### 3.9 Conclusion

Although protected through Commonwealth and State legislation, Ningaloo Marine Park is a rich but fragile environment exposed to environmental and human threats. There are currently large gaps in the knowledge about the marine communities, species and ecosystem processes in Ningaloo Marine Park, particularly in the deeper waters. Improving knowledge of these aspects is critical to improving management of the Marine Park. One of the key gaps in knowledge and research is in the geological origins of the Ningaloo Reef and the emergent flanks of the Cape Range and other anticlines of the region. The presence of deep (50 to>500 m) water over most of the Commonwealth Waters portion of the Ningaloo Marine Park imposes restrictions on research due to technical limitations and high costs. Research in deep
open waters requires the use of larger vessels, heavy sampling and sophisticated technical equipment such as side-scan sonar and remotely operated vehicles. Even aerial surveys of migratory animals such as whales and whale sharks are more expensive due to restrictions on the use of single engine aircraft that necessitate the use of twin engine aircraft at significantly higher cost (Le Provost Dames and Moore, 2000). Coupled with the fact that most of the recognised pressure on the resources of the Park occurs in shallow waters, it is a natural outcome that most research and most of the available funding are being expended in those areas.

While the mechanism itself needs to be further investigated, there is a need for further evaluation of physical and chemical oceanographic processes in order to evaluate the potential effects of development within or adjacent to the Park. This will assist in assessing the potential for ‘trapping’ or recirculation of nutrients and other contaminants which may be discharged into the waters from the land, and for modelling the trajectory of potential oil spills that may enter the Park as a result of a shipping or oil production accident. The available information on the deepwater habitats of the Marine Park is drawn mainly from a small number of oceanographic and fisheries resource surveys. There is a need for a more detailed investigation of the deeper waters, including mapping and characterisation of offshore benthic habitats and identification of any significant geomorphological features which may be present. The potential impact of demersal fishing, particularly trawling, on the seabed means that there is a need for additional information on benthic habitats and the sessile flora and fauna which they support and which are susceptible to trawling impacts.

There is also a need for a better understanding of the population dynamics and reproductive biology of the target and bycatch species.

In the next chapter I focus the attention on these knowledge gaps in coral reef ecosystems. Ecological research is a key strategy critical for the effective management of marine conservation reserves. Research provides key information on
the ecological environment of Ningaloo, an improved understanding of what is “natural” as a benchmark for monitoring programs, and facilitates a better understanding of the short and long-term impacts of human activities. Research programs should, ideally, be designed to fill key gaps in current knowledge of most use to management. Despite the need and importance of such research, there has been traditionally very little funding available. The aims of this thesis is to estimate the monetary value people place on the reef and examine how this can be translated into ways of increasing its conservation and the knowledge about its ecological importance.
Chapter IV

Review of the Environmental Economic Valuation Literature

Non-use value analysis

4.1 Introduction

While the scale and severity of environmental problems continue to grow, the deployment of scarce resources to mitigate these negative trends via environmental conservation highlights a fundamental valuation question. How much environmental conservation should there be, and therefore what is nature’s value? Conventional economics couches its answer in terms of human individual preferences for particular things (including the environment) and the argument that something is of instrumental value to the extent that some individual is willing to pay for the satisfaction of a preference. Underlying this approach is the axiomatic assumption that individuals almost always make choices (express their preference) which benefit (directly or indirectly) them or enhance their welfare (Turner, 1999). Utilizing a cost-benefit approach, economists then argue that nature conservation benefits should be valued and compared with the relevant costs. Conservation measures should only be adopted if it can be demonstrated that they generate net economic benefits.

Some environmentalists (including a minority of economists, such as environmental economists), on the other hand, either claim that nature has non-anthropocentric intrinsic value and non-human species possess moral interests of rights, or that while all values are anthropocentric and usually, but not always, instrumental the economic approach to environmental valuation is only a partial approach (Katz, 1996; Brennan, 1998; Light, 2002).
These environmentalist positions lead to the advocacy of environmental sustainability standards or constraints, which to some extent obviate the need for the valuation of specific components of the environment. Some ecocentrists seem to be arguing that all environmental resources should be conserved regardless of the costs of such a strategy, i.e. that environmental assets are infinitely valuable and the environmental standards are absolute (Hargrove, 1992).

The objective of this literature review is to illustrate the concept and the nature of the environmental values with a focus on marine biodiversity, the techniques that have been used and the results that have been achieved in empirical studies relevant to marine and coral reef biodiversity valuation. The reason why I focus the attention on marine biodiversity is based on the case study, that involve an economic evaluation of biodiversity in Ningaloo Marine Park. It also helps to understand the scenario of coral reef ecosystems which as outlined in previous chapters are very complex and completely different from any sort of terrestrial case study.

I then set out an expanded values classification in order to define the limits of the conventional environmental economics concept of total economic value (use plus non-use values). Particular attention is paid to the Contingent Valuation Methodology and Choice Modelling approach to value environmental goods, because they represent the two most relevant and tested methodologies.

### 4.2 Estimate the Economic Value of Biodiversity

Society needs to make difficult decisions regarding its use of biological resources in terms of habitat conservation, natural resources allocation, management of protected areas, etc. Environmental valuation techniques can provide useful tools to support such policies by quantifying the economic value associated with the protection of biological resources. Pearce (2001) argues that the measurement of the economic
value of biodiversity is a fundamental step in conserving this resource since ‘the pressures to reduce biodiversity are so large that the chances that we will introduce incentives [for the protection of biodiversity] without demonstrating the economic value of biodiversity are much less than if we do engage in valuation’ (in Valuing Biological Diversity: Issues and Overview”. Valuation of Biodiversity Benefits: Selected Studies, OECD 2001, pp. 124).

The OECD (2001) also recognises the importance of measuring the economic value of biodiversity and identifies a wide range of uses for such values, including demonstrating the value of biodiversity, in targeting biodiversity protection within scarce budgets, and in determining damages for loss of biodiversity in liability regimes.

More generally, the role of environmental valuation methodologies in policy formulation is increasingly being recognised by policy makers. For example, the Convention of Biological Diversity’s Conference of the Parties decision IV/10 acknowledges that ‘economic valuation of biodiversity and biological resources is an important tool for well-targeted and calibrated economic incentive measures’ and encourages parties, governments and relevant organizations to ‘take into account economic, social, cultural and ethical valuation in the development of relevant incentive measures’ (Convention on Biological Diversity, 2004).

However, what concerns us here is not whether one should attempt to place economic values on changes in biodiversity, but rather in what the particular difficulties are in doing so. These include incommensurate values or lexicographic preference issues (Rekola, 2003) and the issue I focus on here people’s limited understanding of complex environmental goods (Limburg et al., 2002).

Stated preference valuation methods require survey respondents to make well-informed value judgements on the environmental good under investigation. This requires information on unfamiliar goods to be presented to respondents in a
meaningful and understandable format. Recent studies have found that members of the general public have a low awareness and poor understanding of the term biodiversity, and communicating relevant information within a stated preference study to be difficult (Spash and Hanley, 1995; Glanzig, 2002; Turpie, 2003).

Various surveys have examined the public’s understanding of the term ‘biodiversity’. A recent UK survey found that only 26% of respondents had heard of the term ‘biodiversity’ (DEFRA, 2002). Similar findings are also reported in Spash and Hanley (1995). The lack of public understanding of the term biodiversity will make the valuation exercise difficult; however, people can learn during a survey, and may have preferences for what biodiversity actually means, even if they are unaware of the term itself: the DEFRA (Department for Environment, Food and Rural Affairs) (2002) survey also found that 52% considered the protection of wildlife to be ‘very important’, even though they did not know what biodiversity itself meant.

A related complication is that biodiversity itself is not uniquely defined by conservation biologists. Scientists are in general agreement that the number of species per unit of area provides a useful starting point (Whittaker, 1977). Although such a measure appears to be relatively straightforward, issues such as what constitutes a species (Claridge and Boddy, 1994); and what size of area to count species over complicate this measure (Whittaker, 1977). Even if these questions were resolved, ecologists recognise that some species, such as keystone species, may be more important and/or make a greater contribution to biodiversity than others.

A further complicating factor relates to the extent to which the public is capable of understanding these ecological concepts. Ecologists also recognise that biodiversity may be described and measured in terms of species diversity within a community or habitat (Arts et al., 1990) and in terms of the diversity of ecological functions (Herrera et al., 1997). Finally, the public may have preferences for certain species that display charismatic features such as beauty or speed, or be locally significant, even though these features may not be considered ecologically important (May, 1995). The issues
highlighted above indicate that research that attempts to value changes in biodiversity using a direct elicitation of public preferences will be challenging, since it requires us to identify appropriate language in which complex biodiversity concepts can be meaningfully conveyed to members of the public in ways that are consistent with underlying ecological ideas on what biodiversity is (Christie et al., 2004).

Many of the goods and services provided by biodiversity and ecosystems are crucial, but not always quantifiable in monetary terms. Many of these goods and services are not traded in the market place and so do not have an obvious price or commercial value. The danger is that if these unpriced values are not included in the decision-making process, the final decision may favour outcomes which do have a commercial value. Hence decision makers may not have full awareness of the consequences for biodiversity conservation. People make a variety of claims on biodiversity and environmental resources. Deciding who should use environmental resources and how, where and when is complex. Decisions must weigh the values, variously perceived, of the range of potential uses of the resources. The environmental evaluation of these goods and services provides a useful information to assist the policy makers and to all expert who manage any types of public areas with high level of biodiversity. Valuing biodiversity using economic techniques and incorporating those values into the decision-making process can also be a powerful way to demonstrate the importance of biodiversity protection to the broader public.

4.3 Intrinsic Value in Nature

The term “valuing the environment” means different things to different people depending on which of the world-views they find acceptable. Economists have generally settled for a taxonomy of total environmental value, interpreted as ‘total
economic value’ (TEV), which distinguishes between use values, and a remainder termed non-use value (Hargrove, 1992; Gren et al, 1994; Turner, 2000). Total Economic Value has, however, been the subject of much debate among environmental economists and others, and also provides the fuzzy boundary with alternative concepts of environment value.

Non-use value covers situations in which individuals who do not make use, or intended to make use, of any given environmental asset or attribute would nevertheless feel a “loss” it were to disappear. They may just wish to see various environmental entities conserved “in their own right” (termed existence value); or conservation may be supported on the basis of retaining options and opportunities for one’s children, grand-children, and future generation beyond (termed bequest value). On closer inspection however the non-use category does not have well-defined boundaries. This is because the existence-value component can be defined in a variety of ways to include a range of possible motivations, some of which are “outside” the scope of conventional utilitarian economic thought (Turner et al., 1994).

The Total Economic Value taxonomy can itself be encompassed, in principle, by a more general valuation typology, containing four separate forms of value in relation to environmental resources (see Table 4.1).

It turns out that the TEV taxonomy can itself be encompassed, in principle, by a more general valuation typology, containing four separate forms of value in relation to environmental resources, see Table 4.1. The four categories of value are distinguished in terms of their anthropocentric or non-anthropocentric basis and by their instrumental or intrinsic characteristics. Existence value (as variously defined in the literature) seems to overlap the anthropocentric instrumental value and anthropocentric intrinsic value categories. As one crosses this philosophical boundary the conventional economic notions of utility and welfare cease to always retain their “accepted” relationship, i.e. if welfare is increased, utility increases (Turner and Paavola, 2003).
Table 4.1  A General Value Typology

1. Anthropocentric Instrumental Value

Total Economic Value = use + non-use value. The non-use category is bounded by the existence value concept, which has itself been the subject of much debate. Existence value may therefore encompass some or all of the following motivations:

i. intragenerational altruism: resource conservation to ensure availability for others; vicarious use value linked to self-interested altruism and the “warm glow” effect of purchased moral satisfaction;

ii. intergenerational altruism (bequest motivation and value): resource conservation to ensure availability for future generations;

iii. stewardship motivation: human responsibility for resource conservation on behalf of all nature; this motivation may be based on the belief that non-human resources have rights and/or interests and as far as possible should be left undisturbed.

2. Anthropocentric Intrinsic Value

This value category is linked to stewardship in a subjectivist sense of the term “value”. It is culturally dependent. The value attribution is to entities which have a ‘sake’ or ‘good of their own’, and instrumentally use other parts of nature for their own intrinsic ends. It remains an anthropocentrically related concept because it is still a human valuer that is ascribing intrinsic value to non-human nature.

3. Non-Anthropocentric Instrumental Value

In this value category entities are assumed to have sake or good of their own independent of human interests. It also encompasses the good of collective entities, e.g. ecosystems, in a way that in not irreducible to that of its members. But this category may not demand moral considerability as far as humans are concerned.

4. Non-Anthropocentric Intrinsic Value

This value category is viewed in an objective value sense, i.e. ‘inherent worth’ in nature, the value that an object possesses independently of the valuation of valuers. It is a meta-ethical claim, and usually involves the search for strong rules or trump cards with which to constrain anthropocentric instrumental values and policy.

So we can emphasize the finding that total environmental value is not necessarily equivalent to TEV; much depends on the specific world-view one adopts prior to the valuation exercise.

Instrumental values are relative and usually linked to individuals and their preferences or needs (category 1 in Table 4.1). The economic message is therefore that if more biodiversity conservation, for example, is chosen, then the opportunity to satisfy other preferences or needs is foreclosed. Hence all resource-allocation policy decision incur opportunity costs. Thus the instrumental value of biodiversity is not absolute; it is relative and as such can be balanced (in a cost-benefit assessment) against other ‘good’ things or ‘worthy’ causes that individuals may want to use or support.

Some environmental philosophers (bioethicists) have usually interpreted intrinsic value as ‘inherent worth’ (category 4 in Table 4.1) and as such completely separate from the human-environment valuation relationship. According to this position non-human biota, and perhaps even non-sentient things, have moral interests or rights to existence. An extreme version of bioethics would make environmental rights absolute and therefore not open to trade-offs, on the basis of a “deep ecology” meta-ethical principle (Rolston, 1988).3

It is not, however, necessary to ascribe absolute value to environmental conservation/preservation in order to provide more safeguards against biodiversity and other environmental loss than currently exist.

3 By ‘nature’, Rolston generally means non-human nature. He carefully distinguishes ‘nature’ and ‘culture’. Culture is an artefact made possible by human self-awareness and thoughtfulness, which are found to such an advanced degree in no other species, and which make possible the acquisition and transfer of knowledge, information, science, technology, art, and a host of other human achievements. In contrast to ‘deliberative’ culture, nature is ‘spontaneous’ and ‘non-reflective’. Natural processes are law-like, orderly though also probabilistic, and open to historical novelty, as evidenced in the creativity in evolving ecosystems. Natural selection, combining with genetics, results in the genesis of value.
Such extra safeguards could be justified in terms of ‘altruism’ motivations (value category 2 in Table 2.1) (Randall and Stoll, 1991). Here moral principles recognizing the ‘interests’ of non-human species and their supporting habitats could be used to buttress a case for extra, but not unlimited, sacrifices incurred to better safeguard biodiversity. The values expressed are still anthropocentric but relate to intrinsic qualities in nature.

Existence value therefore derives from individuals who feel a benefit from just knowing that a particular species, habitat, or ecosystems does exist and will continue to exist somewhere on the planet. According to some analysts, the economic literature which seeks to appropriately define and measure existence value as a part of a comprehensive valuation framework has arrived at a consensus view that both use value and non-use value can be distinguished formally using standard welfare measures from neo-classical economic theory (Larson, 1993). Other analyses highlight the differences that have emerged in the literature (Lant, 1994). It seems to us that if there is such a consensus it is only in a restricted context.

A number of writers also seem to agree that existence value can be measured by survey methods such as Contingent Valuation or Choice Modelling (Cummings and Harrison, 1992; Quiggin, 1998; Kling, 1999; Rolfe et al., 2000; Lomis, 2006).

Since existence values involve neither personal consumption of derived products nor in situ contact, economists have used a special structure of preferences to model existence value. The non-market goods cannot be identified via conventional market demand theory and analysis. Existence value of the non-market good cannot therefore be measured by indirect observation of individuals’ behaviour, and the only option is direct questioning via surveys (Lindhjem and Navrud, 2008).

From the strong-sustainability position, both existence and bequest value could be better conserved by the adoption of the principle of a safe minimum standard (a sufficient area of habitat to be conserved to ensure the continued provision of
ecological functions and services at the ecosystem landscape level) unless the social costs of doing so are unacceptably high (Bishop, 1978; Moeltner et al., 2007).

A further principle, the precautionary principle, would, if adopted, ensure the recognition of bequest motivations and value. In essence, this principle lays down that the opportunity set for the future generations can only be assured if the level of biodiversity (our case example) they inherit is no less than that available to present generations. So some sort of “inheritance” is passed intact across time. This bequest will take the form of a stock of human, physical and natural capital (Pearce, 1992). I argue that the motivations behind non-use value are some combination of: individuals’ perceived benefits; altruism towards friends, relatives or others who may be users (vicarious use value); altruism towards future generations of users (bequest value); altruism towards non-human nature in general (existence value).

However, several questions remain to be fully answered, including what precisely is meant by altruistic motives and behaviour and which values are instrumental and which could be intrinsic. We do not yet have anything like a full picture of the mutually exclusive set of motivations underlying individual preferences for environmental goods.

The largely philosophical debate over the need for and composition of an adequate environmental ethics has become rather sterile. In the real world of pragmatic policy-making the instrumental-intrinsic distinction is only usefully maintained if it is interpreted solely in an anthropocentric (human-centred) way. Thus a case for environmental conservation should be supported not only on the grounds of the significant amount of human instrumental value that it is at stake, but also because it allows society to set this things aside (Turner and Pearce, 1993) and exempt these from use. According to Hargrove (1992) this would reflect ‘our desire as individuals, as society, and as a historically evolved culture to value some things non-instrumentally and to set them aside and protect them from exploitation’ (Hargrove, 1992).
4.4 Total Economic Value and the Social Value of Ecosystem

The economic valuation literature indicates that the economic production function approach is a fruitful way to elicit direct and indirect use values of environmental systems. Indirect (revealed-preferences) methods fit into this approach and have been used to estimate recreation/family use values. Direct (stated-preferences) methods such as contingent valuation have proved to be more controversial but the balance of evidence, in the context of use value, does seem to be favourable for a fairly extensive range of environmental goods (Farber and Costanza, 1989; Turner, 1991; Boyle, 2003). The estimation of non-use values is much more complex. Limited pioneering work with conjoint analysis (contingent ranking and/or contingent choice) offers the prospect of more progress in non-use valuation. The contingent-choice format is likely to be more acceptable to economists than the ranking procedure (Adamowicz et al., 1999). The contingent-choice method is considered more acceptable because, first of all it can reveal the value of attributes as well as the value of more complex changes in several attributes and choice approach is more familiar to the respondent than any sort of ‘payment’ approach. Another important aspect of this method is that the ‘strategic behaviour’ should be minimal in choice format, since the choices are made from descriptions of attributes and it will not be clear which choice will over or under-represent a valuation. Recent advances in the development of ecological economic models and theory all seem to stress the importance of the overall systems, as opposed to individual components of that systems (Brander et al., 2007). The economy and the environment are recently jointly determined systems linked in a process of coevolution, with the scale of economic activity exerting significant environmental pressure. The dynamics of the jointly determined system are characterized by discontinuous change around poorly understood critical threshold
values. However under the stress and shock of change the joint systems exhibit resilience, i.e. the ability of the system to maintain its self-organization while suffering stress and shock. This resilience capacity is however related more to overall system configuration and stability properties than it is to the stability of individual resources (Turner, 2000).

Norton and Ulanowicz (1992) advocate a hierarchical approach to natural systems (which assumes that smaller subsystems change according to a faster dynamic than do larger encompassing systems) as a way of conceptualising problems of scale in determining biodiversity policy. For them, the goal of sustaining biological diversity over multiple human generations can only be achieved if biodiversity policy is operated at the landscape level. The value of individual species, then, is mainly in their contribution to a larger dynamic, and significant financial expenditure may not always be justified to save ecological marginal species. A central aim of policy should be to protect as many species as possible, but not all (Tisdell et al., 2005).

Ecosystems health, interpreted in terms of an intuitive guide, is useful in that it helps focus attention on the larger systems in nature and away from the special interests of individuals and groups. The full range of public and private instrumental and non-instrumental values all depend on protection of the processes that support the health of larger-scale ecological systems. Thus when a coral reef, for example, is disturbed or degraded, we need to look at the impacts of the disturbance on the larger level of the landscape (Western, 2007).

The integrity of an ecosystem is more than its capacity to maintain autonomous functioning (its health); it also relates to the retention of ‘total diversity’, i.e. the species and interrelationship that have survived over time at the landscape level (Norton, 1992). A number of ecological services and functions can be valued in economics terms, while others cannot because of uncertainly and complexity conditions. Taking coral reef, as our example inherent to the case study of this research, these systems provide a wide array of functions, services, and goods of
significant value to society such as shoreline protection, storm control, transport, recreation and aesthetics services, etc (Spaninks and Van Beukering, 1997; Cesar et al., 2002; Strand, 2007). We can therefore conceive of ‘valuing’ a coral reef as essentially valuing the characteristics of a system, and we can capture these values in our TEV framework. Since it is the case that the component parts of a system are contingent on the existence and contributed proper functioning of the whole, then putting an aggregate value on coral reef and other ecosystems is quite a complicated matter (Turner, 2000).

Private economic values may not capture the full contribution of component species and processes to the aggregate life-support functions provided by ecosystem (Gren et al., 1994). Furthermore, some ecologists argue that some of the underlying structure and functions of ecological systems which are prior to the ecological production function cannot be taken into account in terms of economic value (De Leo and Levin, 1997; Hobbs and Harris, 2001; Whitehead, 2006). Total Economic Value therefore underestimates the true value of ecosystems. The prior value of the ecosystems structure has been called “primary value” and consists of the system characteristics upon which all ecological functions depend (Turner and Pearce, 1993). The secondary functions and values depend on the continued ‘health’ existence, operation, and maintenance of the ecosystem as a whole. The primary value notion is related to the fact that the system hold everything together (and is thus also referred to as a ‘glue’ value) and as such as, in principle, economic value. Thus the Total Value of the ecosystems exceeds the sum of the values of individual functions (Costanza et al., 1997).

According to Turner (2000), the social value of an ecosystem may not be equivalent to the aggregate private total economic value of that same system’s components, because of the following factors:
1. The full complexity and coverage of the underpinning life-support functions of healthy evolving ecosystems are currently not precisely known in scientific terms (refer to discussion in the previous chapters). A number of indirect use values within systems therefore remain to be discovered and valued (quasi-option value).

2. Because the range of secondary values (use and non-use) that can be instrumentally derived from an ecosystem is contingent on the prior existence of such a healthy and evolving system, there is in a philosophical sense a ‘prior value’ that could be ascribed to the system itself. Such a value would, however, not be measurable in conventional economic terms and is not commensurate with the economic values of systems.

3. The continued functioning of a healthy ecosystem is more than the sum of its individual components. There is a sense in which the operating systems yields or possesses ‘glue’ value, i.e. value related to the structure and functioning properties of the system which hold everything together.

4. A healthy ecosystem also contains a redundancy reserve, a pool of latent keystone species/processes which are required for system maintenance in the face of stress and shock.

Against this background, it is important to consider what are possible methods to assign value to environmental goods.

4.5 Methodologies for Valuing Environmental Goods

Provided that a market for the good to be valued does not exist, or that this market has failures, or is not a competitive one, a number of alternative valuation methods are available.
They could be classified into two groups:

1. Actual market based methods
2. Simulated marked methods

4.5.1 Actual Market Based Methods

The two main methods based on actual markets are the travel cost method (TCM) and the hedonic pricing method (HPM). They can also be combined in the hedonic travel cost method (HTCM).

The TCM consists in collecting and analysing data from users of a good located in a place one has to travel to in order to enjoy it, for instance, a local public good such as a particular coral reef area. The researcher would collect information from visitors or from the population in general. Usually, only visitors are surveyed. Information would typically be obtained through questionnaires (Englin and Mendelsohn, 1991). Questions would include the origin of the trip (so the costs of travelling can be estimated), and the number of trips in, for example, the last twelve months to the site. If only the former question is used, the method is then called zonal travel cost (ZTCM). If frequency of trips over time is known for each visitor, then the individual travel cost method (ITCM) can be applied (Riera, 2001).

A demand function relating frequency of visits and costs can be identified, and the consumer surplus estimated. The procedure used to estimate the function is almost always econometric. Often, a different econometric (and economic) approach is taken, and the frequency of visits over time is modelled using count data models (Riera, 2001). The use of econometric analysis gives us the possibility to explore the relationship among all the possible variables included in the demand function and the weight of each variables.

Whichever of the two main versions (there are also others) is used, the value estimated by TCM is appropriate to the travel cost estimation; there is no clear
consensus as to which items ought to enter the cost calculation. It seems clear that the
cost of the fuel (if the visit involves the use of a car, as it usually does) ought to be
considered, but other car costs are more controversial. Time is also often counted as a
cost. Sometimes accommodation is also considered. The higher the cost considered,
the higher the estimated consumer surplus will be.
The other main method based on actual markets is the hedonic pricing method
(HPM). It is based on the fact that prices of ‘complex’ goods embed information on
the implicit prices of the components of the good. For instance, a house overlooking a
coral reef lagoon may be more expensive than an otherwise equivalent house with a
less interesting view. The landscape view, as well as the size of the house, its
economic distance to services, to amenities (the coral reef), to workplaces, age and
shape of the house, and other characteristics conform the final market price of the
real estate property (Freeman, 1991).
Attending to this fact, if many transactions of the good (housing, in this instance)
could be observed, and the price of the transaction as well as the different relevant
characteristics of the good recorded, a regression analysis explaining the price
according to the characteristics, would estimate the ‘weight’ or ‘contribution’ of each
characteristic to the final market price. This would indicate the value of the
landscape view, or the relative accessibility to coral reef lagoon (Tangerini and Nils,
2005; McConnell and Walls, 2005; Bin et al., 2006).
In most cases, both TCM and HPM only capture use values, leaving non-use values
out of the account. This is not the case, though, with simulated market methods.

4.5.2  Simulated Market Methods

Markets can be simulated, and thus ‘prices observed’. The simulation of the market
for the good to be valued is achieved through a questionnaire to be passed to the
population, or a sample of it. In the simulated market, the supply side is represented
by the interviewer, who typically offers to provide a given amount of units of the
good at a given price. The respondent, who either accepts or rejects the offer,
represents the demand side. One of the most crucial issues in this kind of method is
to be precise enough in the description of the market, and yet simple and clear
enough for people to understand it. This is important, because biological and
landscape diversity are among the goods for which it is difficult to simulate a clear,
credible, precise and understandable market in a poll process (Riera, 2001).
The most widely used method is the contingent valuation method (CVM). This
method is a survey based technique for the elicitation of people's willingness to pay
(WTP) for the provision, preservation or improvement of an environmental good.
The underlying assumption of this method is that individuals have a coherent set of
preferences for goods, including non-market goods like environmental goods, that
these preferences would be revealed in proper markets and that there is a direct
relationship between an individual's statement about their preferences and their true
WTP. To this end, a hypothetical market for the environmental good is constructed
and people are asked to make their decisions about the amount they are willing to
pay contingent on the specific characteristics of the market set out during the
questioning procedure. These contain the definition of the good, the way it would be
provided, preserved or improved, and the mechanism of financing it, e.g. tax
payments, contributions to a fund etc (Fror, 2003).
Although hypothetical in nature, the survey respondents should be led to believe
that they are confronted with a real situation since it is usually explained to them
that their responses will influence public decision making and payments will be real
once a positive decision on the realization of a project has been made. Carson (1997)
terms those questions "consequential survey questions" and argues that only for
those questions does economic theory provide predictions concerning respondent
behaviour.
The second stated preference method was originally developed in the field of
marketing research and transportation economics and has only relatively recently been employed in the valuation of environmental goods. It is based on Lancaster's (1966) characteristics theory of value according to which individuals do not derive utility from a good per se but rather from the characteristics or attributes composing it. In attribute based choice modelling (ABCM), also called conjoint analysis, a good to be valued is constructed by defining a set of attributes which in conjunction characterize the good as a whole (Frør, 2003).

By assigning different levels to the set of attributes, alternative goods can be specified which are called profiles. Various valuation techniques have evolved from this specification. The simplest valuation task presented to a survey respondent, and at the same time the closest to a real market situation, is to choose the most preferred profile from a set of given profiles. Once a profile has been identified as the most preferred, the other profiles become irrelevant. This approach is often called choice experiment or choice modelling (in this study I use choice modelling - CM) and forms the basis for all other ABCM techniques (Hanley et al., 2001; Jacobsen and Hanley, 2007).

The choice between the profiles can be interpreted as reflecting the trade-offs that a respondent makes between the various attributes. By including a price or some other cost factor as an attribute into a profile it is possible to estimate economic values associated with the other attributes. In its simplest form, the choice between two profiles one of which representing the status-quo, the valuation task becomes identical to the CVM with choosing the status-quo being equivalent to stating a WTP of zero. If two alternative profiles to the status-quo are presented to the respondent the valuation task of a choice modelling has already become more complex than in the CVM (Frør, 2003).

A typical SP method involves general characteristics of the good, usually termed attributes. One of the attributes is a monetary payment (or compensation), and the others are physical. For instance, a fringing reef that has as distinctive number of
biological and landscape diversity features under threat by a known risk factor, and that has a program to reduce it, would have the cost of the program as one attribute and the features as the others (Costanza et al., 1997).

Combinations of values for the different attributes yield ‘alternatives’. Each alternative is characterized by a combination of physical attributes and a payment. A number of alternatives are chosen following one of the available techniques for doing that, and properly included in the questionnaire. The questionnaire is otherwise very similar to the CVM ones. Depending on what respondents are asked to state, the SP method varies. When respondents are asked to rate a list of alternatives on a given scale, the method is called contingent rating. If they are asked to rank the alternatives, the method is called contingent ranking. If they are asked to state the most preferred alternative, then the method is called contingent choice method or choice modelling (Riera, 2001).

In all cases, the willingness to pay for the reduction of risk in the variation of each physical attribute can be estimated. The way to estimate it is through econometric models of limited dependent variables, such as ordered probit models, multinomial logit models, and alike (Morey and Rossmann, 2003; Train and Wilson, 2006). Even if the original variations in the physical values expressed to respondents are discrete (and they usually are), the estimated value is expressed in marginal terms. Therefore, a reduction of a biodiversity index, for instance, would be valued in one unit decrease. If the desired change to be valued is discrete, the value is usually extrapolated accordingly.

One of the main advantages of SP methods over subsequent CVM exercises is that SP can account for cross-effects. For instance, people may consider that an increase in biological diversity without allowing access to coral reef lagoon is worth less than the same increase with some public access. There is a cross-effect between both attributes. If valued separately, the relationship effect on value is missing. If valued together by CVM, the individual values are missing. In general, the value of a forest
is not the sum of the values of its attributes. There are often cross-effects, and the value could be higher or lower than the simple sum. The SP methods allow for accounting both individual and global values (Hoevenagel, 2000).

4.5.3 Reliability

All the techniques briefly described above have been applied to biological and landscape related aspects involving coral reef (Cesar et al., 2002; Mathieu et al. 2000; Subade, 2005). Each one of them has some advantages over the rest and some disadvantages. The use of one or another depends mainly on the purpose of the valuation exercise and the availability of data and resources. So far, the most popular has been CVM, with SP methods gaining interest within the academic and practitioner worlds.

The reasons for the momentum of SP methods are diverse. They are relatively new, and more researchers get acquainted with them every year. They have a format that respondents tend to find comfortable, thus reducing the proportion of no-answers and protest-answers. The SP methods can cope with valuing different attributes of a coral reef, like biological and landscape diversity aspects, in an integrated manner, therefore being more informative. They tend to cope better with the so-called embedding problem (valuation being rather insensitive to the scale of the physical change) as far as the respondent gets a richer perspective of the scale of the changes proposed (Riera, 2001).

Both CVM and SP ‘design’ exactly the market as to value the good of interest, whereas with TCM and HPM it is often difficult to isolate the value of the good from other closely related goods. On the other hand, expressing biodiversity changes in simple, accurate, and understandable terms in a questionnaire can prove to be a challenging task (Moran, 2000).
In order to be able to better transmit the market conditions, researchers often use visual aids, such as simulated landscape changes. This implies that interviews cannot be conducted by telephone, but by mail or face-to-face interviews. In general, the latter is the preferred option, especially when the good to be valued is rather complex. Computer aided interviews are becoming more common (Arsenio and Patrício, 2004). There tends to be an inverse relationship between familiarity with the good and the ability of respondents to answer meaningfully. The biodiversity related goods tend to be very unfamiliar for a market situation. Therefore, the use of CVM and SP requires state-of-the-art practice to overcome this and other potential problems (Riera, 2001).

In general, the more specific the change in biodiversity is, the more reliable are the values obtained by all the methods. This is especially the case with CVM and SP. TCM and HPM (Hedonic Price Method) tend to be more suitable for ex post valuation, since they rely on existing markets, whereas CVM and SP tend to be more adequate for valuing changes ex ante. They can also be used in ex post valuation, but there might be a lack of incentives to answer (Moran, 2000).

In summary, even though estimating the economic values of changes in biological and landscape diversity of a coral reef is not a straightforward task, the tools developed by environmental economics make it possible and, overall, fairly reliable, provided, of course, that the methods are applied according to the state-of-the-art.

In the next two paragraphs I focus the attention on two most important techniques used for the estimation of non-market values: the contingent valuation (CVM) and the choice modelling (CM). These two stated choice methods represent the two most appropriate and reliable techniques to value a case study that involves coral reef biodiversity conservation evaluation. Among the stated preference methods, the contingent valuation method (CVM) is most widely used. Other stated preference methods, notably choice modelling (CM), are increasing in popularity amongst environmental economists (Bennett and Blamey, 2001).
4.6 Contingent Valuation Method

The Contingent Valuation Method is a technique used to estimate the monetary value of environmental amenities such as wildlife, clean air and national parks (Wilks, 1990). Mitchell and Carson (1989) expound in depth the various aspects of CVM, which may be employed to estimate values not intimately linked to use, for example, the desire of individuals to pass pristine natural environments on to future generations. They claim that CVM “is potentially capable of directly measuring a broad range of economic benefits for a wide range of goods, including those not yet supplied, in a manner consistent with economic theory” (Mitchell and Carson, 1989 pp 589).

Pearce and Moran (1994) believe that interest in CVM has increased because it is the only means available for valuing non-use values and that the estimates obtained from well designed CVM surveys are as good as estimates from other methods. Moreover, the design, analysis and interpretation have improved greatly considering the developments in sampling and benefit estimation theories, and computerized data management. With regards to the first reason, Spash et al. (2000) stressed that CVM has attracted considerable attention in the literature because of its ability to estimate option, existence and bequest values in addition to direct use values. Stevens et al. (1991) also argued that CVM is the only technique capable of measuring existence values.

As already highlighted, in the past few years, particularly in the last decade, attribute-based methods (ABM), alternatively called conjoint analysis or choice modelling approaches (CM), have emerged due to their ability to incorporate preference heterogeneity of consumers/respondents in environmental valuation. The objective of these approaches is to estimate the economic values of a technically divisible set of attributes of an environmental good (see next section). However, these approaches have been used so far in estimating use values of the environment.
and their application to passive use values (non-use values) have been rare. Moreover, Kristrom and Laitila (2002) stressed that as of now, cost-benefit analyses that need non-market values should rely more on CVM, considering the task complexity that the latter imposes on respondents. Moreover, they believe that the CE standard formula does not handle choice probabilities correctly.

Mitchell and Carson (1989) thoroughly discussed several biases (and the corresponding solutions) that can be encountered in the use of CVM. Pearce and Moran (1994) discussed these biases and suggested solutions in the context of biodiversity valuation. For example, strategic bias or strategic behaviour can be minimized by carefully framing the CVM questions, in an incentive-compatible way such that this type of behaviour/bias is not induced. Moreover, the dichotomous choice (take-it-or-leave-it) elicitation format in CVM has been found to be incentive-compatible in that it is in the respondent’s strategic interest to say yes if his/her WTP is greater than or equal to the price asked, and to say no otherwise (Mitchell and Carson, 1989). Also, by removing the outliers (observations with extreme values) from the data set gathered, the effect of strategic bias can be reduced.

Boyle (2003) pointed out that there might be greater potential for part-whole bias (embedding) or insensitivity to scope in estimating non-use values because respondents generally do not have choice experience or knowledge of the object being evaluated. To minimize the part-whole bias problem, Mitchell and Carson (1989) suggest that the survey instrument include a description of the larger and smaller commodities, and then ask respondents to focus their attention on the smaller commodity. Inclusion of graphic aids such as maps and photographs is also proposed (Boyle, 2003). Spash et al. (2000) pointed out that the embedding problem or part-whole bias can be remedied by careful survey design. Predo (1995) in dealing with possible embedding or part-whole bias, asked respondents to rank their rating of the attributes for the environmental good being studied, the protection of Lake Danao National Park, Philippines. His approach is believed to aid respondents in
proper recognition of the good’s scope/size, and the corresponding valuation.

According to Pearce and Moran (1994), hypothetical bias (i.e. the tendency for hypothetical willingness to pay to be bigger than actual WTP) can be minimized by designing the WTP scenario (specified attitude) so that it closely corresponds to the specified behaviour (the precise good measured). They also suggest ways of addressing the starting point, anchoring, and discrete bid level bias.

4.6.1 Contingent Valuation Method: Consistency with Economic Theory

Do CVM results conform with the predictions of economic theory? There are two obvious tests. First, the percentage of respondents willing to pay a particular price should fall as the price they are asked to pay increases. This condition, similar to a negative own-price elasticity for a marketed good, is almost universally observed in CVM studies (Hökby a and Söderqvist b, 2001; Corrigan et al. 2003; Zhao and Kling, 2004). Second, respondents should be willing to pay more for a larger amount of a desired good. This test, often referred to as a scope test, involves observing changes in the WTP estimate as the quantity or quality of the good is made larger or smaller. This is one of the most debated points concerning the validity of CVM (Flores, 1999). Critics have argued that the apparent lack of sensitivity of CVM estimates to differences in scope is the most serious empirical problem with its use, an assertion that is now routinely repeated in introductory texts on benefit-cost analysis and environmental economics (Andersson and Svensson, 2006).

The price and scope tests have the advantage of being simple unidirectional hypothesis tests with very close ties to the underlying economic theory (Hanemann, 1995). These tests correspond well with economic intuition. One might also make conjectures about the relationship between respondent income and WTP, on the difference between estimates of WTP and WTA, on the effect of the order in a
sequence in which a good is valued, or on the effect of aggregating independently
derived WTP values for different goods (Carson et al., 2001).
Tests of these phenomena are context specific and require judgments about relative
magnitudes (Tisdell et al., 2008). Here I show that the usual economic intuition
developed from observing how the quantity of a private good varies with price
changes is often faulty when it comes to making inferences about what properties
WTP for a public good should have. The fundamental insight is that one needs to
think of a public good as a special case of a quantity rationed good.

4.6.2 CVM: the Willingness to Pay

A scope test looks at whether respondents are willing to pay more for a good that is
larger in scope, either in a quality or quantity sense. It is important to recognize that
failure to pass a scope test can be attributed to one of three factors: (1) lack of the
statistical power used to detect the difference in value which would be plausible
given the difference in scope (Smith, 2005); (2) problems in CVM survey design and
administration which tend to mask sensitivity to scope (Jones-Lee and Loomes,
2003), or (3) CVM survey results that violate economic theory (Snowball, 2007).
The debate that has taken place in the environmental economics literature has been
whether insensitivity to the scope of the good being valued is a ubiquitous
phenomenon or whether this phenomenon occurs only occasionally and, in such
instances, is the problem traceable to a lack of statistical power or problems with the
design or implementation of the specific survey (Carson et al, 2001). A test of
responsiveness to scope can be implemented either internally or externally. In an
internal scope test, the same respondents are asked to value different levels of the
good. External scope tests rely upon asking two different, but statistically equivalent,
sub-samples about two different levels of the good. With internal scope tests, the null
hypothesis that respondents give the same WTP amount, irrespective of the level of
the good they are asked about, has long been almost uniformly rejected (Huhtala,
2000; Andersson and Stevensson, 2006).
Critics of Contingent Valuation have argued strongly that respondents may simply
be trying to be "internally consistent" in their answers (Bateman et al., 2000). Recent
attention has focused on external tests of scope and, in particular, the evidence
presented by Kahneman (Kahneman and Knetsch, 1992) and at the Exxon
symposium (Hausman, 1993), suggesting that respondents to CVM surveys do not
give different values to goods that differ in scope. Carson and Mitchell (1993) have
conducted a comprehensive review of the empirical CVM evidence from split sample
tests in which one sub-sample was offered an environmental good (water quality)
that was of larger scope than that offered another equivalent sub-sample (this project
was carried out in California, United States in 1993). Contrary to claims made by
Kahneman and Hausman concerning the absence of studies other than the few they
consider, there has been a number of studies containing an external scope test. Most
of these split-sample tests were done in CVM studies originally designed for policy
purposes where two or more different levels of a good were of interest to policy
makers.
These studies have advantages over the work of Kahneman and those reported in
Hausman (1993) in that: (1) the goods being valued were usually the subject of real
policy choices, (2) they generally enjoyed a more extensive survey design and pre-
testing effort, and (3) they tended to use more appropriate modes of survey
administration and larger sample sizes. Almost two-thirds of the studies dealt with
situations where passive use considerations were thought to predominate, while the
rest dealt with situations where direct use was thought to predominate (Pearce,
2005).
Four meta-analyses that looked at studies valuing outdoor recreation (Rosenberger
and Loomis, 2000), air quality changes (Smith and Osborne, 1996), wetland functions
(Brouwer, et al., 1999), groundwater contamination (Bergstrom et al., 1992) also rejected the scope insensitivity hypothesis by showing that the CVM estimates from different studies vary in a systematic (and expected) fashion with differences in specific characteristics of the good (Smith, 2005). Poorly executed survey design and administration procedures appear to be a primary cause of problem studies not exhibiting sensitivity to scope. None of the commonly cited studies with scope insensitivity bears much resemblance to the current state-of-the-art CVM surveys where respondents are presented with a substantial amount of information about the good they are asked to value in a manner which facilitates their comprehension of the material (Carson, 2000).

The Kahneman and Knetsch, (1992) work used short telephone surveys with vaguely defined goods, provision mechanisms, and payment obligations. Desvousges et al.’s (1993) study of covering oil ponds to prevent birds from being killed in the Rocky Mountain area was a short self-administered survey done in a North Carolina shopping mall. In other instances, original claims of scope insensitivity do not stand up to the use of simple but more powerful statistical tests. Daraio and Simar (2005) show that their statistical test has no power to detect large differences, and instead, estimate a simple ordinary least squares (OLS) regression of WTP on the number of acres in each of the three wilderness areas.

At this point I believe that out of sample scope tests, to the extent that they divert resources from survey design efforts and sample size, are probably not a good investment, as there is already enough evidence that a well designed survey produces consistent economic results. Further, there is probably more risk to disbelieving a pair of CVM results because they do not show much sensitivity to the scope of the good being valued than the opposite reaction. For many environmental goods, the public may have sharply declining marginal utility for an environmental amenity after a reasonable amount of it has been provided (Ferraro and Pattanayak, 2006).
There is, however, one key area of concern with respect to scope sensitivity and the use of CVM and that is in valuing changes in small probabilities of health risk (Beattie et al., 1998). The inherent problem here is that people are known to have substantial difficulties understanding and dealing with low-level risks. As such, the risk communication problem must be solved first before the CVM exercise can have a chance of working (Smith, 2005).

Corso et al. (2001) look at several different risk communication devices in the context of a CVM survey. They find almost no sensitivity to the scope of the good being valued with a simple verbal description of the risk changes. Yet with one of their visual methods of presenting the risk change, they find significant scope effects with WTP for risk reductions being almost linearly increasing in the magnitude.

A different approach is taken by Sudgen, (2007) who attempts to break the problem into two parts, one involving value elicitation and the other involving standard gambles, chained together to arrive at values for small probabilities. The valuation of risk reductions is likely to remain an active research area for some time.

Summary

There are several methods available to estimate consumer WTP for environmental goods or changes in the qualities of existing goods. In outlining the advantages and disadvantages of elicitation methods, one important factor has to be considered. One of the most important issues surrounding the credibility of an elicitation technique is that of incentive compatible. An elicitation mechanism is considered incentive-compatible if an individual’s dominant strategy is to truthfully reveal their preference for the good in question (Lusk and Hudson, 2004). A closely related issue
is that of hypothetical bias: that individuals respond differently when responding to hypothetical questions than when confronted with real payment. Because many valuation questions involve asking hypothetical questions where incentives may not be properly aligned, this issue is an important consideration. The vast majority of studies suggests that hypothetical bias is a significant problem in Contingent Valuation estimates.

4.6.3 Gaps, Imperfections and Criticisms of Contingent Valuation Method

Contingent valuation method entails a number of characteristics that allow for enhancing the extent to which changes to environmental goods can be assessed on a monetary basis. However, the method also involves some shortcomings. Various studies into CVM have identified a number of problems, (Bishop et al., 1983; Knetsch and Siden, 1984; Desvousges et al. 1987; Mitchell and Carson, 1989; Diamond et al., 1993; Berta et al, 2007). Below, these problems are presented and further discussed:

• Large difference between Willingness to Pay and Willingness to Accept measures;
• Strategic behaviour in responses;
• ‘Protest Zero Bids’ responses
• Implied value cue bias
• Scenario misspecification biases
4.6.3.1 Large difference between willingness to pay and willingness to accept measures

An often cited problem in relation to CVM is large differences between willingness to pay (WTP) and willingness to accept (WTA). The CVM literature has a number of studies demonstrating substantial empirical differences between WTP and WTA (Bishop et al., 1983; Diamond et al., 1993; Shahrabani et al., 2008). Economic theory suggests that the difference between WTP and WTA should be small if income effects are small (Just et al., 1982; Horowitz et al., 2003) or close substitutes exist for the commodity being valued (Hanemann, 1991). However, even when these conditions appear to be met in empirical studies, unreasonably large disparities between WTP and WTA have been observed.

Diamond et al. (1993) argue that the income effects in relation to CVM studies can be expected to be small due to the money values involved and the fact that CVM surveys have indicated that obtained WTP's do not increase in proportion to income. From a theoretical perspective, WTP and WTA should be quite close together for a price change in perfectly competitive private markets (Willig, 1976). However, for imposed quantity changes where the consumer is not free to trade to the desired quantity level, WTP and WTA may be far apart (Hanemann, 1991). Changes in environmental goods tend to fall into the category of imposed quantity changes.

Work proceeded in several directions. The first direction was to show that large differences between WTP and WTA estimates were not an artefact of the survey context. Consistently large differences were found in a variety of settings using actual transactions Even financial assets such as junk bonds and over the counter stocks, when thinly traded, often show much larger bid in WTP than WTA (Nayga et al., 2005).

The second direction was to show that the WTA question format had a number of shortcomings, both from the perspective of its strategic incentives and of getting
respondents to accept it as a legitimate framework for a policy choice (Damschroder et al., 2007). The third direction was to suggest new theories outside the neoclassical framework and to show that within that framework, the theory being applied failed to capture key aspects of the situation (Carson and Groves, 2007). Much of the problem with the current framework may stem from its inherent static nature. Recent models that incorporate bargaining, information effects, transactions cost/experience, and uncertainty show considerable promise in being able to explain the magnitude of the divergence between WTP and WTA amounts (Kolstad and Guzman, 1999; Zhao and Kling, 1999; List, 2000; Venkatachalam, 2004). The key implication of this divergence for applied policy work is that property rights can have a substantial influence on the magnitude of the welfare measure. Particularly when considering a reduction in an environmental service, the common practice of substituting a WTP estimate for the desired WTA measure can result in a substantial underestimate (Haab and McConnell, 2002).

That a price change where the consumer is free to adjust is different from an imposed quantity change where the consumer cannot adjust seems obvious in retrospect. Indeed, it was clear to Hicks (1943) who first clearly developed the concept of utility constant welfare measures. Willig (1976) was also careful to specify that he was looking at price changes. This acknowledgement was largely left behind in the rapid incorporation of Willig’s work in benefit-cost texts. His work showing that WTP and WTA were close in most likely situations involving price changes and that the Marshallian consumer surplus measure lay between WTP and WTA, justified the common applied practice of using the Marshallian consumer surplus as adequate approximation to the desired Hicksian measure (see Marshall, 1936).
4.6.3.2 Strategic behaviour in responses

The possibility of strategic behaviour in the form of free riding has long concerned economists dealing with public good issues (Samuelson, 1954). Economists suspicious of survey based answers made the opposite translation and believed (without theoretical justification) that survey based WTP estimates would be larger than true WTP, since they perceived no money directly changing hands. This led to early recommendations to make survey scenarios as hypothetical as possible in order to avoid strategic behaviour. However, without an incentive for strategic behaviour in a CVM survey, any response is as good as any other and responses provided in such context cannot be given an economic interpretation. Thus, the standard CVM recommendation has long been to offer respondents a real choice and take seriously the opportunities offered for strategic behaviour (Carson and Groves, 2007).

The structure of CVM surveys can lead to strategic behaviour among the respondents. For example, if the respondents perceive that the environmental good is likely to be provided irrespective of the stated preferences then there could be incentives to free-riding implying lower WTP’s. On the other hand if respondents perceive that the provision of the good is contingent on the stated preferences combined with the impression that eventual payment is a fixed amount then that could lead to overstating the true preferences. O’Doherty (1996) argues that careful survey design can minimise the extent to which strategic behaviour occurs. For example, free-riding can be eliminated by ensuring that the participants do not have the impression that the good in focus will be provided irrespective of the stated preferences.

Strategic behaviour, in economics, is simply utility maximizing behaviour. Strategic bias can occur when a respondent’s maximizing answer does not represent truthful preference revelation. The possibility of random responses (Converse, 1974; Fischhoff et al., 1980; Jorgensen et al., 2004) has been raised by psychologists and survey
researchers. This issue is related to the possibility of strategic behaviour since CVM choices cannot be both random and strategic simultaneously.

4.6.3.3 ‘Protest Zero Bids’ Responses

The term “protest zero bids” refers to a situation where respondents indicates that their willingness-to-pay is zero, not because they have no value for the good in question, but because they object to some aspect of the survey. For example, one may indicate a zero willingness-to-pay if this person believes that no monetary value can be placed on the good in question or if they experience a general sense of frustration with the survey.

‘No’ responses in dichotomous choice (DC) questions are generally probed for invalid responses, searching for free-riders, individuals protesting about the payment vehicle, etc. If data are not to be screened for invalid responses, ‘yes’ responses must also be examined, for example, to identify individuals who support the project behaving strategically. Beyond this consistency in the treatment of the data, no established theoretical criteria or generally accepted protocols exist for excluding observations from data analyses (Boyle and Bergstrom, 2001). It appears that a consensus exists that some observations may be invalid, but the exclusion of observations is generally undertaken using ad hoc criteria. The NOAA Panel recommended allowing respondents the option of answering ‘do not know’ in addition to ‘yes/no’ when answering dichotomous choice questions.

5 Dichotomous Choice format is a particular estimation technique used in Contingent Valuation, sometimes referred to as the “take it or leave it” approach. This approach presents the subject with the description of the good, and a single bid, or monetary value, which the consumer may choose to accept or reject.
An additional issue relates to individuals who do not value the good. Individuals who answer ‘no’, but hold a positive value, are treated the same as individuals who answer ‘no’ and hold a value of $0. Consideration of response distributions to other question formats, such as open-ended questions⁶, suggests that a discrete spike might occur at $0 in the distribution of values. Perhaps individuals who answer ‘no’ to dichotomous choice question should be given the opportunity to answer ‘$0’ and these responses should be modelled in the data analyses.

Concerns regarding data screening also apply to open-ended questions, unanchored payment cards, and other question formats. Open-ended questions typically result in zero bids and these bids are also sometimes screened for protests and other type of invalid responses. Non-zero bids are also sometimes screened for invalid responses. Some investigators have used statistical routines to search for data outliers (Meyerhoff and Liebe, 2004), but the fundamental concern remains. No established theoretical criteria or protocols exist for excluding responses. Although the issue of zero values does not arise with most other question formats because an answer of ‘$0’ is allowed (Boyle and Bergstrom, 2001).

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⁶An “open-ended” or “direct question” CVM format would ask the subject to state his or her maximum willingness-to-pay for the hypothetical good described. In theory, this amount of money indicates the individual’s point of indifference; They gain the same utility from having the described good and from having the monetary value that is stated as maximum WTP. This method is problematic because respondents may find it very difficult to simply come up with and state their true WTP. Consequently, this CVM format is associated with a large number of respondent non-responses and protest zero bids.
4.6.3.4  **Implied Value Cue Bias**

Mitchell and Carson (1989), in their extensive discussion of the CVM, describe biases that may result from “implied value cues”. These biases exist because of the individuals proclivity to try and lighten the burden the survey task places upon them, particularly in the case where they are unfamiliar with the questions or the amenity that the survey is concerned with. Survey respondents may be quite uncomfortable with placing a dollar value on many public goods (e.g. marine biodiversity conservation). Critics of the CVM argue that respondents may indicate their willingness-to-pay by simply pulling numbers out of the air, rather than truly grappling with the difficult trade-offs they are being asked to make (Mitchell and Carson, 1989).

Kahneman, *et al.*, (1982) maintain that when individuals are faced with an unfamiliar situation, they tend to make adjustments to some initial starting value to arrive at a final response. This tendency is known as the “anchoring effect”, possibly creating problems for the CVM because the adjustments to the initial value made by the respondents are often inadequate.

As noted above, iterative bidding and “take-it-or-leave-it” elicitation methods are believed to be particularly likely to result in starting point bias. A related form of bias is “yea-saying”, the tendency of respondents to agree to the provision of a particular amenity at the specified bid, regardless of their own economic value for that amenity. Individuals may find it difficult to say ‘no’ to the provision of public goods, as these types of goods are usually viewed as “good causes”. Carson and Groves (2007, pp 181) describe “yea-saying” as “the discrete choice analogue of starting point bias”.

Another case of bias occurs when the information presented on a payment card influences the respondent’s WTP; respondents may consider the monetary amounts listed on the payment card as indicating the “correct” values one should place on the
good being valued. If a particular respondent has a higher WTP, or a lower WTP, than any of the amounts listed on the card, they may be reluctant to reveal their true willingness-to-pay, fearing that it may be considered inappropriate in some way. Carson and Groves (2007) suggest that the possibility of range bias can be mitigated by listing a sufficiently high WTP upper bound and by allowing the respondent to choose from a large number of monetary values.

4.6.3.5 Scenario Misspecification Biases

Mitchell and Carson (1989) also describe another class of related biases, which they term “scenario misspecification” biases. Such biases can be a problem if the respondent perceives some aspect of the contingent market incorrectly. However, the respondent’s so-called “incorrect” perceptions may be due to an oversight on the part of the researcher. Scenario misspecification bias may stem from either theoretical or methodological problems. Theoretical misspecification bias occurs if the scenario described by the researcher is incorrect from a theoretical standpoint or is contrary to established facts. In such a case, although the respondent may understand the presented scenario perfectly, his indicated WTP values are not valid (Mitchell and Carson, 1989).

Methodological misspecification occurs when some aspect of the contingent market is inadequately described, and thus, the respondent perceived the scenario in a way unintended by the researcher. For example, respondents may interpret commonly used words in different ways. Elements of the hypothetical scenario that may be misinterpreted include descriptions of risk, the payment vehicle, and the implied budget constraint.

Some empirical studies have shown that symbolic bias can be a significant problem. For example, Phuong (2003) found that WTP values for a water quality program to
preserve fishing were very similar for two programs that differed only in the extent of geographical coverage: one program benefited a single region in Vietnam, while the other benefited a much larger geographical area. However, a comparison of WTP values for local water quality improvements versus those for national water quality improvements indicates that WTP values for national improvements are four times greater than values for local improvements, suggesting that symbolic bias may not be a problem in many CV surveys (Houtven et al., 2007). Yasunaga et al., (2005) state that the chances of symbolic bias may be minimized by the avoidance of overly simplistic hypothetical good descriptions, special care when valuing a good that is likely to be controversial (e.g. nuclear power risks) or a that may evoke strong emotional reactions (cardiovascular diseases).

4.6.3.6 Conclusion

This section has highlighted a number of issues in relation to the use of contingent valuation method (CVM) to provide monetary values for changes in environmental goods. The majority of contingent valuation practitioners believe that the method shows great promise and is capable of yielding both use and non-use values across an extensive range of environmental contexts. The reliability and validity testing adopted in response to earlier criticisms of contingent is now thought to be sufficient to show that the results are not random (Arrow et al., 1993). Therefore some forms of CVM can provide theoretically consistent and plausible measures of preference value for some types of environmental resources. (Smith, 2005).
Choice Modelling is also a stated preference valuation method that has its origin in conjoint analysis. It was initially developed in the marketing and transport literature by Louviere and Hensher (1982) and Louviere and Woodworth (1983). There has been a number of applications to estimate the value of recreational and environmental goods in recent years (Boxall et al., 1996; Adamowicz et al., 1998; Christie and Azevedo, 2002).

In a CM application, respondents are presented with a series of choice sets, each containing usually three or more alternative goods. An alternative is a combination of several attributes, with each attribute taking on a value, usually called a level. One of the alternatives in each choice set describes the current or future “Business-as-Usual” situation, and remains constant across the choice sets. From each choice set, respondents are asked to choose their preferred alternative. The attributes used are common across all alternatives. Their levels vary from one alternative to another according to an experimental design (Bennett and Blamey, 2001). If human-induced changes in marine ecosystems can be meaningfully represented by a set of attributes, choices made by survey respondents among sets of alternatives can provide resource managers and policy makers with valuable information about public preferences for many potential states of the environment (Holmes and Boyle, 2003).

Adamowicz et al. (1998), Diener et al. (1998), and Hanley et al. (1998) point out that the sensitivity of CM results to the assumptions regarding utility functional form has not been assessed adequately. Scarpa (2000) suggested that the assumptions made about how observed choices are linked to individual preferences are important when the objective is the comparison of welfare estimates.

The application of CM can provide information of the relationship between respondents’ welfare and the attribute levels. An analysis of the higher-order interaction terms in this relationship can help to explain the convergence or
divergence of the welfare measures obtained through different methods (Mogas et al., 2006).

According to Alpizar et al. (2001) there are four steps involved in the design of a CM: (i) definition of attributes, attribute levels and customisation, (ii) experimental design, (iii) experimental context and questionnaire development and (iv) choice of sample and sampling strategy. These four steps should be seen as an integrated process with feedback. The development of the final design involves repeatedly conducting the steps described here, and incorporating new information as it comes along. In this section, I focus on the experimental design and the context of the experiment, and only briefly discuss the other two issues.

4.7.1 Definition of attributes, attribute levels and customisation

The first step in the development of a choice experiment is to conduct a series of focus group studies aimed at selecting the relevant attributes. The focus studies could be in terms of verbal protocols, group discussion and actual surveys, (see for example Layton and Brown, 1998 for a discussion of how to use focus groups for pre-testing the question format and attributes). A starting point involves studying the attributes and attribute levels used in previous studies and their importance in the choice decisions. Additionally, the selection of attributes should be guided by the attributes that are expected to affect respondents’ choices, as well as those attributes that are policy relevant. This information forms the base for which attributes and relevant attribute levels to be included in the first round of focus group studies (Blamey et al., 2002).

The task in a focus group is to determine the number of attributes and attribute levels, and the actual values of the attributes. As a first step, the focus group studies should provide information about credible minimum and maximum attribute levels.
Additionally, it is important to identify any possible interaction effect between the attributes. If we want to calculate welfare measures, it is necessary to include a monetary attribute such as a price or a cost (Alpizar et al., 2001). Credibility plays a crucial role and the researcher must ensure that the attributes selected and their levels can be combined in a credible manner. Hence, proper restrictions may have to be imposed (Marley et al., 2008).

Customization is an issue in the selection of attributes and their levels. It is an attempt to make the choice alternatives more realistic by relating them to actual levels. If possible an alternative with the attribute levels describing today’s situation should be included which would then relate the other alternatives to the current situation. An alternative is to directly relate some of the attributes to the actual level. For example, the levels for visibility could be set 15 per cent higher and 15 per cent lower than today’s level (Louviere, 2004).

A general problem with applying a CM to an environmental good or to an improvement in health status is that respondents are not necessarily familiar with the attributes presented. Furthermore, the complexity of a choice experiment in terms of the number of choice sets and/or the number of attributes in each choice set may affect the quality of the responses (Alpizar et al., 2001). The complexity of a CM can be investigated by using verbal protocols, i.e. by helping the individual to read the survey; this approach has been used in CVM surveys (Campbell et al., 2007), thereby identifying sections that attract the readers’ attention and testing the understanding of the experiment.

4.7.2 Experimental design

Choice Modelling relies on the estimation of the relationship between the probability of choice being made and the relative levels of attributes in the alternative chosen. The model is driven by differing attribute levels in the attribute available to
respondents giving rise to differing probabilities of alternatives being chosen. With multiple attributes and with each attribute varying across multiple levels, it is apparent that for a model to be able to separate out the effects on choice of individual attributes, a lot of choices between alternatives which incorporate a lot of different combinations of attribute levels will need to be observed (Bennett and Blamey, 2001). In fact to identify completely the relationship, all the possible combinations of attributes should be presented to respondents.

Experimental design is concerned with how to create the choice sets in an efficient way, i.e. how to combine attribute levels into profiles of alternatives and profiles into choice sets. The standard approach in marketing, transport and health economics has been to use so-called orthogonal designs, where the variations of the attributes of the alternatives are uncorrelated in all choice sets (Alpizar et al., 2001). Recently, there has been a development of optimal experimental designs for choice experiments based on multinomial logit models (James and Lau, 2004). These optimal design techniques are important tools in the development of a CM (see the methodology chapter for more details), but there are other more practical aspects to consider.

There are several problems with these more advanced design strategies due to their complexity, and it is not clear whether the advantages of being more statistically efficient outweigh the problems. The first problem is obtaining information about the parameter values. Although some information about the coefficients is required for other design strategies as well, more elaborate designs based on utility balance are more sensitive to the quality of information used, and incorrect information on the parameters may bias the final estimates. Empirically, utility balance makes the choice harder for the respondents, since they have to choose from alternatives that are very close in terms of utility. This might result in a random choice (Huber and Zwerina, 1996).

The second problem is that the designs presented here are based on a conditional logit model where, for example, homogeneous preferences are assumed. Violation of
this assumption may bias the estimates (Colombo and Hanley, 2007).
The third problem is the credibility of different combinations of attributes. If the correlation between attributes is ignored, the choice sets may not be credible to the respondent (Johnson et al., 2000; and Caparros et al., 2008). In this case it may be optimal to remove such combinations although it would be statistically efficient to include them.

4.7.3 Experimental context, test of validity and questionnaire development

In the previous section, I addressed the issue of optimal design of a choice experiment from a statistical perspective. However, in empirical applications there may be other issues to consider in order to extract the maximum amount of information from the respondents.

Task complexity is determined by factors such as the number of choice sets presented to the individual, the number of alternatives in each choice set, the number of attributes describing those alternatives and the correlation between attributes for each alternative (Swait and Adamowicz, 1996). Most authors find that task complexity affects the decisions (Adamowicz et al., 1998). Alvarez-Farizo et al., (2008) analyse task complexity by assuming it affects the variance term of the model. The results of Alvarez-Farizo et al. (2008) indicate that task complexity does in fact affect the variance, i.e. an increased complexity increases the noise associated with the choices. Task complexity can also arise when the amount of effort demanded when choosing the preferred alternative in a choice set may be so high that it exceeds the ability of the respondents to select their preferred option (Alpizar et al., 2001).

Another issue to consider in the development of the questionnaire is whether or not to include a base case scenario or an opt-out alternative. This is particularly important if the purpose of the experiment is to calculate welfare measures. If we do
not allow individuals to opt for a status quo alternative, this may distort the welfare measure for non-marginal changes. This decision should, however, be guided by whether or not the current situation and/or non-participation is a relevant alternative. A non-participation decision can be econometrically analysed by e.g. a nested logit model with participants and non-participants in different branches (Blamey et al., 2000). A simpler alternative is to model non-participation as an alternative where the levels of the attributes are set to the current attribute levels.

Another issue is the presentation of choice sets, that is a matter both of clarity for respondents and technically for the analysts. The alternatives that are presented to respondents can be either labelled or unlabelled. A ‘labelled’ or ‘alternative specific’ choice sets includes descriptors of each alternative that go beyond the attributes. The labels may relate, say, to the policy that gives rise to the alternative. For instance, the status quo may be labelled ‘present situation’ (this is the way the status quo is label in this case study) whilst the alternatives may be labelled ‘increased sanctuary zone of 33%’ and ‘no sanctuary zone’ to indicate the broad policies that underpin those alternatives. Where no labels are used, the choice sets are said ‘generic’. The choice between the labelled and generic choice sets formats is important. Where the means of achieving environmental change is considered important (that is, where the policy mechanism is a factor in determining choice) the labelled format is more appropriate (Bennett and Blamey, 2001). With the labelled format, different level ranges can be specified for the attributes in the different alternatives. However, labels can prompt respondents to select their preferred alternative on the basis of the label alone and the impact of the varying levels of the attributes on respondent choice could be trivialised (Huybers, 2004). Whilst this may be a true reflection of people’s choices in some cases, in others it may simply be a reflection of the difficulties respondents are having in dealing with the choices presented in the format of a questionnaire. A case-by-case assessment of these matters during focus group testing is required to determine which format is more appropriate.
4.7.4 Sample and sampling strategy

The choice of survey population obviously depends on the objective of the survey. Given the survey population, a sampling strategy has to be determined. Possible strategies include a simple random sample, a stratified random sample or a choice-based sample. A simple random sample is generally a reasonable choice. One reason for choosing a more specific sampling method may be the existence of a relatively small but important sub-group which is of particular interest to the study. Another reason may be to increase the precision of the estimates for a particular sub-group. In practice the selection of sample strategy and sample size is also largely dependent on the budget available for the survey (Alpizar et al. 2001).

The advantages of CM are that values for each attribute as well as marginal rates of substitution between non-monetary attributes can be obtained. Moreover, rigorous tests of internal validity can be performed. The success of CM depends on the design of the experiment which, as repeatedly stressed, is a dynamic process involving definition of attributes, attribute levels and customisation, context of the experiment, experimental design and questionnaire development. Important tasks for future research include improving the knowledge about how respondents solve a choice experiment exercise and if preferences are consistent over the course of the experiments. Furthermore, the choice sets created by the chosen experimental design strategy have an important impact on the results.

4.7.5 Summary

Choice Modelling is a stated preferences technique for the estimation of non-market values. It has some distinct advantages over other technique, such as the Contingent Valuation Method, that have been more widely applied. Its ability to provide a disaggregated view of values is a key feature. With respondents’ preferences broken
down into components associated with the attributes that go to make up a good, it is possible to use Choice Modelling results to investigate the relative importance of attributes and estimate the values associated with various combinations of attribute levels (Bennett and Blamey, 2001). This method gives the value of a certain good by separately evaluating the preferences of individuals for the relevant attributes that characterize that good, and in doing so it also provides a large amount of information that can be used in determining the preferred design of the good (Alpizar et al., 2001).

I believe that applications of this technique will become more frequent in other areas of environmental economics as well. For example only recently has the aim of damage assessment in litigation shifted from monetary compensation to resource compensation. Therefore identification and evaluation of the different attributes of a damaged good is required in order to design the preferred restoration project (Adamowicz et al., 1998; Banerjee et al., 2007).

Choice experiments are especially well-suited for this purpose, and one could expect this method to be a central part of future litigation processes involving non-market goods. Considering that the aim of this project is to analyse the relationship among all the variables that forms the respondents’ utility function, Choice Modelling technique represents the most appropriate methodology to estimate the non-market value of the biodiversity conservation of Ningaloo Reef Marine Park.

4.8 Conclusion

What is not being argued in environmental economics literature, is that all environmental assets have significant unmeasured value and therefore all assets should be protected. Rather it is the ongoing ‘healthy’ system that possesses primary value and this requires biodiversity conservation at the landscape scale.
There is still, however, the thorny problem of actually deciding, on a rational basis, the ‘scale’ from which to manage environmental public goods. The ‘scale’ choice problem is in fact a public policy decision and as such is underdetermined by the mere provision of scientific information. Available scientific information contains inaccuracies and uncertainties such that it is not possible to specify minimum viable populations and minimum habitat size for the survival of species (Hohl and Tisdell, 1993).

Biodiversity and other environmental conservation decisions, for a considerable time to come, will have to be based on ethical considerations. It has been concluded that ‘society may choose to adopt the safe minimum standard not because it result from a rigorous model of social choice, but simply because individuals in the society feel that the safe minimum standard is the “right thing to do” (Ready and Bishop, 1991).

Also, let us not forget the significant instrumental value that biodiversity and other environmental resources possess. A suitably comprehensive and long-term view of instrumental value (one that protects ecosystems’ services by protecting the health and integrity of systems over the long run) is probably sufficient to realize the case for more environmental conservation and will carry with it aesthetic and intrinsic moral values as well (Turner, 1988; Costanza et al., 1993; Sloan, 2002; Lundquist and Granek, 2005).

Before we explore the potential choice modelling offers to estimate in monetary terms the non-use value of Ningaloo Marine Park, the Chapter to follow analyses other previous studies on economic valuation of biodiversity.
Chapter V

Previous Studies on Economic Valuations of Biodiversity

5.1 Introduction

The objective of this literature review is to illustrate the techniques that have been used recently and the results that have been achieved in empirical studies relevant to marine and coral reef biodiversity valuation. The aim of this section is to explore the environmental economics literature with a focus on marine biodiversity issues, to better understand and introduce this case study involving on the biodiversity conservation evaluation of Ningaloo Reef Marine Park, and analyse all the difficulties and problems related to the marine ecosystems valuation. Very little has, in fact, been done that relates only to marine biodiversity, while an extensive amount of research has been done that covers related areas, such as coastal resource valuation, or terrestrial biodiversity valuation. The purpose of this section is not to provide an exhaustive review of all of the valuation literature that may be relevant; such a review would encompass literally thousands of articles. I have taken the approach to review a number of key studies that have attempted to measure the economic value of different elements of biodiversity. In particular, I distinguish studies that have valued biological resources by value categories including existence and option value; harvested product valuations; recreation and tourism valuation; education and research values.
5.2 Existence and Option Values

Hundloe et al. (1987) use contingent valuation methods (CVM) to estimate the value of coral sites within the Great Barrier Reef to “vicarious” users. From adult Australian citizens, willingness-to-pay (WTP) bids to ensure that the reef is maintained in its (then) current state are used to calculate a consumer surplus of AU$45 million a year. Bids from survey respondents who had visited the reef are excluded, but the motives behind bids from non-users were not distinguished. Therefore, although the estimate represents non-use value, it does not separate option and existence values. In any case, the authors stress that the valuation is an underestimate because it excludes the vicarious value of the reef to overseas residents.

For the Galapagos National Park, de Groot (1992) estimates option value. He also estimates “inspirational” and “spiritual” values which are included here because these could be considered vicarious non-use values. The option value is estimated to be at least equal to the combined value of all the so-called productive and conservation (ecological) uses of the park. The value of cultural and artistic inspirational use is based on the value of book and film sales. The value of spiritual use is based on financial donations because, the author argues, at least part of donated money indicates an ethical or intrinsic value attached to the park. As existence and option valuations involving coral reef habitats are scarce, studies involving other types of habitats were reviewed for their methodological approaches to valuing non-use benefits.

One of the best examples of non-market values (focus on existence and option value) having an impact on public decision-making is the case of allowing tributary waters to flow into Mono Lake in California versus diverting the flows for municipal and
industrial water users in Los Angeles. In 1983, the California Supreme Court ordered a re-evaluation of Los Angeles’ water rights and a balancing of public trust water uses. A contingent valuation study by Loomis (1987) showed that people were willing to pay for the protection and conservation of birds and fish in Mono Lake and that these benefits far exceeded the replacement cost of water from other sources. As a result of this initial study, California’s Water Resources Board required that the state’s Environmental Impact Report include non-use ecosystem values in its analysis of water reallocation alternatives. In the analysis, non-use ecosystem values were compared dollar for dollar to the hydropower and water supply benefits. Eventually, the state required that tributary flows to Mono Lake be increased significantly, and Los Angeles’ water rights were cut almost in half. Although the driving concerns were air and water quality, the economic analysis showing that the new allocation generated important non-use economic benefits likely influenced this major policy shift (Loomis, 2000b).

For the North Sea, Canada, Beattie et al. (2008) use a new methodology called Eco-seed to evaluate existence value of biomass. They use a new applied game theory tool Eco-seed, that operates within a temporally and spatially explicit biomass dynamics model, to evaluate the efficacy of marine protected areas in the North Sea in both ecological and economic terms. The Eco-seed model builds Marine Protected Areas (MPA) based on the change in values of predicted economic rents of fisheries and the existence value of biomass pools in the ecosystem. Beattie et al. (2008) consider the market values of four fisheries operating in the North Sea: a trawl fishery, a gill net fishery, a seine fishery, and an industrial (reduction) fishery. Existence values, scaled such way that their aggregate is similar to the total fishery value, were assigned to six biomass pools of concern: juvenile cod, haddock, whiting, saithe, seals, and the collective pool ‘Other predators’ that include marine mammals. Beattie et al. (2008) discover that existence values will be negatively impacted unless
the MPA is very large. The Eco-seed model also suggests that policy goals based solely on existence values will negatively impact most fisheries. Under policy options that included ecological considerations, maximum benefits were derived from MPA that covered 25-40% of the North Sea, placed along the southern and eastern coasts.

The Eco-seed model is a simple multi-player, cooperative or non-cooperative model. The players in the model are the fishery managers or other interested parties (e.g. the regulator), and the fishing fleets. The game is modelled in two stages. In stage 1 the regulator decides what broad policy objective it wants to pursue. In stage 2 the fleets decide where and how to fish within the constraints set forth by the regulator, in order to maximize their own private rents through the redistribution of their effort within the unprotected area. The regulator can explore several strategies (policy objectives): either to maximize the fleet rent or to maximize the benefit to a species, or group of species or increased habitat leading to an increased species biomass may be a surrogate (Christensen and Walters, 2000).

The major goal of an Eco-seed model game is to allow the regulator to evaluate as many differing policy scenarios as possible. The Eco-seed model does not provide the ‘right’ numbers. It can only shed light on the expected direction and magnitude of change resulting from strategies undertaken, given the set of input parameters. As such, an Eco-seed model should also assist in the design of monitoring programs that should be part of the establishment of any MPAs.

In developing a perspective and providing expert advice on valuing marine ecosystems, it is necessary to begin with a clear discussion and statement of what it means to value something and of the role of “valuation” in environmental policy decision-making. Environmental issues and ecosystems have been at the core of many recent philosophical discussions regarding value (Sagoff, 1997; Justus, 2004; Delord, 2006). Fundamentally, these debates about the value of ecosystems derive from two points of view. One view is that some values of ecosystems and their
services are non-anthropocentric, that nonhuman species have moral interests or value in themselves. The other view, which includes the economic approach to valuation, is that all values are anthropocentric.

Another important issue related to the measure of existence and option values is the problem of using the approach of the Willingness to Pay that would probably be very sensitive to the level of information in the questionnaire. Hanley et al (1995) demonstrate that the WTP for biodiversity conservation increases with the level of information provided. Similarly, in their study of the WTP to restore the Wadden Sea (The Wadden Sea stretches from Den Helder in the Netherlands in the southwest, past the river estuaries of Germany to its northern boundary at Skallingen north of Esbjerg in Denmark) wetland to its ‘natural state’, Spaninks et al. (1996) demonstrate the significant influence of information about the present and "natural state" of the area. These, and other studies, thus raise the question of the appropriate level of information to be provided.

5.3 Harvested Product Valuations

All of the valuations use a change in productivity approach with varying degrees of linkage complexity. Two studies (Driml, 1999, De Groot, 1992) do not incorporate ecological economic linkages: the valuations simply represent the gross financial value of harvested products. Other studies try to link reef quality to fishery productivity: reef quality is viewed as a factor of production, a change which leads to a change in reef productivity; the productivity change is measured in terms of output levels. These approaches rely on ecological quantitative analysis and ecological economic linkages.

The harvested products category includes a valuation of coral reef aquarium fish production. The estimate represents the gross financial value of the trade, and
includes an estimate of the potential change in value with improved production practices. For its methodological interest, we also include a study of harvested products in a wetland habitat. It uses a relatively complex ecological economic linkage model which treats habitat area as a variable input to fisheries production (McAllister, 1988).

Three types of weakness are often evident in these types of valuations. First, and most serious, is that fisheries value is usually assumed to be its gross revenue, thus ignoring the opportunity cost of capital and labour in fishing effort. Such gross value estimates for fisheries over-state the net benefits from such activities and often make it politically difficult to find other economically benign and sustainable uses of a reef area (Brown et al., 2006; Jones et al., 2007). Second, the dynamics of the coral reef and surrounding natural systems are often simplified, if not ignored. Leis (2004) argue that the dynamics of natural systems are characteristically highly non-linear, discontinuous, and sometimes irreversible around a range of critical thresholds. Third, a less obvious weakness of many of these approaches is that they usually base harvest rates on some level of extraction effort which is implicitly assumed to be value-maximizing. In the simplest cases, current (observed) extraction rates are assumed to occur in perpetuity, even though these may be either above the socially optimal rate (from the usual types of over-fishing practices) or, more rarely, below the optimal rate, e.g., where there are barriers to entry, (Murillas and Chamorro, 2005).

Even in such cases, however, it is important to note that Maximum Sustainable Yield (MSY) does not necessarily coincide with an economic optimum, and standard fishery and bio-economics studies teach us that it may be economically optimal to extract at rates either below or above the MSY depending on the attributes of the specific fishery (Armstrong and Skonhoft, 2004; Susilowati et al., 2005). In cases where current harvest rates are used, it is likely that the methods over-estimate value; while estimates based on MSY will likely underestimate economic value.
Driml (1999) estimates the gross financial value for the commercial fishery of the Great Barrier Reef. Effort and catch data on selected major commercial fish species were obtained from the Queensland Fisheries Management Authority. Price data were obtained by a brief survey of the fish and prawn markets. Volume and price data yield an estimated gross financial value of AU$143 million (1996$).

For Hawaii, Cesar et al. (2002) uses CVM to compare the potential productive value of coral reef fisheries, to the value of those same fisheries in the presence of different threats to reef quality and productivity. Threats include poison fishing, blast fishing, over-fishing, coral mining, and sedimentation. Each threat is analysed in isolation from the others, and in terms of its net benefits on a per square kilometer basis. Therefore, a hypothetical reef area faces only one threat which provides a net private benefit to the individuals responsible for it, as well as societal losses due to the detrimental treatment of the reef (Jackson et al., 2001).

Potential productivity of reef fisheries is that associated with an intact reef area, and a level of effort which achieves the MSY of that area. Additional assumptions about fish prices, labour, and other input costs provide a net benefit valuation. The private net benefit of destructive fishing practices is based on threat-specific assumptions regarding prices, effort, yield, input costs, the rate of coral death, the rate of yield decline, and the rate of coral recovery, if any. Coral death and fishery yield are assumed to be linearly related. The societal loss to fisheries is the difference between the net private benefit of the destructive fishing practice, and the net benefit associated with the MSY level of effort (McClellan, 2008).

In the cases of coral mining and sedimentation there are only net losses to fisheries. Private benefits accrue in other sector such as: construction and logging. Losses to reef fisheries from coral mining is the difference between the MSY of an intact reef, and the yield of a gradually destroyed reef. It is therefore based on assumptions regarding the rate of coral destruction from mining, and the associated yield decline.
For the threat of sedimentation, the calculation of reef fisheries yield decline is based on the ecological linkage coefficient estimates of Hodgson and Dixon (2003).

In an often cited study of the value of Philippines coral reefs, McAllister (1998) calculates the change in fisheries productivity as a result of reef damage from dynamiting, poisoning, and muro-ami fishing. The valuation methodology is simply a comparison of current yields with potential yields. The productive area of the reef (some 33,000 km$^2$ out of a total 44,000 km$^2$) is disaggregated according to its condition: poor, fair, good, or excellent. The yield associated with each condition is calculated and the total yield for the productive area is compared with the potential yield were the entire reef in good condition.

Chabanet et al., (2005) estimate foregone earnings in the production of marine aquarium fish. Sodium cyanide is typically used for gathering marine fish, which damages the reef and reduces the price of the final product (net-caught tropical fish command a higher price). Based on the reported value of the Philippines trade in aquarium fish, the authors estimates that a 50 percent increase in value could be realized if the aquarium fish were produced on a sustainable basis.

The Hodgson and Dixon (2003) study estimates the gross revenue value of fisheries in Bacuit Bay, Palawan in Philippines with and without a logging scenario. It is the most complex of the coral reef valuations examined, in that it first undertakes a quantitative analysis of the natural systems affecting fisheries. Using environmental data, linkage coefficients are estimated to determine: (i) the relationships between sedimentation, coral cover and coral diversity; and (ii) the relationships between fish biomass, coral cover and coral diversity. The coefficients were obtained using linear regression analysis; this implicitly assumes constant returns to scale of the natural systems, a considerable simplification of the functioning of natural systems.

For the Galapagos National Park, (Gonzalez et al., 2008) estimates the gross financial
value of legally traded ornamental goods, local fish and crustacean harvest, and the value of construction materials. Associated capital and labour costs are excluded from the calculations, as are any consideration of the functioning of the underlying natural systems providing these products.

Some analysts base their assessments on maximum sustainable yield (MSY) to introduce some form of sustainability constraint (Newton et al., 2007). Even in such cases, however, it is important to note that MSY does not necessarily coincide with an economic optimum.

5.4 Recreation and Tourism Valuation

The recreation and tourism direct use value attributable to a coral reef is usually estimated by accounting for the tourism revenue generated by a particular coral reef holiday destination. From a utility perspective, these values ignore the consumer surplus generated by the recreation experience and as a result underestimate the value of the recreation experience. From a production perspective, gross tourism revenue – the figure most often calculated – ignores the labour and capital costs of supplying the services, as well as the costs associated with the environmental impacts of tourism (Diedrich, 2007).

Another problem with using tourism revenue relates to the bundling of a vacation destination’s attributes. When a coral reef is just one attribute of the bundle, tourism revenue cannot be solely attributable to the reef. The more important the reef attribute in the vacation experience bundle, the higher the proportion or tourist revenue that can be attributable to the reef (Cartier and Ruitenbeek, 1999).

The value of recreational fishing and boating was estimated using survey work by Blamey and Hundloe (1993), and current records of registered private boats adjacent to the park. Survey data showed that 63% of registered private boats are used for
recreational fishing; the data also provided an estimate of average yearly expenditure on recreational fishing and boating. With these data Driml (1999) calculates recreational fishing and boating in the GBR to be worth AU$123 million (1996$).

Hundloe et al. (1987) first use the Travel Cost Methodology (TCM) to estimate the consumer surplus for both domestic and international tourists to the Reef Region. The Reef Region comprises all the islands and reefs within the outer boundaries of the Great Barrier Reef Region. The study then isolates the consumer surplus associated with visits to coral sites. Coral sites are areas within the Region where coral can be viewed. For this, travel cost data was collected from visitors who had visited or planned to visit coral sites, as part of their visit to the Region. The consumer surplus associated with visits to the Region is calculated to be AU$144 million per year; the surplus associated with visits to coral sites within the region is AU$106 million per year. However, the researchers felt that the latter estimate still included all the attributes of the Reef Region, valued by those who had come to view coral as part of their vacation package. To calculate the consumer surplus of only the coral sites, with all other attributes of the Region removed, a CVM study was conducted by Hundloe, (1990) that focused only on tourists visiting the reef sites. The resultant consumer surplus was estimated to be AU$6 million per year; this might be regarded as a lower bound of the direct recreational value of the reef.

In another example of isolating the coral reef attribute of a vacation site, a study of Negril, Jamaica, estimates the consumer surplus of Negril as a vacation destination, as well as that part of the surplus attributable solely to the coral reef attribute of the vacation experience. Wright (1995) begins by conducting a CVM survey to determine the value of coral reef quality to vacationers. The study then uses the TCM to estimate a demand curve and the associated consumer surplus for a Negril vacation experience. Assuming a parallel shift (downward) of the demand curve, the study nets out the consumer surplus associated with maintaining coral reef quality in its
current condition. From the shift, and further assuming a fixed average cost of supply, the decrease in tourism volume as a result of coral degradation is calculated. The value of the change in tourism revenue is then used as input into a cost-benefit analysis.

Various ecological and economic analyses have been conducted for Bonaire, Netherlands Antilles. Dixon et al. (2001) calculate gross revenues from tourism, the carrying capacity of coral sites, and the consumer surplus associated with diving in the Marine Park. Arguing that quality diving is the primary attribute of Bonaire, the researchers calculate gross revenues from dive-based tourism of US$23.2 million. Capital and labour costs associated with providing tourism services are not included in the estimate. Dixon et al. (2001) also conduct a CVM survey of divers and calculate a consumer surplus of US$325,000 for divers in 2000.

Also for dive-based tourism in the Bonaire Marine Park, (Green and Donelly, 2003) estimates net revenue and consumer surplus for 1991. Net revenue is calculated using net revenue and local ownership data (obtained from Bonaire’s Department of Revenue and its Tourism Corporation). Consumer surplus is calculated using the TCM. The travel demand function uses marine park permit data (which provides tourist origin data), and surveys of vacationers. Net revenue ranges from US$7.9 to US$8.8 million per year; estimated consumer surplus is US$19 million annually. Arguing for a project appraisal approach for the valuation of resource protection, Green and Donelly (2003) also estimates the net present value of the Bonaire Marine Park to the local economy, and to tourists. For the NPV calculation, it is assumed that the Park is just being established. Over a 20 years period, at a 10 percent discount rate, the net present value of the Park to the local economy is US$74.21 million; and the NPV of consumer surplus enjoyed by tourists is US$179.66 million.
Using the Travel Cost Method, Leeworthy *et al.*, (2005) estimate consumer surplus for the John Pennekamp Coral Reef State Park in Florida. Survey data obtained from over 300 people includes number of trips taken to the park in the past year, round trip mileage, travel time, activities undertaken at the Park, and various socio-economic data. Nine model specifications using linear and semi-log functional forms are estimated. Consumer surplus estimates derived from the semi-log forms are rejected on the basis that the magnitudes were out of range of previous studies. The results of two linear models are accepted based on data fit and respective consumer surplus estimates. The two models differ only in that one included the opportunity cost of time; it is found that inclusion of this variable significantly increased consumer surplus estimates in all the model specifications.

For Indonesia, Cesar (2002) uses costs and benefits analysis to compare the potential productive value of reef-based tourism to its value in the presence of poison fishing, blast fishing, and coral mining. This model calculated costs and benefits for a hypothetical situation on 1 km$^2$ of coral reef, which was in pristine condition, and which was without other concurrent threats. The potential tourism value of a hypothetical reef area is estimated as a range, the bottom of which represents a low potential tourism scenario, while the top of the range represents a high potential tourism scenario. The low potential value is an average of the net revenue generated in an area of no tourism, and that generated in an area of moderate tourism. The high potential value is an average of the net revenue generated in an area of moderate tourism, and that generated in an area of major tourism. A case study of tourism in Lombok (Cesar, 2002) provides an estimate of net revenue in an area of major tourism potential; data gathered in Ambon provide an estimate of net revenue in an area of moderate tourism potential. The net benefit estimates are on square kilometer of reef basis, and represent a 25-year period discounted at 10 percent.
In Thailand, Seenprachawong (2001) focused only on economic values of coral reefs in the Andaman Sea of Thailand. Phi Phi, the site analysed, is rich in reefs and is envisioned as an ecological tourism destination by government planners. It has been found that Phi Phi provides large economic values through recreation. The consumer surplus estimated by a travel cost method reveals an annual value of 8,216.4 million Baht (US$205.41 million). The study also employed a contingent valuation method to estimate both use and non-use values of Phi Phi’s coral reefs representing an annual value of 19,895 million Baht (US$497.38 million).

In Philippines, (see Ahmed et al., 2007), the value of recreational and conservation benefits of coral reefs along the Lingayen Gulf, Bolinao, Philippines is evaluated using travel cost and contingent valuation methods, respectively. Empirical results from this study generated consumer surplus valued at PhP10,463 (US$223) per person per annum or potential net annual revenues to the local economy worth PhP220.2 million (US$4.7 million) from an estimated 21,042 visitors to Bolinao in 2000. However, willingness to pay (WTP) values (in absolute terms and as a percentage of income) for the conservation of coral reefs at Bolinao that were elicited are low, particularly among domestic tourists. This implies that preservation of natural resources and the environment may not be an immediate priority among local travelers due to socio-economic considerations in developing countries, such as the Philippines and the public goods nature of the recreational services provided by coral reefs. These results have further implications for determining the values of coral reefs to support public investment for their conservation and management. The roles of advocacy, education, and awareness campaigns have been highlighted to create a larger WTP for the management of coral reefs.

In Jamaica, Edwards (2008) explores the feasibility of implementing a sustainable funding mechanism for ocean and coastal management. Results show that tourists are more willing to pay for an “environmental tax” than a general “tourism
development tax”. This study found that an environmental surcharge of US$2 per person could generate $3.4M per year for management with 0.2% rate of decline in tourist visitation. Negative impacts from the imposition of additional taxes on annual tourist visitation rates could be minimised by providing information on how the revenues from the tax will be allocated for management activities.

Recreation is often cited as the most significant economic function of coral reefs. Three approaches to estimating value are usually evident: change in production, contingent valuation methods (CVM), or travel cost methods (TCM). From a utility perspective, these values ignore the consumer surplus generated by the recreation experience and as a result underestimate the value of the recreation experience. From a production perspective, gross tourism revenue ignores the labour and capital costs of supplying the services, as well as the costs associated with the environmental impacts of tourism. Inclusion of such costs is required to obtain a fair estimate of production values.

5.5 Ecological Function Valuations

Ecological functions provided by coral reefs include: (i) biological support to other ecosystems and organisms; (ii) physical protection to terrestrial, and other marine habitats; and, (iii) global life support through calcium – and, potentially, carbon – storage. The economic value of coral reefs for their carbon and calcium storage functions has not been attempted, although there exist volume estimates of their carbon and calcium storage capacities.
McAllister (1998) estimates the protection function value of coral reefs in the Philippines by calculating the costs of replacing the reefs with artificial devices to protect the coast. This type of calculation is considered to be minimum estimate of the protection value afforded by reef because: (1) delayed response time could mean that terrestrial productivity is lost in the interim; and, (2) artificial devices will forever need maintenance. The estimate obtained by McAllister is based on the per unit area cost of installing a certain type of barrier (concrete tetrapod devices) and multiplying that unit cost by the length of coastline fringed by coral reefs. The estimate does not allow for variations in the protective requirements along the coastline, given varying rates of coastal erosion and levels of economic activity.

For Indonesia Cesar (2002) uses CBA to compare the potential value of the coastal protection function of a coral reef, to its value as it succumbs to the impacts of blast fishing and coral mining. Replacement costs are used to estimate the potential value of the function. Calculated on a per square kilometer basis and discounted over a 25-year period, a range of value is estimated with low and high scenarios. The low scenario is an average of land value and replacement costs in, respectively, remote and moderately built-up areas. The high scenario is an average of replacement costs in moderately built-up areas, and those in areas with major infrastructure. The CBAs treat blast fishing and coral mining separately; the hypothetical reef faces only one threat at a time. In each analysis, the value of the societal loss of the reef’s protective function is the decline in the potential value of the protective function as the reef is destroyed. The yearly losses in protective function value are based on threat-specific assumptions regarding the rate of reef destruction, the point at which the level of destruction starts to impair the ability of the reef to provide coastline protection, and the ability of the reef to recover.

In the Galapagos, de Groot (2001) estimates values for a number of ecological functions. A fishery nursery function value of the Galapagos refugia is estimated
using a benefit transfer approach. Based on similarities of the Dutch Wadden Sea and Galapagos estuarine areas, de Groot assumes that 10 percent of the Galapagos fisheries is dependent on the inlets and lagoons of the Park. He also estimates the waste recycling function of the Galapagos marine area by calculating the cost of artificial purification technology. The valuation is based on an estimate of the total recycling capacity of the Galapagos sea shelf, and the unit cost of recycling organic waste.

De Groot (2007) estimates also values of two biological support functions: “biodiversity maintenance” and “nature protection”. Arguing that biodiversity maintenance is a necessary precondition to other functions and human activities, he assumes a shadow price of 10% of the value of any activity directly or indirectly dependent upon this function. Activities included all the productive uses ranging from recreation, to education and research. According to de Groot, the nature protection function relates to the value to society associated with preserving natural areas of particular naturalness, diversity, and uniqueness. The budget of the Galapagos National Park Service is used to estimate the value of this particular function.

Gren (2005) estimates the nitrogen retention and recycling function of wetlands in Gotland, Sweden. The approach is quite complex in comparison to those described above. It involved: (i) a natural systems hydrological model; (ii) an estimate of the absorptive capacity of wetlands; and (iii) a CVM analysis to determine the WTP for improved water quality by area residents.
5.6 Summary and Conclusion of Economic Valuations of Biodiversity Literature

The literature reviewed in this section reveals the challenges to decisionmakers in relation to coastal planning as well as the importance of effective management of a destination. The alarming statistics and scientific discoveries about coral reefs emphasize the urgency of proper reef management and improved coastal planning. After examining the valuation studies that focused on coral reefs, I find that:

- existence and option valuations are rare; only one study estimated the existence value of a coral reef site (the Great Barrier Reef) in Australia;
- most valuation studies involving coral reefs are concerned with their recreational and tourism use value;
- no studies estimate the genetic resource use value of coral reefs, although all acknowledge it;
- the most commonly valued harvested product of coral reefs is fisheries; but the natural systems underlying the harvest (e.g. reef/fish relationships) are simplified, if not ignored;
- the education and research values are based on expenditure estimates, or on budget allocations from funding institutions; and,
- coastal protection afforded by the coral reef habitat is the only ecological function valued;
- no studies estimate the existence and option value in Ningaloo Reef (Western Australia).

There is a significant gap in this literature and taking into consideration to already outlined threats to coral reef ecology, there is urgent need for further research to be carried out in order: first, improve on the available methodologies for valuing non-use values, and second, to build a reliable picture of the situation with Ningaloo Reef.
Chapter VI

Choice modelling methodology: An alternative approach to survey design and model specification

6.1 Introduction

In the last two decades, the demand for dollar estimates of non-market values, especially those associated with environmental impacts, has grown steadily. In the public sector, decision makers assessing capital works proposals and alternative natural resource management policies have sought quantitative assessments of environmental costs and benefits. In the private sector, an increasing number of firms find it useful to incorporate environmental value estimates in their project appraisals and environmental reporting processes (Bennett and Blamey, 2001). To meet this demand, economists have developed an array of techniques that go beyond traditional market-based means of estimating benefits and costs.

Interest in stated preference methods has been kindled by their capacity to yield estimates of the full array of use and non-use environmental benefits. The most commonly applied method in this type, the contingent valuation method (CVM) has been widely criticised (Bishop et al., 1983; Desvousges et al. 1987; Diamond et al., 1993; Boyle and Bergstrom, 2001) because of a range of potential estimation biases that it may generate. Most notably, CVM studies have been criticised because of the potential for ‘strategic bias’ whereby respondents deliberately misrepresent their preferences in order to influence the decision making process in their favour.

In addition, other stated preference methods have been developing. One such method is Choice Modelling that is used in this study. The first and perhaps most significant reason why this model is chosen instead other non-market valuation techniques such as the CVM, is that it allows the simultaneous presentation of a pool
of alternatives/scenarios. Respondents have to consider explicitly complementary and substitution effects in the choice process, and because the amenity of interest can be hidden with the pool of available goods, problems of bias can be minimised. Another advantage is that using Choice Modelling in this project it allows a much more realistic trade-off of opportunity costs than other non-market valuation techniques. Choice Modelling allows the introduction of a variety of opportunity costs, not just a WTP mechanism.

Another benefit that is worth noting is that Choice Modelling tends to concentrate choices on the underlying characteristics of the environmental amenity, in this case study the biodiversity conservation and protection of the Ningaloo Marine Park, rather than encouraging respondents to make subjective responses by association with other factors. The Multinominal Logit Model (MNL) used in this project enables a more realistic internal framing of choice to occur where some hierarchical decision processes are being followed. The MNL model essentially suggests that choices occur on different levels, and hence allows the grouping together of alternatives that may not be viewed simultaneously (or independently) by respondents.

This study uses a different approach of Choice Modelling survey design. Two different questionnaires were used. The first questionnaire represents the first Choice Modelling experiment and contains eight choice sets. The aim of this questionnaire is to select two hypothetical scenarios compared to the status quo (one with increased protection and the other with decreased protection) preferred by the respondents. The data obtained from the first questionnaire are used only to create a single choice set for the second questionnaire. The aim of the first questionnaire is to reduce the number of combinations from eight choice sets created for questionnaire 1, to one choice set for questionnaire 2.

The use of only one choice set for the questionnaire 2 (which contain three scenarios with different level of attributes) facilitates the understanding of the respondents to chose the scenario preferred, while with the traditional Choice Modelling format,
respondents are usually faced with many choice card options that could create some confusion.

Another particularity of this new approach is that in the first questionnaire, no financial attribute is included in the choice sets, because the aim of this questionnaire is to gather information only about the respondents’ environmental issues focus on biodiversity conservation related to some hypothetical management scenarios for Ningaloo Marine Park.

All the data used for the economic valuation of biodiversity conservation on NMP are collected by the second questionnaire which includes a separate section dedicated to the willingness to pay for conservation. In this second questionnaire, the willingness to pay is not fixed a priori as an attribute in the choice set. A separate section in the questionnaire is dedicated to gather information about the WTP. The respondents are free to put an amount of money they prefer and they can also chose which payment vehicle they prefer to be used to protect Ningaloo Marine Park, for the next generation. In this way, the willingness to pay is much more accurate and realistic than the traditional Choice Modelling approach, where the researcher had to fix a priori an amount of money to be paid for conservation. The willingness to pay estimation is extrapolated by the second questionnaire.

The first part of the chapter introduces the theoretical framework of Choice Modelling methodology used in this study. The second part is dedicated to the implementation of Choice Modelling that is divided in following sections: 1) identification of the problems; 2) questionnaire development 3) selection of attributes and levels; 4) experimental design; 5) sample sizing and data collection; 6) estimation methodology. The last part of this chapter is dedicated to the welfare measurement and the willingness to pay extrapolation method.
Choice Modelling Methodology: Theoretical Framework

Choice modelling is a stated-preference approach as it studies individual behaviour and estimates related values of the goods by asking people to state their own preferences for alternative circumstances. The method is used in many fields: marketing (Gilbride et al., 2004; Moe, 2005), health (Hall et al., 2002; Telser and Zweifer, 2003), cultural (Danchev and Mourato, 1997; Mazzanti, 2001), transport (Ben-Akiva, 1984; Vovsha and Bekhor, 1998; Han et al., 2001; Bierlaire and Frejinger, 2005), environmental economics (Hanley et al., 1998; Bennett and Blamey, 2001). In recent years, it has been applied in environmental economics for analysing conservation choice and destination choice on the basis of the attractiveness of destination and trip attributes (Crouch and Louviere, 2004). One of the main advantages of the method is that it allows for analysing hypothetical situations in those cases where no market exists.

A Choice Modelling application involves asking survey respondents to make a sequence of six to eight choices involving a constant ‘status quo’ situation (often referred to as the constant base) and a number of different proposed situations. Each choice question involves the status quo option and several (perhaps two or three) proposed alternatives. The groupings of status quo and proposed alternatives (or scenarios) are known as choice sets. The proposed alternatives in each choice are all different in terms of the condition of the environment described to respondents and the financial burden they impose. The descriptors of the environment and the financial impost involved are known as the attributes of the alternatives. They may be characteristics such as the “number of endangered species”, “the area of healthy coral reef communities remaining” or the “reduction of coral reef coverage” (Bennett and Blamey, 2001). Different levels are assigned to attributes to create the proposed alternatives for inclusion in the choice sets according to a systematic process known as experimental design.
By observing and modelling how people change their preferred option in response to the changes in the levels of the attributes, it is possible to determine how they trade-off between the attributes. In other words, it is possible to infer people’s willingness to give up some amount of an attribute in order to achieve more of another (Adamowicz et al., 1999). Given that one of the attributes involved is a dollar cost, it is possible to estimate how much people are willing to pay to achieve more of an environmental attribute. This is called a part worth or implicit price estimate and can be estimated for each of the non-monetary attributes used in the choice sets.

Furthermore, it is possible to use Choice Modelling results to infer the amounts people are willing to pay to move from the status quo bundle of attribute levels to specifically defined bundle levels that correspond with outcomes that are of interest. In other words, the willingness to pay to change from the status quo to a specific alternative can be derived. These estimates of compensating surpluses are consistent with the principles of welfare economics and are therefore suited for inclusion as value estimates in benefit-cost analyses of policy alternatives (Bennett and Blamey, 2001).

Monetary estimates of the values ascribed to particular resource use alternatives (described by specific boundless of attribute levels) may not be considered applicable in some circumstances. Choice Modelling results can provide another type of information to policy makers. The relative support that various alternatives could be expected to receive from the public can be estimated from CM data. Where there is a number of competing alternatives (status quo included) between which policy makers must choose, the percentage of the public that choose each can be estimated and this can inform further policies or decision making.
6.3 Implementation of Choice Modelling Methodology

The aim of this section is to describe step by step the implementation of the choice modelling methodology used in this case study. It is divided in the following six sections: identification of problems, attributes selection, questionnaire development, experimental design, sample sizing and data collection, and estimation methodology.

6.3.1 Case Study: Identification of the Problems

Below is a summary of the issues to be studied based on the detailed information provided in the first part of this thesis. The Ningaloo Marine Park is located along the coast of Western Australia, stretching for about 300 km northwards, from just below the Tropic of Capricorn (21°40′S to 23°30′S and 113°45′E). Ningaloo has more than 200 species of corals, a myriad of marine landforms, high water quality, gardens of captivating sponges, diverse life forms in the seabeds and fringing forests of mangroves. These support an amazing diversity of wildlife including 600 species of shellfish and other molluscs, 500 species of fish including whale sharks, manta rays and other tropical and subtropical fish, and a variety of other invertebrates. The reef is also on the migration path of humpbacks and other whales. Dugongs can often be seen in lagoons while the sandy beaches of the coast provide habitat for four species of turtle, three of which nest in the region (Hutchins et al., 1996). Considered one of the healthiest reef environments in the world, Ningaloo sits in a special biogeographic zone where the distributions of tropical and temperate marine and terrestrial organisms overlap.

Ningaloo is internationally recognized by the World Conservation Union (IUCN) as a highly productive and biodiverse marine ecosystem of potential World Heritage listing (Oceanwise Environmental Scientists, 2002). Currently, this fringing barrier reef system and its coasts are subject to significant human pressure. Unlike the Great
Barrier Reef, Ningaloo Reef is particularly susceptible to visitor disturbance due to its unique proximity to the coast. Commercial and recreational fishing have the potential for major negative impacts on the marine life of Ningaloo Reef waters. Some of these include: significantly reducing the distribution and abundance of target species thus changing the population structure; reducing population levels of non-target species through by catch; major impacts on benthic communities including destruction of flora and fauna, and loss of demersal fish and other fauna through habitat modification, e.g. from trawling (Moran et al., 1995).

The petroleum industry in Australia has a generally good environmental record (CSIRO, 2001). An independent scientific review of research into the environmental implications of offshore petroleum exploration was conducted by Swan et al. (1994). The review found that the offshore exploration and production industry in Australia not only met statutory requirements, but had set an excellent example in taking all possible steps to safeguard the marine environment. More recent research has been funded by individual petroleum companies and by the Australian Petroleum Production and Exploration Association (APPEA, 2005) with a view to further improving the industry’s environmental management and continuing to reduce impacts and risks associated with industry activities.

Despite this, there is still the potential for damage to the sensitive marine communities from exploration and extraction activities, considering that The North West Shelf, to the north of Ningaloo Marine Park, is a major area for oil and gas production and exploration and the Ningaloo region is considered as prospective. Offshore exploration has been carried out within the Marine Park prior to its establishment and has continued in areas adjacent to it (LeProvost Dames and Moore, 2000).

The aim of this study is to provide policy makers with much needed information on the public benefits that Ningaloo Reef generates in terms of non-use values that accrue to the Western Australia public. The non-use value estimated in this study is
the biodiversity conservation that can be used in benefit-cost analysis of alternative marine conservation management scenarios, thereby enabling sustainable management of the Ningaloo Marine Park. To accomplish this aim, the non-use values of the Ningaloo Reef conservation are estimated using the recently developed non-market valuation method, Choice Modelling.

6.3.2 Selection of Attributes and Levels

In choosing the attributes to be included in the Choice Modelling experiments there were a number of considerations, apart from ensuring they were feasible and credible:

- The attributes had to describe fully the environmental impacts of each scenario, or at least capture all the elements that were important to people in their decision.

- The number of attributes that people can think about when asked to make a choice is limited. In focus groups it was found that five attributes was about the best combination. Considering that many attributes reduce the willingness to answer the questions, and could affect response rates and the quality of the data, the attributes in this study were condensed to five.

- The attributes needed to be, as far as possible, independent. This was both for ease of analysis (satisfying independence of residuals in the statistical analysis) and to assist in the willingness to answer the survey questions.

- The attributes would preferably be quantifiable, and have some scaling that allowed for relative magnitude of changes to be assessed.

The attributes were used to describe a combination of considerations to the decision for the conservation and protection of Ningaloo Marine Park. The attributes and levels described below, are those used questionnaire 1. Questionnaire 2 uses the
same attributes, but the levels are condensed to create a single choice set for logistical and modelling purposes.

1) The percentage of the sanctuary zones. As biodiversity conservation is a key issue in the protection of marine life ecosystems in Ningaloo Marine Park, the percentage of sanctuary zones represents the most important tool to preserve and avoid any sort of human impacts into the coral reef ecosystems. At the moment (status quo) the percentage of sanctuaries is only the 33% of the coastline of the Park, so different hypothetical scenarios were selected. For Scenario II “increased protection” the percentage of sanctuary zones was presented to the respondents with the following amount: 40%, 45%, 50%, 60%, 66%, 75%, 80%, and 90%. Scenario III “decreased protection” started from 0% and increased to 3%, 7%, 10%, 15%, 20%, 25% and 30%.

2) The risk of reduction of coral reef coverage, caused by industrial oil spills, pollution from harbours activities and commercial fishing are directly related to the percentage of the sanctuaries, because at the moment only the 33% of the Park is protected, and in the rest of the ‘general use zone’ many commercial and recreational activities are allowed. So if we increase the percentage of sanctuaries inside the Park, we can reduce the risk of reduction on coral reef coverage and vice versa. It is very hard to predict the percentage of reduction on coral reef coverage if we move from one scenario to another, because the processes of the chemical and physical impacts to the coral reef are not yet well understood and any predictions for future years are not easy to do. Hence the risks in reduction of each scenario in terms of percentage were approximate, namely: ±10%, ±20%, ±30%, ±50%, ±60%, ±80%, ±90%, and ±100% (e.g.: in a scenario with 20% of sanctuary zones we have ±80% risk of reduction on coral reef).

3) Decrease of marine life biomass. As we continue to industrialize our seas, the
problem of ocean pollution worsens. A combination of commercial fishing, shipping, oil and gas exploration and production, dredging, construction, has resulted in dramatic increases in marine life loss throughout the Ningaloo waters. The risk of decrease of marine life biomass in Ningaloo waters depends on many factors not related only to the activities allowed inside the park but are also affected by other potential threats such as commercial fishing and shipping outside the boundary of Ningaloo Commonwealth waters. Because it is very hard to predicted the risk of decrease in marine life, these levels were coded as: very low, low, high and very high.

4) **Decrease in income for local communities of fisheries.** Commercial fishing is a very significant industry in the Ningaloo region, with two of the Western Australian state’s most valuable managed fisheries: Exmouth Gulf Prawn and the developing fishery for blue swimmer crabs based primarily in Carnarvon, valued in the range of $40-50 million annually in 2004 (DoF, 2005). The scenarios with increased protection and decreased protection have different economic impact for the local communities of fishers based in Carnarvon and Exmouth because they usually fish along the Ningaloo coast. This attribute was presented with the following levels as decreased income: none, very low, low, high, and very high.

5) **Loss of income for mining and petroleum exploration.** There are no oil exploration or production permits covering the Commonwealth Waters portion of the Marine Park and, although exploration permits cover some parts of the State Waters portion, Western Australian Government policy is not to allow oil exploration drilling and production within the Park. Any future threat to the Park from oil exploration/production would only come from the conduct of these activities in adjacent waters. The region in which the Marine Park is located is, however, considered prospective for oil and gas and it is likely that further activity will be undertaken in the area surrounding the Park. Also the
mining exploration and production are not allowed inside the Park, even if there is only one big salt mining in Lake MacLeod, at the south border of Ningaloo Marine Park. The level of this attribute related to each different scenario, was coded as: none, very low, low, high, and very high.

6.3.3 Questionnaire Development

Questionnaire 1

The first questionnaire was designed to gather information about perception of Western Australian tourists of some characteristics on current or hypothetical scenarios for Ningaloo Marine Park. In this questionnaire, respondents were told that there were three broad options available for the management of Ningaloo Marine Park: to continue the current situation (status quo), to increase protection and conservation, or reduce the protection and increase the industrial activities along Ningaloo coast, such as mining, commercial shipping, petroleum exploration, commercial fishing and tourism activities. Respondents were told that the status quo is not adequate to prevent all the environmental threats caused by the industrial activities outside the sanctuary zones. To facilitate the understanding of these environmental impacts to coral reef ecosystems, the oral explanation of these characteristics and levels was accompanied by different photos of coral damages (see for example Figure 3.7 in Chapter III). At the same time all possible economic benefits that industrial activities can generate for the local and state economy, in case respondents preferred or were interested in pro-development scenarios, were discussed. Eight choice sets were presented to the respondents. Each choice sets contains three typologies of scenarios: status quo, increased protection, reduced protection, and respondents had to consider only one option for each choice sets (see Appendix I for the full choice sets of questionnaire 1).
Two groups of hypothetical scenarios were presented in Questionnaire 1:

- Scenario II “increased protection” is the first group of hypothetical scenarios where the sanctuary zones increase in size and number compared to the present situation (33% of sanctuary zones), and this percentage ranges from 40% to 90%. In this scenario, the maximum protection hypothesis is 90% of sanctuary zones and not 100% because it does not exclude completely the recreational fishing which for Western Australians represents an important activity. A 100% protection is likely to be chosen only by few environmental activists and such a scenario is not a real alternative to the *status quo*. Scenario II will be chosen by Western Australians who have a ‘pro-conservation’ attitude because the aim of this scenario is to increase the protection of the reef ecosystems and reduce the areas dedicated to any sort of human activities that have a negative impact on the environment.

- Scenario III is the second group of alternatives labelled as “reduced protection”, an option where inside Ningaloo coast any industrial, commercial and mass tourism activities are allowed. Thus, these scenarios have less percentage of sanctuary zones than the *status quo*, and range from 0% to 30%. In this scenario the economic benefits are massive, considering the natural resources available in the north-west coast of Australia, the increased job opportunities related to the activities and also the opportunities for international companies to invest in industrial and tourism infrastructure. With low percentage of sanctuary zones, a drastic decline in the abundance and diversity of marine life along the coast, and decline of coral coverage is inevitable. This scenario was chosen by the respondents who had a ‘pro-development’ attitude.

The options in the choice sets were defined using five different attributes: percentage of sanctuary zone, risk of reduction on coral reef coverage, decrease of marine life biomass, decreased income of local fisheries, and loss of income for mining and petroleum companies. In each choice set the attributes were presented at different
levels.

The aim of this questionnaire was to select the preferred scenarios of Western Australian tourists (status quo, increased protection, and reduced protection) to create a single choice set for Questionnaire 2. The reason for reducing the number of alternatives/scenarios in Questionnaire 2, is to concentrate the attention of the respondents only on one choice set that includes three different scenarios, and avoid the confusion to present many different choice sets. Table 6.1 shows graphically an example of one choice set from questionnaire 1 with the different level of sanctuary zones related to the possible industrial use of Ningaloo Marine Park.

Table 6.1 Example of choice set: ‘percentage of sanctuary zone’

<table>
<thead>
<tr>
<th>PROTECTION</th>
<th>INDUSTRIAL USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>66%</td>
<td>33%</td>
</tr>
<tr>
<td>33%</td>
<td>66%</td>
</tr>
<tr>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**SCENARIO II**

**STATUS QUO**

**SCENARIO III**
Questionnaire 2

The respondents’ results from questionnaire 1, clearly showed (see next chapter) that the two hypothetical scenarios preferred were: Scenario II ‘increased protection’ with 66% of sanctuary zones for a ‘pro-conservation’ alternative, and Scenario III ‘reduced protection’ with 0% of sanctuary zone choosen by respondent who preferred a development scenario for Ningaloo coast. Thus the three scenarios introduced in the single choice set of questionnaire 2 are:

- Scenario I: the status quo;
- Scenario II: ‘increased protection’ with 66% of sanctuary zones;
- Scenario III: no protection (0% of sanctuary zone).

All the data used for the economic valuation of biodiversity conservation on NMP are collected using questionnaire 2 and include a separate section dedicated to the willingness to pay for conservation.

Questionnaire 2 is composed of five sections (see Appendix II for the full version of questionnaire 2 schedule). The first section “GENERAL INFORMATION OF ENVIRONMENTAL CONCERN” collects information on respondents’ environmental protection characteristics with a focus on Western Australia. Question Q.3 aims to gather information about what kind of environmental issues are most important for the Western Australian resident. The second section “NINGALOO REEF KNOWLEDGE AND VISITS” aims to identify information about the opportunities for recreational activities, right to fish, and marine protection in the Ningaloo Marine Park. Other questions (Q.4 and Q.5) collect information about visits to Ningaloo.

Section III “ECOLOGICAL KNOWLEDGE” is a single question that aims to test the respondents’ marine ecosystems knowledge about coral reefs. Three levels of biodiversity knowledge were created: (1) 0-2 errors good knowledge, (2) 3-4 errors
average knowledge, (3) 5+ errors poor knowledge. The information allows me to have a
general picture of Western Australian marine ecological knowledge with a focus on
coral reef ecosystems. This is an important variable (BIOK) introduced in this model,
to explore the relation between the biodiversity knowledge of the respondents and
the willingness to pay for biodiversity conservation in Ningaloo. The relationship
between biodiversity knowledge and respondents’ education is estimated to see if
the variable (BIOK) influences the probability to choose one scenario instead of
another.

Section IV “NINGALOO SCENARIOS” of the questionnaire contains the choice
experiment for which the main task was the development of scenarios able to
account for the complexity of the Ningaloo Reef’s offer, which combines marine
conservation, commercial activities and recreational aspects. As anticipated in the
introduction, the first questionnaire was used only to select the preferred
combination of scenarios.

The three scenarios proposed in this section are:

- **Scenario I Present Situation.** This is the current situation of Ningaloo Marine Park,
managed predominantly for conservation, recreation and education, with 33% of the
coast dedicated to the Sanctuary Zone, which are fully protected waters where all
detrimental human activities are prohibited. The activities prohibited inside the Park
are the following: mining, commercial fishing, petroleum and mineral exploration,
recreational fishing inside the Sanctuaries. The activities allowed are: access by boats
permitted throughout the marine park and management area; recreational shore-
based fishing; recreational fishing is also permitted in the general use zone;
commercial fishing is permitted only outside the general use zone of Point Maud and
north of Tantabiddi. To help the respondent to understand the scenario, I listed the
benefits of marine sanctuaries (such as increased biomass and abundance of marine
life, increased number and viability of species, reduced the probability of extinction
of threatened species, etc.) and the disadvantages of the sanctuaries (decreased income for fishing charters, restricted rights for fishers, reduced income from mining, etc.).

- **Scenario II Increased Sanctuary Zone – Minor Impact.** This is the first hypothetical scenario introduced to create a different situation, called “minor impact”, where the percentage of Sanctuary Zone, is increased to 66% of the coastline. The activities prohibited and allowed inside the marine park are the same as for Scenario I, but with the difference that the increase of sanctuaries has a determinant influence in terms of positive benefits for marine life and different impacts to any sort of commercial activities related to fishers.

- **Scenario III Ningaloo Reef without conservation – Major Impact.** This scenario considers the hypothetical case of the Ningaloo region without any kind of protection or conservation along the coast, except for Cape Range National Park. In this scenario, any sort of human activities are allowed inside and outside the reef. The economic benefits are enormous, considering that all industrial activities are allowed (mining, petroleum exploration, house and resort construction, fishing, industrial cargo harbour). On the other hand, the impact on the environment could be irreversible for the marine and terrestrial ecosystems. I listed in the questionnaire some of the main disadvantages of this scenario:

**Environmental Impacts of Industrial Activities**

- Pollution from industrial activities, such as heavy metals and other toxic waste
- Handling of liquid bulks may require pipelines, which provide the potential for leaks, emissions and spillages.
- Biocides and bleach: Fouling of harbour structures, such as slipways, steps, jetties, pontoons, can result in surfaces becoming covered in layers of bacterial and algal slime that must be removed.
• The impact of chlorine on the marine environment is extremely toxic to shellfish and fish as well as causing the localised lowering of species’ diversity.

Environmental Impacts of Urbanization

• Sand mining and dredging lead to shoreline erosion and coastal alteration.
• Deterioration of water quality by sewage, sediment runoff, solid waste materials, high nutrient loads and pathogens.
• Demand for construction materials (sand and gravel) can lead to disturbance and removal of benthic organisms at offshore extraction sites (sensible choice of extraction sites can reduce the disturbances).

Environmental Impacts of Fisheries & Mariculture

• Dramatic decline in the abundance and diversity of marine life along the coast.
• Bottom trawls cause irreparable damage to coral reef.
• Fast decline of coral coverage.

Section V ELITITACION is the financial part of questionnaire 2 and is the payment vehicle of an annual contribution that the Western Australian citizens would make to a fund exclusively dedicated to the Ningaloo conservation programme. Payment value is originally expressed in Australian dollar (AU$).

In this questionnaire, the WTP is not presented in the choice set as an attribute, as is the typical Choice Modelling format. A different approach is used to collect the information about the willingness to pay. Section V “ELITITACION” is used specifically to ask the respondents their willingness to pay for conservation, after they had already chosen the preferred scenario. With the traditional approach of CM, the researcher had to chose a particular payment vehicle recognized to be the more appropriate and then select also the amount of dollars for each scenario considered feasible, credible and possible for everybody. In this way the respondents have no choice about the financial attribute (WTP) and they have to choose an option they prefer in the choice sets, without expressing any preferences about the amount of
money they are willing to pay or about the payment vehicle they like because the WTP attribute is fixed \textit{a priori}. With the developed new approach to collecting the information about the WTP, the respondents have the possibility to express their preferences about the payment vehicles such as:

1. Park entrance fees from 0$ to 100$
2. Donation from 0$ to 100$
3. Increase income tax 0.1\%, 0.5\%, 1\%, 1.5\%, 2\%, 2.5\%
4. Others (specify)...........
5. None

So, for example, if the respondents choose the first payment vehicle, the entrance fees, they are free to put an amount of money they preferred. The advantage of this new approach, is first of all that more information’s gathered about the willingness to pay attitude and the preferred payment vehicle, that with the typical choice sets is not possible. Another important advantage is that respondents could express their willingness to pay for conservation also for the \textit{status quo} scenario, which at moment is free entrance. In fact, 35 people expressed their WTP as entrance fees for the \textit{status quo}, it means that they like the way Ningaloo Marine Park is managed and the percentage of sanctuaries, but they preferred to pay entrance fees because they realized that the Park authorities and its management need more funds to control and increase the quality of protection in the Park. With the traditional format of Choice Modelling it is not possible to obtain this information. This is very important and significant for future considerations related to the strategic plan and management of the Park. It also allows a potential weakness of the Choice Modelling methodology (improvement in the valuing of the \textit{status quo}) to be eliminated.

Respondent were also asked a series of demographic questions in section VI “DEMOGRACIFIC QUESTIONS”, such as their gender, age, education and income.
Education, income and age represent the socio-economic variables introduced in later in the model.

### 6.3.4 Experimental Design

Experimental design is concerned with how to create the choice set in an efficient way, i.e. how to combine attribute levels into profiles of alternatives and profiles into the choice set. The standard approach in marketing, transport and health economics has been to use the so-called orthogonal designs, where the variations of the attributes of the alternatives are uncorrelated in all choice sets. These optimal design techniques are important tools in the development of a choice modelling. A design is developed in two steps: (i) obtaining the optimal combinations of attributes and attribute levels to be included in the experiment and (ii) combining those profiles into choice sets (Alpizar et al., 2001).

A starting point is a full factorial design, which is a design that contains all possible combinations of the attribute levels that characterize the different alternatives. In general, a factorial design is simply the factorial enumeration of all possible combinations of attribute levels. A complete factorial design guarantees that all attribute effects of interest are truly independent. Thus, the statistical effects or parameters of interest in such models can be estimated independently of one another and all possible effects associated with analysis of multiple linear regression models can be estimated from a complete design factorial analysis (see the following section on estimation methodology). The statistical advantages possessed by complete factorial designs make them practical only for small problems involving either small numbers of attributes or levels. In this case study the complete factorial is too large. In fact in this case, we have in total five attributes with three different levels. Such complex problems can be reduced to practical sizes by using fractional factorial
design. Fractional factorial design involves the selection of a particular subset or sample (see Table 6.2) of complete factorials, so that particular effects of interest can be estimated as efficiently as possible. The five components related to the three scenarios options presented in the choice set is a three level blocking factor used to create three versions of scenarios.

Table 6.2 Choice set for Ningaloo Questionnaire 2

<table>
<thead>
<tr>
<th>IMPLICATIONS</th>
<th>SCENARIO I STATUS QUO</th>
<th>SCENARIO II INCREASED SANCTUARY (Minor Impact)</th>
<th>SCENARIO III WITHOUT CONSERVATION NO SANCTUARY (Major Impact)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of sanctuary zone</td>
<td>33%</td>
<td>66%</td>
<td>0%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 60%</td>
<td>± 30%</td>
<td>100%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>Low</td>
<td>Very Low</td>
<td>High</td>
</tr>
<tr>
<td>Decrease income of local communities of fisheries</td>
<td>High</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>

6.3.5 Sample Sizing and Data Collection

A general problem with applying choice modelling to an environmental good is that respondents are not necessarily familiar with the attributes presented. In order to make clear and homogeneous the comprehension of attributes and to facilitate the individual decision process, the oral explanation of these characteristics and levels
was accompanied by the presentation of drawings and photos representing each scenario. In particular some photos of possible damages caused by commercial fishing, petroleum exploration and mining activities that affect the coral reef and the landscapes were shown to the respondents (see Figure 3.7 as an example).

Questionnaire 1

The survey with questionnaire 1 was undertaken in September 2006, and 50 respondents were interviewed inside Ningaloo Marine Park. In this questionnaire, respondents were told that there were three broad options available for the management of NMP, but with different levels of protections and conservations. The fundamental idea behind the choice experiment was to mimic how different Ningaloo Marine Park management scenarios impact on the coral reef ecosystems. These different management scenarios were shown to the respondents through eight choice sets. This survey did not include the financial attribute willingness to pay for conservation, because the aim was to collect information focussing only on hypothetical management scenarios for Ningaloo Marine Park. This questionnaire was not created to generate data for model estimation, but to develop questionnaire 2 to be used in a further survey. The results from this questionnaire are discussed in the Chapter VII.

Questionnaire 2

This questionnaire collected the data used for the non-use values estimation of Ningaloo Marine Park. A face-to-face survey was conducted in the months of October and November 2006. The questionnaire was designed to gather information on the perception of Western Australian tourists about certain characteristics of current and hypothetical scenarios for Ningaloo Marine Park, to be used in the choice
modelling to analyse the attitude of Western Australians towards the conservation of Ningaloo and their willingness to pay to preserve its marine biodiversity. The collected information includes the individual characteristics of tourists, their general marine biodiversity knowledge, their attitude toward conservation or industrial development, characteristics and evaluations of the tourist experience in Ningaloo. The questionnaire aimed to be representative of the typical experienced tourist of Ningaloo (i.e. who recently spent his/her holiday in Ningaloo), but clearly cannot properly represent all potential tourists to this destination. On this basis, 100% of the interviews were with Western Australian household tourists. Only Western Australians were included in this survey, because the willingness to pay for conservation is strongly affected by the distance to the amenity that we consider, so for example the WTP for conservation in Ningaloo is completely different to Australian citizens who live in Queensland compared to people who live in Western Australia. The effect of the willingness to pay on distance does decline as the distance increases and was already tested by Pate and Loomis, (1997) in a case study of wetlands and salmon in California; Zweifel et al., (2005) tested the spatial effects in WTP; also Concu (2007) investigated the distance effects on environmental values. Both genders were equally represented in the sample. Interviews were carried out in different places in order to collect information also from those tourists whose main reason to spend holidays in Ningaloo is not the seaside resort. I started to interview people in vacation along the north west coast, from Gnaraloo Bay in the middle of October 2006, which coincided with the Australian school holidays and can be considered as peak season. I continued the interviews going up north in the following spots:

- **Warroora**, a minor tourist node located on a dune and cuspat e spit coast in a semi-remote setting;
- **Elles Camp**, located on a narrow coastal plain, situated between the beach strand and the toe of a broken dune range;
- Maggies, the area is popular with fishers who tend to camp adjacent to the boat launch and beach access point;
- Coral Bay, little town along the coast considered as an icon for tourism limited to a total of 3600 overnight visitors (tourists);
- Doddy’s Camp, a small valley behind the coastal fore dune in a close proximity to a coastal beach;
- Cape Range National Park, South Mandu camping area, a reef retreat eco-camp;
- Yardie Creek homestead.

The remote areas were preferred because I could find more Western Australians in holidays that have chosen those areas for camping and enjoying the wilderness of Ningaloo Marine Park.

6.3.6 Estimation Methodology and Specifications of the Utility Functions

The theoretical foundation of the discrete Choice Modelling is given by Lancaster (1966), who developed a characteristic approach for the analysis of demand. Since choice modelling elicits preferences from consumers, this method provides information about preference orderings within a set of choice options. The analysis of the data is based on random utility model (RUM), originally proposed by Thurstone (1927).

In psychology, random utility models date back as far as Thurstone (1927) as a way of conceptualising semi-rational behaviour. The psychological interpretation, exposited in Luce and Suppes (1965), assumes that each decision-maker carries a distribution of utility functions internally and selects one at random whenever a decision must be made. McFadden’s (1974) simple insight was to re-interpret the
randomness as arising from cross-sectional variation in utility functions across the population rather than from time-series variation within a given individual. McFadden was the first to recognize the broad power of the RUM as a tool in econometric analysis, but he was careful to acknowledge connections with other work in economics. McFadden [III, 1974, footnote 7] notes that the RUM idea is implicit in random coefficient models of classical consumer demand.

Random utility models are derived from the concept of utility maximization. Decision-makers are assumed to be rational, and to perform a choice in order to maximize a quantity, called utility, associated with each of the alternatives under consideration. The utility is modelled by a random variable, in order to account for the many sources of uncertainty in the decision process itself, and in the methodological assumptions. The Choice Model is based on the assumption that the set of alternatives considered by the decision-maker, or choice set, is discrete. Random utility models assume, as neoclassical economic theory, that the decision-maker has a perfect discrimination capability. In this context, however, the analyst is supposed to have incomplete information and, therefore, uncertainty must be taken into account. The random utility model requires that the stochastic component (error) enter the utility function directly.

The utility is modelled as a random variable in order to reflect this uncertainty. More specifically, the utility that individual $i$ is associating with alternative $a$ is given by:

$$U_a^i = V_a^i + \epsilon_a^i$$

where $V_a^i$ is the deterministic part of the utility, and $\epsilon_a^i$ is the stochastic part (error) capturing the uncertainty.

The implementation of the technique is based on asking respondents to choose among the three different alternative scenarios, defined in terms of product attributes. Differences among alternatives are due to (systematic) combinations of diverse attribute levels. Having submitted choice sets, the resultant sequence of
choices enables to model the probability of any alternative to be chosen. In accordance with the random utility model, the chosen alternative among those proposed in the choice experiment corresponds to the combination of attribute levels that brings the highest utility. In other words, the choice made by respondents identifies the combination of the attribute levels which maximizes the utility across alternatives in a given choice set.

The econometric analysis presented in this methodology is based on a multinomial logit (MNL) model. The word ‘logit’ is a contraction of the logarithmic transformation of an odds ratio. Under the MNL procedure, the probability of choosing an alternative is modelled as a function of the attributes and the socio-economic characteristics of the respondents. The probability of a respondent choosing an alternative increases as the levels of desirable attributes in that alternative rise and the levels of undesirable attributes falls relative to the levels of the attributes in the other alternatives that are available. The probability is therefore an indication of the relative utility (defined by economists as well-being or satisfaction) provided by alternatives, given that an individual will choose the alternative that provides the greatest utility (Bennett and Blamey, 2001). What the modelling of respondents’ choices is able to provide is a sequence of equations each of which describes the probability that alternatives will be chosen.

Formally, given a sample of H individuals, with h=1,2,.......H and a set of alternative choices, j=1,...,J, the random utility specification can be represented as follows (Louviere et al., 2000):

\[ U_{hj} = V_{hj} + \epsilon_{hj} \]  

where the latent and unobservable utility value for the choice alternative j made by
consumer h is given by the sum of a deterministic component with a random term, \( \varepsilon_{ih} \). The conditional logit specification is obtained by assuming that these random terms are independently and identically distributed (IID) according to a Gumbel\(^7\) distribution.

The deterministic component usually takes the following linear additive form:

\[
U_{hj} = \beta' x_{hj}
\]  

[2]

With this specification, the deterministic component is a function of the attributes of the alternatives and (in principle) of individual characteristics, \( x_{hp} \) and a set of unknown parameters, \( \beta \). Given the presence of the random term in equation 1, the probability of choosing the alternative \( i \) can be expressed as follows:

\[
P(i \mid C_h) = P[(V_{ih} + \varepsilon_{ih}) > (V_{jh} + \varepsilon_{jh})].
\]  

[3]

Expression [3] defines the probability that consumer h chooses \( i \) within the choice set \( C_h \), as the probability that the sum of the systematic and random utility terms of option \( i \) is greater than the corresponding terms for any other option \( j \) in the choice set \( C_h \). The independence of irrelevant alternative assumption across alternatives for the \( \varepsilon_s \) entails the property of independence of irrelevant alternative (IIA), which means that the relative probability of an alternative being chosen over another is independent of the availability of additional attributes or alternatives.

---

\(^7\)Extremes are unusual or rare events. In classical data analysis tasks extremes are often labelled as outliers and even ignored. This means the data gets wrapped to fit the model. If we only seek estimations about everyday events, it might not matter if you cut off extreme data, but if you ask questions about events that do not happen very often, we should apply the Extreme Value Theory (EVT). In probability theory and statistics the Gumbel distribution (named after Emil Julius Gumbel (1891–1966)) is used to find the minimum (or the maximum) of a number of samples of various distributions.
Broadly speaking, once a choice has to be taken between three scenarios, the decision does not depend on the existence of other alternatives (McFadden, 1984). Therefore, if some alternatives are excluded from the choice set, the estimates are still consistent. Thus, the information provided by a dataset with a smaller number of choice alternatives is still representative of consumers’ behaviour (Train, 2003).

In order to mimic the choice process actually undertaken by consumers in real life, econometric analyses do not need to consider simultaneously all real alternatives (which would make experiments or data collecting quite complex and difficult). In the conditional logit model, the probability that an individual $h$ picks alternative $i$ out of $J$ alternatives can be represented as follows:

$$ P[y_h = i] = \frac{1}{\sum_{j=1}^{J} \exp[-(V_{ih} - V_{jh})]} $$ [4]

or

$$ P[y_h = i] = \frac{\exp(\beta x_h^i)}{\sum_{j=1}^{J} \exp(\beta x_h^j)} $$ [5]

where $y_h$ is a choice index, which represents the choice made by individual $h$.

The estimation of equation (5) yields the $\beta$ coefficients which can be used to evaluate the rate at which respondents are willing to trade-off one attribute for another. This substitution rate can be easily calculated by dividing the $\beta$ coefficient of one of two attributes into consideration by the $\beta$ coefficient of the other attribute and multiplying by -1.

$$ Substitution rate = \frac{\beta_k}{\beta_s} $$ [6]
When the attribute to be “sacrificed” \((x_s)\) in order to obtain more of the other \((x_k)\) is expressed in monetary terms (WTP), this estimated trade-off is an “implicit price”, such as in the case of this study, the amount of money respondents are willing to pay in order to obtain more of the other attribute (more conservation on Ningaloo Marine Park) \((x_i)\).

In general, the coefficient used to value the marginal substitution rates in monetary term is the one associated with an attribute expressed in monetary terms and is an approximation of the negative of the marginal utility of income. These estimates rely on the assumption that the marginal utility of income is constant over the range of implicit income changes involved by the choice. This assumption is reasonable if the cost of a choice alternative represents a small amount with respect to individual income. When attributes are discrete variables, implicit prices take the form of “values of level change”, for which the substitution ratio is:

\[
\text{Substitution rate} = \frac{\beta \Delta x_i}{\beta_s} \quad [7]
\]

These ratios provide important information for public authorities aiming to evaluate the relative weight of each attribute when a modification to the structure of the current supply is introduced. In this study two different multinominal logit (MNL) are estimated using the data from Ningaloo Reef survey (questionnaire 2). Definitions of the variables used in these models are presented in Table 6.3
### Table 6.3 Variable description

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC1, ASC2</td>
<td>Dummy variables: alternative specific constants for Scenario I and Scenario II</td>
</tr>
<tr>
<td>SANCT</td>
<td>Percentage of Sanctuary Zone inside Ningaloo Reef</td>
</tr>
<tr>
<td>REEF</td>
<td>Reduction of coral reef coverage</td>
</tr>
<tr>
<td>BIO</td>
<td>Decrease of marine life biomass</td>
</tr>
<tr>
<td>FISH</td>
<td>Decrease in income of local communities of fishers</td>
</tr>
<tr>
<td>MININ</td>
<td>Loss of income for mining and petroleum companies</td>
</tr>
<tr>
<td>WTP</td>
<td>Willingness to pay for conservation and protection</td>
</tr>
<tr>
<td>INCOME</td>
<td>Respondents’ household income</td>
</tr>
<tr>
<td>EDU</td>
<td>Level of respondents’ education</td>
</tr>
<tr>
<td>AGE</td>
<td>Age of respondents</td>
</tr>
<tr>
<td>BIOK</td>
<td>Dummy variable: marine biodiversity general knowledge focused on coral reef</td>
</tr>
</tbody>
</table>

The first model [8] shows the importance of choice set attributes in explaining respondents’ choice across the three different options (the scenarios). The second model [9] includes both socio-economic and attitudinal variables in addition to the attributes in the choice set.

Three utility functions ($V_{1-3}$) are derived from the initial MNL model. Each function represents the utility generated by one of the three options. Options 1 is the Present Situation: Scenario I, options 2 is hypothetical scenario with increased protection: Scenario II, and option 3 is the hypothetical scenario without conservation: Scenario III.

Present situation \[ V_1 = \beta_1 \cdot SANCT + \beta_2 \cdot REEF + \beta_3 \cdot BIO + \beta_4 \cdot FISH + \beta_5 \cdot MININ + \beta_6 \cdot WTP \] [8]

Scenario 2 \[ V_2 = ASC1 + \beta_1 \cdot SANCT + \beta_2 \cdot REEF + \beta_3 \cdot BIO + \beta_4 \cdot FISH + \beta_5 \cdot MININ + \beta_6 \cdot WTP \]

Scenario 3 \[ V_3 = ASC2 + \beta_1 \cdot SANCT + \beta_2 \cdot REEF + \beta_3 \cdot BIO + \beta_4 \cdot FISH + \beta_5 \cdot MININ + \beta_6 \cdot WTP \]
The \( \beta \) values are the coefficients associated with each of the attributes.

For the three utility functions, utility is determined by the levels of the five attributes in the choice set, plus the WTP extrapolated by the separate section ‘Elicitation’ (SANCT, REEF, BIO, FISH, MININ, WTP). Hence, the model provides an estimate of the effect of a change in any of these attributes on the probability that one of these options will be chosen. A likelihood ratio test will be conducted to test whether the multinominal logit is the true model.

**The likelihood ratio test**

The log likelihood function is a useful criterion for assessing overall goodness-of-fit when the maximum likelihood estimation (MLE) method is used to estimate the utility parameters of the MNL models. This function is used to test the contribution of particular (sub) sets of variables (Louvriere et al., 2000). The procedure is known as the likelihood ratio test (LR). To test the significance of the MNL model in large sample, such as this case study, a generalised likelihood test is used. The null hypothesis is that the probability of an individual choosing alternatives \( i \) is independent of the value of the parameters in MNL utility function. If this hypothesis is retained, we can infer that the utility parameters are zero. Thus, the usefulness of the likelihood ratio test is its ability to test if subsets of the \( \beta \)s (the coefficients associated with each of the attributes) are significant.

As well as the levels of the attributes, modelling constants must be included in the rows of data. These constants are known as the ‘alternative specific constants (ASCs).

In this case, with three alternatives in the choice set, two alternatives must be associated with an ASC. The two ASCs are associated with the two hypothetical scenarios. Hence, new ‘attributes’ had to be created for two of the three alternatives, which take on the value of 1 in the line of data relating to their alternative and 0
otherwise. It is the role of the ASCs\textsuperscript{8} to take up any variation in choices that cannot be explained by either the attributes or the socio-economic variables. The choice models of data are generated by statistical routines with the software package STATA 8.0. In the second model a socio-economic and attitudinal variables are included in MNL models in two different ways. The first way is by interactions with attributes in the choice sets. In this model, two socio-economic (INCOME and AGE) and one attitudinal variable (BIOK ‘marine biodiversity knowledge’) are interacted with the variable WTP. These interactions will tell us how the variables income \& age and marine biodiversity knowledge modify the effect of the willingness to pay for conservation on the probability of choice.

The second method used to include socio-economic and attitudinal variables is through interactions with the alternative specific constant (ASC1 and ASC2). In this model four variables are included as interactions with the alternative specific constant for the scenario 2 and scenario 3 (INCOME, BIOK, EDUCATION and AGE). These interactions show the effect of various attitudes and socio-economic characteristics on the probability that respondent will choose either scenario 1, 2 or 3.

---

\textsuperscript{8} Due to limitations in model specification, but also in the quality of the data available, it is never possible to capture all information that affects the choice of a given decision-maker. As such, the utility of a given alternative is not fully observed, and an error term, or unobserved part of utility, remains. By adding alternative specific constants (ASC) to the utility of alternatives, the mean of this randomly distributed error term is added into the observed utility function, such that the remaining error term has a mean of zero. These ASCs thus capture the mean effect of all unobserved variables attributes, including general attitude towards an alternative, while the remaining error term captures the variation in this effect.
The specification for the second model is as follows:

\[ V_1 = \beta_1 \cdot \text{SANCT} + \beta_2 \cdot \text{REEF} + \beta_3 \cdot \text{BIO} + \beta_4 \cdot \text{FISH} + \beta_5 \cdot \text{MININ} + \beta_6 \cdot \text{WTP} + \beta_7 \cdot \text{WTP} \cdot \text{INCOME} + \beta_8 \cdot \text{WTP} \cdot \text{BIOK} + \beta_9 \cdot \text{WTP} \cdot \text{AGE} \]

\[ V_2 = \text{ASC1} + \text{ASC1} \cdot \text{INCOME} + \text{ASC1} \cdot \text{BIOK} + \text{ASC1} \cdot \text{EDUCATION} + \beta_1 \cdot \text{SANCT} + \beta_2 \cdot \text{REEF} + \beta_3 \cdot \text{BIO} + \beta_4 \cdot \text{FISH} + \beta_5 \cdot \text{MININ} + \beta_6 \cdot \text{WTP} + \beta_7 \cdot \text{WTP} \cdot \text{INCOME} + \beta_8 \cdot \text{WTP} \cdot \text{BIOK} + \beta_9 \cdot \text{WTP} \cdot \text{AGE} \]

\[ V_3 = \text{ASC2} + \text{ASC2} \cdot \text{INCOME} + \text{ASC2} \cdot \text{BIOK} + \text{ASC2} \cdot \text{EDUCATION} + \beta_1 \cdot \text{SANCT} + \beta_2 \cdot \text{REEF} + \beta_3 \cdot \text{BIO} + \beta_4 \cdot \text{FISH} + \beta_5 \cdot \text{MININ} + \beta_6 \cdot \text{WTP} + \beta_7 \cdot \text{WTP} \cdot \text{INCOME} + \beta_8 \cdot \text{WTP} \cdot \text{BIOK} + \beta_9 \cdot \text{WTP} \cdot \text{AGE} \]

In this model ASC1 and ASC2 are coded as dummy variables. In econometric theory a dummy variable is an artificial variable constructed such that it takes the value unity whenever the qualitative phenomenon it represents occurs, and zero otherwise. So, if the dependent variable is set up as 0-1 dummy variable (for example our case, the dependent variable is set equal to 1 for those choosing to protect the biodiversity in Ningaloo Marine Park and equal to 0 for those not choosing to protect Ningaloo Marine Park) and regressed on the explanatory variables, we would expect the predicted values of the dependent variable to fall mainly within the interval between 0 and 1. This suggests that the predicted value of the dependent variable could be interpreted as the probability that an individual will choose to protect NMP, given the values of the explanatory variables for the individual’s characteristics. Logit model is used in this project and is again calculated with the software package STATA 8.0.
6.4 Welfare Measurement: Willingness to Pay Extrapolated from Choice Modelling Estimates

The object of the Choice Model task and the associated model estimates is to understand the economic impact of changing attributes of Ningaloo Marine Park conservation scenarios. In economic terms this is known as welfare measurement, which refers to the amount that individuals are willing to pay for quality changes. In this study, welfare measures refer to the amounts that Western Australians are willing to pay for quality improvements in Ningaloo Marine Park. This provides a way to ‘monetise’ the benefits of environmental improvements to measure them on the same scale as and compare them to other marine protected areas already measured in monetary terms. The estimated models, presented in the previous sections, can be used to estimate the willingness to pay for a change from the current situation to the hypothetical scenarios (Scenario 2: 66% increased sanctuary zone and Scenario 3: no protection, %0 of sanctuary zone). To estimate the overall willingness to pay it is necessary to include the alternative specific constant (ASC). The alternative specific constant captures systematic but unobserved information about why respondents chose a particular option, that is unrelated to the choice set attributes. To illustrate this process, estimates are provided for three alternative scenarios. The present situation and the other two scenarios are as follows:

**Scenario 1:** Sanctuary zone 33%, reduction on coral reef coverage +/- 60%, decreased of marine life biomass low, high loss income for local fisheries communities, high loss income of mining and petroleum exploration companies.

**Scenario 2** Sanctuary zone 66%, reduction on coral reef coverage +/- 30%, decrease of marine life biomass very low high loss income for local fisheries communities, very high loss of income for mining and petroleum exploration companies.

**Scenario 3** No protection inside Ningaloo Reef (sanctuary zone 0%), reduction on coral reef coverage around 100%, decrease of marine life biomass high, very high income and opportunities for local fisheries communities, extremely high income for mining and petroleum companies.
Estimates of compensating surplus (CS) are calculated using the following equation:

$$CS = - \frac{(V_C - V_N)}{\beta_M}$$  \[10\]

where $\beta_M$ is the marginal utility of income;

$V_C$ represents the utility of the current situation; and

$V_N$ represents the utility of the new options (scenario).

To use this equation to estimate compensating surplus it is first necessary to calculate the utility associated with the present situation and the scenario being considered. Using Model 1, this is achieved by substituting the model coefficient and attribute levels for the present situation (that is $V_1$):

$$V_C = \beta_{SANCT} \cdot SANCT + \beta_{REEF} \cdot REEF + \beta_{BIO} \cdot BIO + \beta_{FISH} \cdot FISH + \beta_{WTP} \cdot WTP$$  \[11\]

The value of the utility of the alternative scenario is estimated in a similar way, and the coefficient for the alternative specific constant ASC1 for Scenario 2 (major protection, 66% of sanctuary zone) is included; see below:

$$V_N = ASC1 + \beta_{SANCT} \cdot SANCT + \beta_{REEF} \cdot REEF + \beta_{BIO} \cdot BIO + \beta_{FISH} \cdot FISH + \beta_{WTP} \cdot WTP$$  \[12\]

The compensating surplus for change from the present situation to the new Scenario 2 is estimated by calculating the difference between these two values ($V_C$ and $V_N$) and multiplying these by the negative inverse of the coefficient for willingness to pay. The results of this calculation are shown and commented in the next chapter dedicated to the results. There I also analyse the coefficients of attitudinal attributes, such as income, education, age, and variable ‘biodiversity knowledge’ that affect the willingness to pay. This econometric analysis helps us to understand better the socio-demographic attribute variables that influence positively or negatively the willingness to pay for conservation.
6.5 Conclusion

The development of Choice Modelling appears to offer several advantages over other non-market valuation techniques such as Contingent Valuation. The first and perhaps most significant advantage of CM over other non-market valuation techniques is that it allows the simultaneous presentation of a pool of alternative and substitute goods. Respondents have to consider explicitly complementary and substitution effects in the choice process, and because the amenity of interest can be hidden with the pool of available goods, problems of bias can be minimised.

The second major advantage of Choice Modelling is that it allows a much more realistic trade-off of opportunity costs than other non-market valuation techniques. Choice Modelling allows the introduction of a variety of opportunity costs, not just a WTP mechanism (Adamowicz et al., 1998). For example, other important trade-off that might occur against the prevision of an environmental amenity are effects on local or regional income and economic activities (in our case the income of local fisheries), and the loss of property rights or visitation opportunities over the environmental amenity. Modelling these opportunity costs may be an important way of developing realistic scenarios, and de-emphasises WTP mechanisms as the only means for supporting environmental causes.

The third benefit of CM is that the Multinominal Logit Model (MNL) enables a more realistic internal framing of choice to occur where some hierarchical decision process is being followed. The MNL model essentially suggests that choices occur on different levels, and hence allow the grouping together of alternatives that may not be viewed simultaneously (or independently) by respondents. Another benefit that is worth nothing is that Choice Modelling tends to concentrate choices on the underlying characteristics of the environmental amenity in question, rather than encouraging respondents to make subjective responses by association with other factors (Blamey et al, 1997).
The new approach used in this study to design and collect the data appears more flexible and capable to generate accurate data about the willingness to pay for conservation on Ningaloo Marine Park, and also able to analyse the WTP for the *status quo*, that is not possible with the traditional choice modelling methodology.

The demonstration of these advantages involves careful design and statistical and econometric procedures, particularly in the use of Multinominal Logit Model (MNL) and the combining of data sets with the aid of scale parameter estimates. The random utility model (RUM) represented by the MNL function provides a very powerful way to assess the effects of a wide range of policies. Policies impact individuals to varying degree, hence, it is important to be able to determine individual-specific effects prior to determination of market-share effects (Louvriere et al., 2000). If the estimated model is carefully developed, and the systematic utility is well-specified empirically, the model should be a very flexible, policy-sensitive tool. In the next chapter the results obtained with this new approach of choice modelling are discussed.
Charter VII

Survey and Estimation Results

7.1 Introduction

The theories and methods for estimating the non-use value of biodiversity conservation were identified in the previous chapters. A survey method for measuring the biodiversity conservation benefits was also elaborated in the Chapter Six. This chapter aims to estimate the non-use value of Ningaloo Marine Park using the survey output. A willingness to pay value for the participants of Ningaloo survey is derived and inferred for the residents of Western Australia. Particular attention is payed for the socio-economic-demographic factors that affected the respondents’ willingness to pay for conservation.

The first section of this charter briefly highlights the results from questionnaire 1 which collected the data to create an accurate and appropriate scenarios choice set for the second questionnaire. The second section presents the results from questionnaire 2 and the following issues arising from this survey: general level of Western Australian environmental concern, visits to Ningaloo, recreational fishing, eco-tourism, commercial activities, integration of local communities for future development, ‘Ningaloo Reef ecologically valuable as the Great Barrier Reef’ and biodiversity knowledge.

The rest of the chapter focussed the attention on the model estimation using the multinominal logistic model (MNL). The results obtained with the logistic regression are discussed. The last section presents the willingness to pay extrapolation and its relation with all variables considered in the model, namely income, age, education and the attitudinal variable biodiversity knowledge.
7.2 Results from Questionnaire 1

The survey with this questionnaire was undertaken in September 2006, and 50 respondents were interviewed inside Ningaloo Marine Park. In this questionnaire, respondents were told that there were three broad options available for the management of the NMP, but with different levels of protection and conservation. The fundamental idea behind the choice experiment was to mimic how different Ningaloo Marine Park management scenarios impact on the coral reef ecosystems. As the aim of this questionnaire was to select two hypothetical scenarios (one with increased protection and the other with decreased protection) to be included in the scenario choice set of questionnaire 2, the results were grouped in two sections: 1) Scenario II ‘Increased protection’ and 2) Scenario III ‘decreased protection’. Decreased and increased protection are related to the status quo (Scenario I) with the actual 33% of sanctuary zones, thus in the first option scenarios we have a protection that range from 40% to 90%, while the ‘decreased protection’ options ranges from 0% to 30% of sanctuary zones. See the results in Table 7.1.

Table 7.1 Alternative scenarios selected from Questionnaire 1

<table>
<thead>
<tr>
<th>Scenario II Increased Protection</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% of sanctuary zone</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>45% of sanctuary zone</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50% of sanctuary zone</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>60% of sanctuary zone</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>66% of sanctuary zone</td>
<td>26</td>
<td>52</td>
</tr>
<tr>
<td>75% of sanctuary zone</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>80% of sanctuary zone</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>90% of sanctuary zone</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario III Decreased Protection</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% of sanctuary zone</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>3% of sanctuary zone</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7% of sanctuary zone</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10% of sanctuary zone</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>15% of sanctuary zone</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20% of sanctuary zone</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25% of sanctuary zone</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30% of sanctuary zone</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>
The results clearly show that the preferred hypothetical scenario for increased protection was 66% of sanctuary zone, chosen by 52% of the respondents, and 0% of sanctuary zone (no protection along Ningaloo coast) for 16% of the respondents, who preferred an industrial and commercial development scenario for Ningaloo. Thus, these two scenarios were introduced in the choice set of questionnaire 2 as alternative/option to the status quo.

7.3 Results from Questionnaire 2

This survey was carried out in spring 2006. In particular 152 respondents were contacted on the beach and inside the camping area, during the day (with a maximum of 5 interviews per day). The remote areas were preferred for sourcing respondents for the questionnaire because I could find more Western Australians in holidays who prefer those areas for camping and enjoyment of the wilderness of Ningaloo coastline. I interviewed people in vacation along the north west coast, from Gnaraloo Bay in the middle of October 2006, which coincided with the Western Australian school holidays and could be considered as peak season. I continued the interviews going up north in the follow spots: Warroora, Elles Camp, Maggies, Coral Bay, Doddy’s Camp, Cape Range National Park, South Mandu and Yardie (see the Map 2.2 in Appendix). The paragraphs that follow describe, step by step, all the data collected with this survey and used for measuring biodiversity conservation benefits.
The aim of the first section of the questionnaire was to gather information about environmental issues in Western Australia. The national goal of protecting nature, ecosystems and controlling pollution in WA had a very high percentage of consent: 88.8% of respondents believed that this issue was ‘very important’. The second question ‘Does WA need to concentrate more on protecting the environment, or on development?’ gave me a clear idea that the respondents had a very strong attitude towards conservation; in fact 84.8% prefer that WA concentrate more on protecting the environment, while only 8.5% had a ‘pro-development’ attitude. The third question focuses the attention on which are the most important environmental issues in Western Australia. The following environmental issues were suggested: **Combat pollution, increase nature conservation of flora/fauna, stop logging of old growth native forest, prevent uranium mining, sustainable planning of urban areas, control soil erosion and soil salinity, increase health of water ways, secure sustainable water supplies, decrease greenhouse effect, dispose more carefully of waste, make roads more environmentally sensitive, increase biodiversity conservation of Ningaloo Reef, increase number and size of National Parks, reduce mining in environmentally sensitive areas, better manage WA coastal environment, Promote renewable energy.**

According to the respondents’ replies, the most important issue was ‘Increase of the number and size of National Parks’ with 58 preferences, the ‘prevent uranium mining’, followed by ‘stop logging of old growth native forest’. Increase biodiversity conservation in Ningaloo was the fourth issue of importance. The results from this three questions section are shown in Table 7.2.
Table 7.2  SECTION I GENERAL LEVEL OF ENVIRONMENTAL CONCERN

How important is a national goal of protecting nature, ecosystems and controlling pollution?

<table>
<thead>
<tr>
<th>Importance</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very important</td>
<td>135</td>
<td>88.8</td>
</tr>
<tr>
<td>Somewhat important</td>
<td>17</td>
<td>11.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>152</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Does WA need to concentrate more on protecting the environment, or on development (social and economic)?

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>More on environment</td>
<td>129</td>
<td>84.8</td>
</tr>
<tr>
<td>More on development</td>
<td>13</td>
<td>8.5</td>
</tr>
<tr>
<td>Reasonable balance</td>
<td>10</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>152</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

The four most important environmental issues in WA

<table>
<thead>
<tr>
<th>Issue</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1° Increase number and size of National Park</td>
<td>58</td>
</tr>
<tr>
<td>2° Prevent uranium mining</td>
<td>49</td>
</tr>
<tr>
<td>3° Stop logging of old growth native forest</td>
<td>46</td>
</tr>
<tr>
<td>4° Increase biodiversity conservation in Ningaloo</td>
<td>40</td>
</tr>
</tbody>
</table>

This environmental conservation attitude of the respondents was also confirmed by the results obtained in the question Q7a: ‘I would like to see all species of Ningaloo Reef protected for future generations’. The respondents expressed their consents to protect ‘all species on Ningaloo’ with the following percentages: 85.5% strongly in favour, 14.5% in favour, and none opposed to protecting all species.

7.5  Visits in Ningaloo Marine Park

The aim of this section was to investigate if respondents usually spent their holydays in marine protected areas and if they recently (in the last 12 months) had visited Ningaloo Marine Park. The result was impressive: 95.4% of respondents have spent holiday time in MPAs in the last 12 months in 2006. It means that people contacted inside Ningaloo during the survey had a strong desire to spend their holiday time on the coast and they strongly preferred the MPAs as tourist destination. The reason for this response could be attributed to the fact that the Western Australians have a
strong preference to spend their time in a wild and remote untouched marine areas and Ningaloo Reef was one of the preferred spots, considering that 60.5% of the respondents visited Ningaloo Reef in the last 12 months. This result was very important because it shows that the people targeted for interviewing were representative for this questionnaire analysis, as the aims of this project was to focus the attention on Western Australian tourists who choose marine protected areas for their holidays. Question 6 shows that Ningaloo Reef Marine Park is best know as coral reef wildlife (75), wilderness/unspoiled environment (73) and as tourist attraction. All results are shown in Table 7.3.

Table 7.3  SECTION II  NINGALOO REEF KNOWLEDGE AND VISITS

Spend time in Marine Protected Area in the last 12 months

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>145</td>
<td>95.4</td>
</tr>
<tr>
<td>No</td>
<td>7</td>
<td>5.6</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Visited Ningaloo Reef in the last 12 mounts

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>92</td>
<td>60.5</td>
</tr>
<tr>
<td>No</td>
<td>60</td>
<td>39.5</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Ningaloo Reef Marine Park is best know for

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1° Coral reef wildlife</td>
<td>75</td>
</tr>
<tr>
<td>2° Wilderness/unspoiled environement</td>
<td>73</td>
</tr>
<tr>
<td>3° Tourist attraction</td>
<td>41</td>
</tr>
</tbody>
</table>

7.6  Recreational Fishing

Recreational fishing represents one of the most important recreational activities for Western Australians: ‘Recreational fishing is a major social activity, involving around one
third of the population and it contributes more than $570 million to the State’s economy every year (DoF, 2007b). In 1987, the Australian Bureau of Statistics (ABS) estimated that 26.6 per cent or 284,000 Western Australians over the age of 15 years fished, producing an estimated three million recreational fishing days. Recent surveys (DoF, 2007b) indicate that participation rates for recreational fishing now average 36 per cent of the State’s population across all age groups between 18 and 65, with a higher participation rate in regional areas. This places the number of recreational fishers in excess of 620,000 and it is estimated they contribute over $500 million a year to the State’s economy.

In recent years tourism has become one of the major growth sectors of the Gascoyne economy (Ningaloo Reef is located inside the Gascogne Region). The tourism industry development has been based both on domestic demand and on the increase in eco-tourists from Europe and America. Over 209,000 people visited the Shire of Carnarvon and Exmouth in 2006 (Tourism WA, 2007) to experience the range of unique attractions in the region of the Ningaloo Reef. An important component of this sector is the fishing-based tourism. The Gascoyne is home to some of Western Australia’s most important and impressive recreational species and almost all accessible areas of the coastline in the region are utilised by recreational fishers.

In particular, Ningaloo offers a diversity of fishing experiences including fishing from cliffs at Steep Point and Quobba for mackerel and cobia, dinghy fishing for pink snapper, black snapper and baldchin groper, beach fishing for tailor and whiting, reef fishing for cods, coral trout and emperors, game fishing off Exmouth.

Considering this important recreational activity, I introduced in this survey a question about recreational fishing asking the respondent if: ‘It is my right to fish at Ningaloo’ and I interviewed people in the most important spots for recreational fishing (spots that have some facilities for fishers, such as boat ramp). The results from the questionnaire look quite controversial if we compare the increased amount of number of people that visit this region with the purpose of fishing and the results
(see Table 7.4). Only 17.6% are strongly in favour and 13.8% in favour of fishing inside Ningaloo. The rest were opposed (31%) or strongly opposed (37.6%). Hence more than 68.6% of the respondents were not in favour of fishing inside Ningaloo.

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly in favour</td>
<td>27</td>
<td>17.6</td>
</tr>
<tr>
<td>In favour</td>
<td>21</td>
<td>13.8</td>
</tr>
<tr>
<td>Opposed</td>
<td>47</td>
<td>31.0</td>
</tr>
<tr>
<td>Strongly opposed</td>
<td>57</td>
<td>37.6</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>

It seems that people who spend time inside Ningaloo Marine Park realise how important and fragile the coral reef ecosystems are, and preferred a protected scenario to preserve this unique marine park.

7.7 Eco-tourism

Eco-tourism is tourism that is based on enabling people to experience the natural environment in a manner that is consistent with the principles of sustainable development. The term ‘marine eco-tourism’ is intended to denote eco-tourism activities that take place in the coastal zone, in the marine environment, or in both. The development of marine eco-tourism may be perceived as an opportunity to help regenerate coastal communities that are experiencing economic hardship as a result of the decline of their traditional economic sectors, such as agriculture or commercial fishing and seaside tourism. Marine eco-tourism can also generate positive outcomes for the natural environment, for example by raising funds that can be used for environmental protection, by providing economic alternatives to activities that degrade or deplete the natural environment, and by more widely propagating eco-
awareness and the principles of sustainable development. Yet experience has shown that if marine eco-tourism is to play this role effectively, it must be developed within a planning framework that ensures that the practice of eco-tourism is compatible with sustainability principles. Marine eco-tourism involves bringing tourists close to nature: an activity that carries with it the risk of causing serious harm the very things that eco-tourism providers are helping tourists to protect. Since 1994, in Ningaloo coast the licensed eco-tourism industry has been expanding and attracting visitors from all over the world, particularly the United States and Japan, contributing significantly to the local economy. The expansion of diving activities has led to the discovery of aggregations of whale sharks in other parts of the world and there is now increasing interest in whale shark-based eco-tourism, as well as in tagging studies to find out more about movement patterns of local populations (Stevens, 2006).

The opportunities for eco-tourism are distributed in a different way if we consider the ‘pro-conservation’ answers trend (see Table 7.5). Of all respondents, 29.6% are strongly in favour and 25.6% in favour, so more than 50% agree that eco-tourism is an opportunity for the future, but this percentage doesn’t reflex the very high percentage of respondents who exhibit ‘pro-conservation’ attitudes. In fact when I analysed further this response I found that not all ‘pro-conservation’ respondents are ‘pro eco-tourism’. Hence it appears that not all respondents believed that eco-tourism is a sustainable activity for the ecosystems in the park, and many respondents were strongly opposed to the increased whale shark-based eco-tourism.

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly in favour</td>
<td>45</td>
<td>29.6</td>
</tr>
<tr>
<td>In favour</td>
<td>39</td>
<td>25.6</td>
</tr>
<tr>
<td>Opposed</td>
<td>42</td>
<td>27.6</td>
</tr>
<tr>
<td>Strongly opposed</td>
<td>26</td>
<td>17.2</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>
7.8 Commercial Activities inside Ningaloo Marine Park

The term ‘commercial activities’ I used in question Q7 embraces the following activities: commercial fishing, commercial shipping, oil exploration and production, and tourism industry. Before asking the questions about ‘commercial activities’ I discussed with the respondents some of the most important environmental threats and also the potential economic benefits for the local community.

The results of this question, shown in Table 7.6, reflect the trend and the percentage of the ‘pro-conservation’ attitude of the respondents. In fact, only 2.6% were strongly in favour and 9.2% in favour of the development of these ‘commercial activities’. The total share of respondents opposed and strongly opposed represents almost 90%. It may be that the discussion with the respondents about all possible threats from these activities (showing also some photos of possible damage to the ecosystems) before the question about ‘more commercial development at Ningaloo’ played an important role in the decision, as most people were not familiar with the environmental impacts caused by these commercial activities.

Table 7.6 More commercial development at Ningaloo

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly in favour</td>
<td>4</td>
</tr>
<tr>
<td>In favour</td>
<td>14</td>
</tr>
<tr>
<td>Opposed</td>
<td>30</td>
</tr>
<tr>
<td>Strongly opposed</td>
<td>104</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
</tr>
</tbody>
</table>

7.9 Integrating Local Communities for Future Development

The local communities along the Ningaloo coast, such as Carnarvon, Coral Bay and Exmouth could play an important role in the future development. The Department of Environment and Conservation is encouraging the Coral Coast community to
become involved in the future management of Ningaloo Reef (NatureBase, 2008). The results from this section highlight high percentage of ‘indecision’, in fact 27% were indifferent about this theme (see Table 7.7). Another 43.3% were opposed to considering the local communities options about future development and only 29.7% were in favour. During the survey I witnessed many Western Australian respondents criticizing the policy and the management of the local communities along the Ningaloo coast. Most of them were ‘critics’ of how these local communities are organized to manage tourism, and this could be part of the reasons for this response rate.

Table 7.7  The future of Ningaloo should be up to local communities

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly in favour</td>
<td>17</td>
<td>11.3</td>
</tr>
<tr>
<td>In favour</td>
<td>28</td>
<td>18.4</td>
</tr>
<tr>
<td>Indifferent</td>
<td>41</td>
<td>27.0</td>
</tr>
<tr>
<td>Opposed</td>
<td>29</td>
<td>19.0</td>
</tr>
<tr>
<td>Strongly opposed</td>
<td>37</td>
<td>24.3</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>

7.10  Ningaloo Reef Ecologically Valuable as the Great Barrier Reef

Coral reefs are among the most biologically rich ecosystems on earth. About 4,000 species of fish and 800 species of reef-building corals have been described to date. However, experts have barely begun to catalog the total number of species found within these habitats. The Great Barrier Reef, is recognized to be the world’s largest system of coral reefs (Bryant et al. 1998; Hopley et al., 2007). Even if the GBR is considered the most important coral reef ecosystems in Australia and around the world, the high biological diversity of Western Australia’s Ningaloo Reef is recognised by the respondents as important as the Great Barrier Reef and 70.3% agreed that Ningaloo is as ecologically valuable as the GBR. Respondents also
believed that Ningaloo is one of the richest marine environments in Australia. Family and friends are the first source of information about Ningaloo (see Table 7.8 and 7.9).

Table 7.8  Ningaloo Reef is as ecologically valuable as the Great Barrier Reef

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly in favour</td>
<td>77</td>
<td>50.6</td>
</tr>
<tr>
<td>In favour</td>
<td>30</td>
<td>19.7</td>
</tr>
<tr>
<td>Indifferent</td>
<td>28</td>
<td>18.4</td>
</tr>
<tr>
<td>Opposed</td>
<td>10</td>
<td>6.5</td>
</tr>
<tr>
<td>Strongly opposed</td>
<td>7</td>
<td>4.8</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 7.9  Main source of information about Ningaloo

<table>
<thead>
<tr>
<th>Source</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1° Family/friends</td>
<td>48</td>
</tr>
<tr>
<td>2° Newspapers, Magazines and books</td>
<td>37</td>
</tr>
<tr>
<td>3° Television</td>
<td>34</td>
</tr>
<tr>
<td>4° General world of mouth</td>
<td>33</td>
</tr>
</tbody>
</table>

7.11  Respondents’ marine ecological knowledge

Ecological knowledge is complex and represents the accumulated knowledge about species, environments, and their interactions accrued and passed down over multiple generations. Researchers increasingly recognize the value of the so called ecological knowledge, which is defined as “a cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment” (Berkes  et  al. 2000, pp1251). Traditional ecological knowledge, which is site specific, represents the information necessary for cultural survival, accumulated through trial and error over many years (Drew, 2005).

To determine respondents’ knowledge of marine ecology and environment, a sixteen-item question was included in the questionnaire which assesses
understanding of respondents on key concepts and knowledge. Respondents were asked to evaluate the 16 statements as true or false. The results were classified in three categories: good knowledge (0-2 errors), average knowledge (3-4 errors) and poor knowledge (5+ errors). The good knowledge class was represented by the 27.6%, the average by the 31.5% and the poor by the 40.9% (see Table 7.10). The interesting result was that people who fall into the class ‘good knowledge’ had a very strong correlation with the willingness-to-pay variable: 95% of the respondents with maximum 2 errors put an amount of money in the WTP section. Also the class ‘average knowledge’ had a correlation with the WTP attitude: 67% of them were in favour and put an amount of money in the WTP section. With the third class ‘poor knowledge’ the correlation between ecology knowledge and the WTP was lower: only 47% of this class of respondents were in favour to put an amount of money in the WTP (see Table 7.11). Hence when we move from the class ‘good knowledge’ to the class ‘average’ and ‘poor knowledge’ the WTP for conservation decreases and also the percentage of respondents in favour of the scenario with increased protection decreases. This was a very interested information obtained by using this variable. It revealed that people with ‘good’ and ‘average knowledge’ had high WTP attitude, while the respondents that had a ‘poor knowledge’ were less interested to pay for conservation. Please refer to section 7.12.3 to understand better the weight of this variable, where I describe the main factors that influence the respondents’ WTP.

Table 7.10  Section III Biodiversity Knowledge

<table>
<thead>
<tr>
<th>Knowledge Level</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good knowledge (0-2 errors)</td>
<td>42</td>
<td>27.6</td>
</tr>
<tr>
<td>Average knowledge (3-4 errors)</td>
<td>48</td>
<td>31.5</td>
</tr>
<tr>
<td>Poor knowledge (5+ errors)</td>
<td>62</td>
<td>40.9</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Table 7.11  Relationship between biodiversity knowledge and WTP

7.12  Demographics of the Sample

A total of 152 questionnaires were completed with in-person interviews and were usable for model estimation purposes. In addition to the responses to the choice scenarios, other data were collected using the questionnaire. This included various socio-demographic characteristics of respondents such: sex, age, household income, education and labour force participation. The social and economic characteristics of the sample are similar to those of the Western Australia population with the exception of income, and education (see Table 7.12). Respondents were well represented by gender with 47% women and 53% men. Lower income groups were over-represented compared to Western Australian population standards due to the high presence of students and retired people that spend time in Ningaloo Marine Park. The presence of this type of visitors is also reflected in differences in labour force participation rates. In fact, the percentage of full-time employed in this sample (44.8%) was lower than the State average (61%) due to the high percentage of university students (this also affects also the education variable). Almost 30% of the
respondents were young people (20-30 years of age) that usually spend more than 1 month in Ningaloo and they tend to work part-time in order to have long holiday time, especially during the Australian winter. The median age across the sample however did not differ significantly: 34 years for the sample and 36 years for Western Australia.

In this study I didn’t analyse the place of origin of the respondents, due to the particular configuration of Western Australian population. In fact, almost three quarters (73%) of the Western Australian resident population (1,950,000 people) lives in Perth statistical division (Australian Bureau of Statistics, 2006). Hence, it is not significant to analyse the composition of respondents according usual residence. As expected, almost 85% of the survey respondents were from Perth.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample average</th>
<th>WA population average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (% females)</td>
<td>47%</td>
<td>50.2%</td>
</tr>
<tr>
<td>Sex (% males)</td>
<td>53%</td>
<td>49.8%</td>
</tr>
<tr>
<td>Age (median)</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>Household income (year)</td>
<td>$51,200</td>
<td>$55,736</td>
</tr>
<tr>
<td>Education Certificate</td>
<td>43.2%</td>
<td>47.6%</td>
</tr>
<tr>
<td>Education Bachelor degree</td>
<td>14.0%</td>
<td>18.1%</td>
</tr>
<tr>
<td>Education Postgraduate degree</td>
<td>9.2%</td>
<td>7.6%</td>
</tr>
<tr>
<td>Labour force employed full-time</td>
<td>44.8%</td>
<td>61.0%</td>
</tr>
<tr>
<td>Labour force employed part-time</td>
<td>33.5%</td>
<td>28.4%</td>
</tr>
</tbody>
</table>

*Source: Ningaloo Reef Survey, 2006
**Source: Australian Bureau of Statistics 2006.

7.13 Model Estimation

Two different multinomial logit (MNL) models were estimated using the data from the Ningaloo second questionnaire. The first is a basic model which shows the importance of choice set attributes in explaining respondents’ choices across the three different options. The second model includes both socio-economic and
attitudinal variables in addiction to the attributes in the choice sets. The multinominal logit model analysis which allows us to fit the choice among nominal alternatives was affected by characteristics of the alternatives that vary across the three different scenarios. The data were analysed using the statistical software STATA 8.0. In the first model, there are three utility functions derived from the multinominal logit model. Each represents the utility generated by one of the three options. Option 1 is the status quo (Scenario I), options 2 and 3 are options whereby more protection (Scenario II) or no protection (Scenario III) are presented for Ningaloo Reef. Definitions of the coefficients used in these models were presented in Table 6.3 as described earlier, the first set of models is:

Present situation \( V_1 = \beta_1 . SANCT + \beta_2 . REEF + \beta_3 . BIO + \beta_4 . FISH + \beta_5 . MININ + \beta_6 . WTP \)

Scenario 2 \( V_2 = ASC1 + \beta_1 . SANCT + \beta_2 . REEF + \beta_3 . BIO + \beta_4 . FISH + \beta_5 . MININ + \beta_6 . WTP \)

Scenario 3 \( V_3 = ASC2 + \beta_1 . SANCT + \beta_2 . REEF + \beta_3 . BIO + \beta_4 . FISH + \beta_5 . MININ + \beta_6 . WTP \)

The main selection probability axiom used to develop the MNL operational model is known as the Independence-from-Irrelevant Alternatives (IIA) axiom. *This states that the ratio of the probabilities of choosing one alternative over another is unaffected by the presence or absence of any additional alternatives in the choice set* (Louvriere et al., 2000). This property states that the relative probabilities of two options being selected are unaffected by the introduction or removal of other alternatives. This property follows from the independence of the error terms across the different options contained in the choice set. The IIA is based on eliminating one alternative from the choice set to see if underlying choice behaviour from the restricted choice set obeys the independence from irrelevant alternatives property. This condition is both a strength and weakness of this model: its strength is that it provides a computational convenient choice model, and permits introduction and/or elimination of alternatives in choice sets without re-estimation (Long and Freese, 2006). Its
weakness is that the observed and unobserved attributes of utility may not be independent of one another, and if the unobserved components of utility are correlated among alternatives, this leads to biased utility parameters. To test whether the MNL model was appropriate, the Hausman and McFadden (1984) test for the IIA property was used (statistical software STATA 8.0). The IIA test involves constructing a likelihood ratio test around the different versions of the model where the choice alternatives are excluded. If IIA holds then the model estimated on all choices should be the same as that estimated for a sub-set of alternatives. The results of the test are shown in table 7.13, indicating that IIA property cannot be rejected at the 99% level. Therefore the MNL model is the appropriate model for estimation of this data.

Table 7.13 Test of Independence of Irrelevant Alternatives (IIA)

<table>
<thead>
<tr>
<th>Alternative Dropped</th>
<th>Chi-Square Value</th>
<th>Degrees of Freedom</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario I</td>
<td>23.44</td>
<td>5</td>
<td>0.0003</td>
</tr>
<tr>
<td>Scenario II</td>
<td>54.28</td>
<td>5</td>
<td>0.0000</td>
</tr>
<tr>
<td>Scenario III</td>
<td>90.68</td>
<td>5</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

7.13.1 Model 2 with Socio-demographic and Attitudinal Interactions

Basic conditional logit model assumes homogeneous preferences across respondents. However, preferences are in fact heterogeneous and accounting for this heterogeneity enables estimation of unbiased estimates of individual preferences and enhances the accuracy and reliability of estimates of demand, participation, marginal and total welfare (Greene, 1997). Furthermore, accounting for heterogeneity enables prescription of policies that take equity concerns into account. An understanding of who will be affected by a policy change in addition to understanding the aggregate economic value associated with such changes is necessary (Adamowicz and Boxall,
One way of accounting for preference heterogeneity is by using respondent’s social, economic and attitudinal characteristics directly as interaction terms. Interaction of respondent-specific characteristics with choice specific attributes and with ASC of the indirect utility function is a common solution to dealing with the heterogeneity problem as well as with violations of the IIA (Rolfe et al., 2000).

To account for heterogeneity of preferences across respondents the effects of their social, economic and attitudinal characteristics on their choice of Ningaloo Reef management scenario must be investigated. In random utility models the effects of social and economic characteristics on choice cannot be examined in isolation but as interaction terms with choice attributes (Birol et al., 2005). Due to possible multicollinearity problems, it is not possible to include all the interactions between the social, economic and attitudinal characteristics of the respondents collected in the survey and the six Ningaloo Reef management attributes when estimating the conditional logit model with interactions. In this model I included the socio-economic and attitudinal variables through interactions with the alternative specific constants (ASC1 and ASC2). Three variables were included as interactions with the alternative specific constant for the scenario 2 and scenario 3 (INC, BIOK, and EDU). These interactions show the effect of various attitudes and socio-economic characteristics on the probability that respondents will choose either scenario 1, 2 or 3. The results from these two models are shown in Table 7.14.

The specification for the second model as previously stated is as follows:

\[ V_1 = \beta_1 \text{SANCT} + \beta_2 \text{REEF} + \beta_3 \text{BIO} + \beta_4 \text{FISH} + \beta_5 \text{MININ} + \beta_6 \text{WTP} + \beta_7 \text{WTP*INC} + \beta_8 \text{WTP*BIOK} + \beta_9 \text{WTP*EDU} \]

\[ V_2 = \text{ASC1} + \text{ASC1.INC} + \text{ASC1.BIOK} + \text{ASC1.EDU} + \beta_1 \text{SANCT} + \beta_2 \text{REEF} + \beta_3 \text{BIO} + \beta_4 \text{FISH} + \beta_5 \text{MININ} + \beta_6 \text{WTP} + \beta_7 \text{WTP*INC} + \beta_8 \text{WTP*BIOK} + \beta_9 \text{WTP*EDU} \]

\[ V_3 = \text{ASC2} + \text{ASC2.INC} + \text{ASC2.BIOK} + \text{ASC2.EDU} + \beta_1 \text{SANCT} + \beta_2 \text{REEF} + \beta_3 \text{BIO} + \beta_4 \text{FISH} + \beta_5 \text{MININ} + \beta_6 \text{WTP} + \beta_7 \text{WTP*INCOME} + \beta_8 \text{WTP*BIOK} + \beta_9 \text{WTP*EDU} \]
Table 7.14  Multinominal logit results for Model 1 and Model 2

<table>
<thead>
<tr>
<th></th>
<th>Model 1 (standard error)</th>
<th>Model 2 (standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC1</td>
<td>-0.3024*</td>
<td>-1.58***</td>
</tr>
<tr>
<td>ASC2</td>
<td>-0.0546* (0.0846)</td>
<td>-0.0526* (0.0074)</td>
</tr>
<tr>
<td>SANCT</td>
<td>1.5688*** (0.1323)</td>
<td>1.5564*** (0.1588)</td>
</tr>
<tr>
<td>REEF</td>
<td>2.4792*** (0.1621)</td>
<td>2.4934*** (0.1124)</td>
</tr>
<tr>
<td>BIO</td>
<td>0.9024*** (0.1286)</td>
<td>0.9743*** (0.0146)</td>
</tr>
<tr>
<td>FISH</td>
<td>0.0164*** (0.0124)</td>
<td>0.01466***(0.0122)</td>
</tr>
<tr>
<td>MININ</td>
<td>0.0228*** (0.0134)</td>
<td>0.01369**(0.0117)</td>
</tr>
<tr>
<td>WTP</td>
<td>-0.0145***(0.8126)</td>
<td>-0.0124*** (0.0129)</td>
</tr>
<tr>
<td>WTP*INC</td>
<td>- -</td>
<td>0.8071*** (0.0028)</td>
</tr>
<tr>
<td>WTP*BIOK</td>
<td>- -</td>
<td>1.0026*** (0.0018)</td>
</tr>
<tr>
<td>WTP*EDU</td>
<td>- -</td>
<td>1.2007*** (0.0005)</td>
</tr>
<tr>
<td>ASC1*INC</td>
<td>- -</td>
<td>2.9868*** (0.0003)</td>
</tr>
<tr>
<td>ASC1*BIOK</td>
<td>- -</td>
<td>2.5344*** (0.2468)</td>
</tr>
<tr>
<td>ASC1*EDU</td>
<td>- -</td>
<td>4.4487*** (0.78239)</td>
</tr>
<tr>
<td>ASC2*INC</td>
<td>- -</td>
<td>0.2489*** (0.7654)</td>
</tr>
<tr>
<td>ASC2*BIOK</td>
<td>- -</td>
<td>1.0834*** (0.0848)</td>
</tr>
<tr>
<td>ASC2*EDU</td>
<td>- -</td>
<td>2.8642*** (0.0034)</td>
</tr>
</tbody>
</table>

Summary statistics

<table>
<thead>
<tr>
<th>Observations</th>
<th>456</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log-likelihod</td>
<td>-1874.457</td>
</tr>
<tr>
<td>χ² (constants only)</td>
<td>362.038</td>
</tr>
<tr>
<td>ρ²</td>
<td>0.247</td>
</tr>
<tr>
<td>ρ² adjusted</td>
<td>0.156</td>
</tr>
</tbody>
</table>

*** 1% significance level, ** 5% significance level, * 10% significance level with two-tailed tests

At this point, before discussing the results, it is useful to consider the overall goodness-of-fit tests. The log likelihood function evaluated at the mean of the estimated utility parameters is a useful criterion for assessing overall goodness-of-fit when the maximum likelihood estimation method is used to estimate the utility parameters of MNL models. The procedure is known as the likelihood ratio test. The
smallest this ratio $\rho^2$ (rho-squared), the better statistical fit of the model. In this case the overall model was statistically significant, considering that $\rho^2$ value is 0.29 as shown in Table 7.14.

### 7.13.2 Results from Model 1

The coefficients for all of the attributes in the choice sets are significant at the 1% level and all have the *a priori* expected sign. This study indicates that positive non-use values exist for both environmental and social outcomes (i.e. respondents valued the environmental attributes of Ningaloo reef protection and they also valued the non-use benefits of fish biomass protection created by the conservation development). The overall model is also significant at the 1% level, as shown by the chi-squared statistic. The negative sign on the ASC coefficients implies that respondents are highly responsive to changes in choice set quality and they make decisions that are closer both to rational choice theory and the behaviour observed in reality (Kontoleon, 2003). The variable ‘risk of reduction on coral reef’ and the variable ‘decrease of marine biomass’ are the two most significant and important attributes that affected the decision to choose the scenarios with protection management (Scenario I and Scenario II). Also the variable ‘percentage of sanctuary zone’ looks very important for the respondents. While, the ‘reduction of income for mining and petroleum exploration companies’ and the ‘reduction for local fishing communities’ had a very low impact in the probability to choose the option with increased protection.

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The $\rho^2$ value in multinomial logit models is similar to $R^2$ in conventional analysis, except that significance occurs at lower levels. Hensher and Johnson (1981) comment that values of $\rho^2$ between 0.2 and 0.4 are considered to be extremely good fits.
These results reflect the pro-environmental trend of the respondents that choose the scenarios with increased protection (75%) because these respondents were more concerned about the risk of reduction on coral reef coverage and fish biomass than the risk of income reduction for mining and fishing companies.

7.13.3 Results from Model 2

The results from this model are shown in the right column of Table 7.15. The three variables (INC, BIOK, and EDU) interacted with the alternative specific constant for options 2 and 3 and are significant at the 1 percent level. Consistent with expectations, these interactions show that respondents were more likely to support either options 1 or 2 if they: (1) had a higher income; (2) had high ‘biodiversity knowledge’ and (3) had high level of education such as university level. As it can be seen from the positive interactions between the ASC and the three characteristics, higher levels of biodiversity knowledge and higher education (a university degree), increased the likelihood that the respondent will select Scenario 2 with increased protection. Respondents with higher payment levels (higher household income) have a positive attitude towards the willingness to pay for the scenarios with protection. Also the interaction with the ASC2 in the scenario without protection was significant, but not very useful for this survey, considering that only 3.3% of respondents preferred this ‘no protection’ scenario. Table 7.15 shows the percentage of the scenarios preferred.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario I Present Situation</td>
<td>33</td>
<td>21.7</td>
</tr>
<tr>
<td>Scenario II Increased Conservation</td>
<td>114</td>
<td>75.0</td>
</tr>
<tr>
<td>Scenario III Without Conservation</td>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
</tr>
</tbody>
</table>
7.14 Estimation of Willingness to Pay

In this study I used a novel approach to gather information about the respondents’ willingness to pay, as explained in the methodology section. The WTP variable was entered in the multinominal logit model as a financial variable, but was not presented to the respondents as an attribute in the choice set (it was shown in a separate section of the questionnaire). This different approach had the following advantages:

i) the willingness to pay estimations are much more accurate because every respondents could express the amount of money they preferred; otherwise with the traditional choice modelling format, the amount of money to pay for protection must be determined \textit{a priori} and not reflect what people really would like to pay;

ii) with this different approach, respondents expressed their willingness to pay also for the present situation scenario, that actually is free entrance, and this information was particularly important because it revealed that 37% of respondents who choose the \textit{status quo} put an amount of money in the WTP section, it means they like the way Ningaloo Marine Park is managed and protected, but they preferred to pay an entrance fee to improve the available funding and to increase the quality of infrastructure for the Park;

iii) the respondents that were in favour of paying for conservation had different payment vehicles to choose, while with the traditional format the researcher had to choose \textit{a priori} in which way the money for the conservation would be collected (i.e. increased tax).

In this case study, the only payment vehicle preferred by the respondents was entrance fee. This could have been expected, considering that the 34.7% of the visitors in Ningaloo Marine Park are from overseas and this is the only way to collect money also from this kind of tourists. Most of the Western Australians interviewed were opposed to the WTP option \textit{‘increase in tax’} because they believed that they
already pay enough taxes. The last WTP option ‘donation’ was considered inappropriate by respondents to finance the protection of Ningaloo. Table 7.16 shows the relationship between the percentage of WTP for each scenario. The WTP was concentrated in scenario increased protection, where 95.8 percent of the respondents that choose this option put an amount of money for protection with an average WTP of $15. As already indicated, important information obtained with this different approach to gathering information about the WTP, is the opportunity to find that of the 21.7% of respondents who chose the option ‘Present Situation’ about 37% of them were in favour of paying an amount of money as entrance fees. Scenario III reflects the ‘pro-development’ attitude of respondents who chose this scenario without protection.

Table 7.16  Relationship between the scenario preferred and the WTP

<table>
<thead>
<tr>
<th>Scenario preferred</th>
<th>% of WTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario I</td>
<td>20%</td>
</tr>
<tr>
<td>Scenario II</td>
<td>80%</td>
</tr>
<tr>
<td>Scenario III</td>
<td>0%</td>
</tr>
</tbody>
</table>

7.14.1  The Implicit Prices

The estimated models can be used to estimate the willingness to pay for a change in one of the choice attributes. Estimates of the willingness to pay for a change in one of the attributes in the choice sets can be found by estimating implicit prices. Implicit
prices as already point out, are the marginal rates of substitution between the attribute of interest and the monetary attribute. This is equal to the ratio of the coefficient of one of the non-monetary attributes and the monetary attributes. In other words, the implicit price (IP) for Ningaloo protection is:
\[ IP = -1 \left( \frac{\beta_{\text{attribute}}}{\beta_{\text{monetary variable}}} \right) \]

Estimates of implicit prices for each of the non-monetary attributes in the choice sets are reported in Table 7.18. When the attribute being sacrificed is monetary, the estimated trade-off are “implicit prices”, the amount of money respondents are willing to pay in order to receive a change in the considered attribute. The estimate of implicit prices, reported in Table 7.17 are made on a ceteris paribus hypothesis, namely for an increase in the attribute of interest, given that everything else is held constant. The implicit prices, or marginal willingness to pay (WTP) values for each of the Ningaloo attributes with the respective 95% confidence intervals are calculated using the above equation. These are all positive implying that respondents have a positive WTP for increases in the quality of each attribute.

These estimates indicate that, for example, respondents were willing to pay for high levels of biodiversity protection (increased percentage of sanctuary zone) in Ningaloo from $12.37 (basic conditional logit model) to $12.45 (conditional logit model with interactions) for an extra percentage of sanctuary zone. Similarly, respondents were willing to pay to avoid the risk of reduction of coral reef coverage from $19.56 (basic conditional logit model) to $19.60 (conditional logit model with interactions). The WTP to reduce the risk for of decrease in marine biomass was quite consistent, ranging from $7.11 to $7.12. The WTP for the reduction in the loss of income for local communities was very low, ranging from 13 cents to 14 cents and quite similar was the WTP to reduce the loss if income for mining and petroleum exploration companies: 18 cents. The WTPs were different between Model 1 and Model 2 due to the interactions with socio-demographic variables in the second model.
Table 7.17  Estimates of implicit prices (AU$ 2006)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Model 1</th>
<th>95% confidence interval</th>
<th>Model 2</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>SANCT</td>
<td>12.37</td>
<td>12.36-12.39</td>
<td>12.45</td>
<td>12.43-12.47</td>
</tr>
<tr>
<td>BIO</td>
<td>7.11</td>
<td>7.10-7.12</td>
<td>7.12</td>
<td>7.11-7.13</td>
</tr>
<tr>
<td>FISH</td>
<td>0.13</td>
<td>0.12-0.14</td>
<td>0.14</td>
<td>0.13-0.15</td>
</tr>
<tr>
<td>MIN</td>
<td>0.18</td>
<td>0.17-0.19</td>
<td>0.185</td>
<td>0.18-0.19</td>
</tr>
</tbody>
</table>

7.14.2  Estimates of compensating surplus

The implicit prices reported in Table 7.17 above, do not provide estimates of compensating surplus. Estimating the overall willingness to pay for a change from current situation requires further calculations. This is because the attributes in the choice sets do not capture all reasons why respondents might choose to increase protection for Ningaloo Reef. To estimate the overall WTP for Ningaloo protection it is necessary to include the ASC, which captures the systematic but unobserved information about why respondents select a particular option (that is unrelated to the choice set attributes). Estimates of compensating surplus (CS) are calculated using the following equation:

\[ CS = - \frac{1}{\beta_M} * (V_C - V_N) \]  \[13\]

where \( \beta_M \) is the marginal utility of income;

\( V_C \) represents the utility of the current situation; and

\( V_N \) represents the utility of the new option (scenario).

To use this equation to estimate compensating surplus it is first necessary to calculate
the utility associated with the present situation and the scenario being considered. Using Model 1, this is achieved by substituting the model coefficient and attribute levels for the present situation (that is $V_c$):

$$V_c = \beta_{SANCT} \cdot SANCT + \beta_{REEF} \cdot REEF + \beta_{BIO} \cdot BIO + \beta_{FISH} \cdot FISH + \beta_{WTP} \cdot WTP \quad [14]$$

The value of the utility of the alternative scenario is estimated in a similar way, and the coefficient for the alternative specific constant ASC1 for Scenario 2 (major protection, 66% of sanctuary zone) is included; see below:

$$V_N = ASC1 + \beta_{SANCT} \cdot SANCT + \beta_{REEF} \cdot REEF + \beta_{BIO} \cdot BIO + \beta_{FISH} \cdot FISH + \beta_{WTP} \cdot WTP \quad [15]$$

In order to estimates the respondents’ WTP for alternative Ningaloo management scenarios, three possible options were created. The estimates of the three scenarios are reported in Table 7.19. These are marginal estimates showing WTP for a change from the status quo. Considering the result obtained with this different approach eliciting the WTP and the respondents’ intention to pay an amount of money for the present situation scenario (the 37% of respondents that preferred the Scenario I expressed an amount of money in WTP section, even if at moment the Park is free entrance), I created an extra scenario Present Situation-bis. This new hypothetical scenario is exactly the same as the status quo, from management and conservation point of view, but with entrance fees for the Park of $9 (the average amount of money expressed by the respondents).
The scenarios are presented below:

**Status quo**
Sanctuary zone 33%, risk of reduction on coral reef coverage +/- 60%, decrease of marine life biomass low, high loss income for local fisheries communities, extremely high loss income of mining and petroleum exploration companies, no entrance fees for the Park.

**Scenario 1  Present Situation-bis**
Sanctuary zone 33%, risk of reduction on coral reef coverage +/- 60%, decrease of marine life biomass low, high loss income for local fisheries communities, extremely high loss income of mining and petroleum exploration companies, entrance fees for the Park: $9.

**Scenario 2  Minor Impact**
Sanctuary zone 66%, reduction on coral reef coverage +/- 30%, decrease of marine life biomass very low, very high loss income for local fisheries communities, total loss of income for mining and petroleum exploration companies, entrance fees.

**Scenario 3  Major Impact**
No protection inside Ningaloo Reef (sanctuary zone 0%), reduction on coral reef coverage around 100%, decrease of marine life biomass high, very high income and opportunities for local fisheries communities, extremely high income for mining and petroleum exploration companies, no entrance fees.

Estimates of compensating surplus are calculated for both models using equation 9. The results of the compensation surplus are shown in Table 7.18
Table 7.18  Estimates of compensation surplus for each scenario

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Basic conditional logit Model 1</th>
<th>Conditional logit with interactions Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1 Present Situation bis</td>
<td>$19.96</td>
<td>$23.32</td>
</tr>
<tr>
<td>Scenario 2 Minor Impact</td>
<td>$72.84</td>
<td>$85.00</td>
</tr>
<tr>
<td>Scenario 3 Major Impact</td>
<td>$7.14</td>
<td>$8.32</td>
</tr>
</tbody>
</table>

These are marginal estimates showing WTP for a change from the current situation. When estimating consumer surplus using the conditional logit model with interactions, the social and economic variables were all set to the sample averages. Hence, the willingness to pay per household for this new Scenario I is equal to $19.96. Increasing the protection and conservation for Ningaloo generated a higher willingness to pay, for the Scenario II the WTP was $72.84. This amount of money indicates that to maintain utility at level $V_C$ (status quo), given an improvement in Ningaloo ‘quality’ in terms of increased protection, annual household income must be reduced by $72.84. The WTP for Scenario III was the lowest compared to the other scenarios and this result was expected considering that people who preferred this scenario had a very high ‘pro-development’ attitude and consequently their willingness to pay for conservation was extremely low, as they preferred a scenario dedicated to the development of industrial and mass tourism activities on the Ningaloo coast.

7.14.3  Main factors that influence respondents’ WTP

The aim of this investigation was to understand the socio-economic variables that affect the willingness to pay for conservation and determine what factors could explain or predict respondents’ WTP. Impacts of the socio-economic indicators on WTP were analysed by linear regression (OLS), using WTP as the dependent variable.
and the socio-economic indicators as the independent variables. Stepwise regression was used to identify the main factors that influence respondents’ willingness to pay. The zero WTP samples were not excluded from the analysis. In order to measure the attitudinal variable BIOK (biodiversity knowledge) I introduced into the regression the three levels of this variable obtained from the surveys: low, was for poor level of knowledge (+5 errors); average (2-3 errors) and good knowledge (0-2 errors). Education entered in the regression with two levels: mid (education without university level) and high (university level). I created two levels of income mid income and high income (> $55,730), while the variable age was entered with the median value (34 years). See Table 7.19 for the regression results.

### Table 7.19  WTP regression results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>Std. Error</th>
<th>t-Test</th>
<th>Marginal effects</th>
<th>t-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low_knowledge</td>
<td>0.2464</td>
<td>0.1564</td>
<td>1.48*</td>
<td>0.0239</td>
<td>1.56*</td>
</tr>
<tr>
<td>Average_Knowledge</td>
<td>0.3378</td>
<td>0.1993</td>
<td>1.70*</td>
<td>0.0512</td>
<td>1.71*</td>
</tr>
<tr>
<td>Good_Knowledge</td>
<td>0.4135</td>
<td>0.2040</td>
<td>2.03</td>
<td>0.0627</td>
<td>2.05*</td>
</tr>
<tr>
<td>Mid_income</td>
<td>0.2489</td>
<td>0.3028</td>
<td>0.82</td>
<td>0.0362</td>
<td>0.85</td>
</tr>
<tr>
<td>High_income</td>
<td>2.0976</td>
<td>0.4890</td>
<td>4.37***</td>
<td>0.4568</td>
<td>4.06***</td>
</tr>
<tr>
<td>Age</td>
<td>0.0022</td>
<td>0.4066</td>
<td>0.02</td>
<td>0.0018</td>
<td>0.04*</td>
</tr>
<tr>
<td>Mid-education</td>
<td>0.5820</td>
<td>0.3068</td>
<td>1.79*</td>
<td>0.0742</td>
<td>1.85*</td>
</tr>
<tr>
<td>High-education</td>
<td>1.0944</td>
<td>0.5682</td>
<td>2.86*</td>
<td>0.0928</td>
<td>2.64*</td>
</tr>
<tr>
<td>Constant</td>
<td>0.0903</td>
<td>0.9655</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sample size                  | 150           |
| Log-Likelihood               | -255.80       |
| LR test                      | 218.58        |
| Chi-squared                  | 132.48        |
| Prob>Chi                      | 0.0000        |
| Pseudo R-squared             | 0.2024        |

* Indicates statistical significance at 0.1
** Indicates statistical significance at 0.01
*** Indicates statistical significance at 0.001

A positive (+) sign means that higher values of the explanatory variable increase the probability of higher values of the dependent variable. Regarding the attitudinal
variable, biodiversity knowledge, which was of great importance in this analysis. It was found that the value of this variable was positively related to the WTP probability and also statistically significant. This result indicates that an individual with good biodiversity knowledge, possesses a higher probability of paying for a biodiversity conservation on Ningaloo Reef. In particular, the WTP probability increased by 6.27% \((ceteris paribus)\) if the individual had a good biodiversity knowledge. The probability decreased to 5.12% for average knowledge and 2.39% for poor knowledge. This result shows that the WTP is strongly affected by the level of biodiversity knowledge in this case.

The positive sign of income indicates that a higher level of income increases the probability of higher WTP. The regression result illustrates that under the significant level of 0.001, household income was a positive explanatory variable for the household’s WTP in both level. As I expected, higher income increased strongly the probability of WTP as we can see in Table 7.20, while if we move to the average class of household income the probability dropped. The variable \(age\), was statistically significant, but considering that the level of its coefficient was very low it means that the age increases the probability of WTP only about 0.18% and had a very low influence in the WTP.

7.15 Conclusion

The results from this study indicated that there are positive and significant non-use values associated with the environmental, economic, and social attributes of Ningaloo Marine Park biodiversity conservation. The impacts of social, economic, and attitudinal characteristics of respondents on their valuation of Ningaloo Marine Park conservation attributes are significant and conform with economic theory. These results assert that choice modelling can produce valid non-market estimates of
non-use value.

The flexibility to estimate values across a number of policy uses is also notable. For instance, through the decomposition of values into their component “implicit prices” policy makers are able to explore the potential of different policy options in achieving socially desirable outcomes. The model estimation results, highlight how the socio-attitudinal characteristics, such as high education level and good biodiversity knowledge are able to strongly affect the willingness to pay for conservation.
Chapter VIII
Conclusion and Policy Recommendations

8.1 Introduction

Economic valuation of biodiversity and ecosystem services is potentially a very powerful tool for halting the loss of biodiversity while maintaining incomes and livelihoods. Yet rarely have such approaches been applied to tropical coral reef hotspots, which house the vast majority of the planet’s species, and this study is the first application to the Western Australian Ningaloo Marine Park.

This chapter summarizes the major findings of this research and formulates some recommendations which can contribute to informed policy making. In doing this, an attempt is made to answer the research questions of the study formulated in Chapter I. The last part of the chapter contributes to knowledge and theory development; it also provides some suggestions for further research required for improving the methods of non-use valuation, and generally improving biodiversity knowledge about coral reefs.

8.2 Summary of Major Findings

This thesis contributes to the literature on estimation of non-use values of coral reef ecosystems using Choice Modelling, and is the first coral reef valuation study that has been undertaken in Australia. The results indicate that there are positive and significant non-use values associated with environmental, economic, and social attributes of Ningaloo Marine Park. The impacts of social, economic, and attitudinal
characteristics of the survey respondents on their valuation of coral reef attributes are significant and conform with economic theory. These results assert that Choice Modelling can produce valid non-market estimates of non-use value. This case study has also demonstrated the potential of the Choice Modelling technique for estimating non-marketed values in the context of policies involving environmental impacts. The technique was shown to be capable of yielding estimates that are cost-effective to obtain because an array of values can be estimated from a single application. The flexibility to estimate values across different policy uses of the Ningaloo coast is also notable. For instance, through the decomposition of values into their component “implicit prices” policy makers are able to explore the potential of different policy options in achieving socially desirable outcomes.

The summary and conclusions from this study are categorized in the following four areas: (i) Western Australians’ attitude towards conservation and protection of Ningaloo Marine Park; (ii) validity and accuracy of Choice Modelling analysis of NMP non-use values; (iii) economic valuation of non-use values; (iv) socio-economic-demographic factors affecting respondents’ willingness to pay for conservation.

8.2.1 Attitude towards Conservation and Protection of Ningaloo Marine Park

Ningaloo Marine Park was selected as a case study for in-depth analysis of marine biodiversity conservation in coral reef ecosystems and to examine the economic valuation of non-use benefits of its protection. The major potential or current human-induced pressures identified as affecting the physical, ecological, social and cultural values of Ningaloo Marine Park (Commonwealth Waters) are pollution, impacts on target and non-target species from commercial and recreational fishing, and impacts from tourism, introduced species, operations for the exploration and production of petroleum products or minerals, and commercial shipping.
This study suggests that Ningaloo Marine Park is highly valued by the Western Australian respondents. The results from the Ningaloo survey reveal that the respondents strongly support the idea of increasing protection of its marine biodiversity ecosystems. In fact, 75% of the respondents were in favour of increasing the percentage of sanctuary zones from the current 33% to 66%.

Strong pro-conservation attitude is also revealed by the fact that almost 90% of the respondents were opposed to the possibility of increasing any commercial activities inside NMP, such as: commercial fishing, commercial shipping, oil exploration and production, and tourism industry. Respondents with stronger pro-environmental attitudes are more likely to participate in a conservation and protection programmes. A significant relationship between respondents’ willingness to pay for conservation and their attitude to accept the increased percentage of sanctuary zones was observed.

The participants also identified a series of initiatives to increase marine ecosystem conservation, such as: restrict areas for recreational and commercial fishing; provide more opportunities for eco-tourism and recreational activities; provide information programmes inside the Park, aimed at reducing litter which may negatively impact on wildlife and water quality; and minimise coral reef damage caused by tourists.

The random utility model applied in this study to estimate the benefits from increased protection, using the data from the Ningaloo survey, was able to measure the benefits that respondents receive from improved conservation scenarios, and also estimated the different factors that influence respondents choice at different levels of protection.
Environmental economics has become an important subject within economics as people have become increasingly concerned with pollution and other forms of environmental damage (Pearce, 2001). The fact that some wild fauna and flora species are threatened and endangered can be considered a special form of environmental damage. Therefore, ideas from environmental economics are relevant to biodiversity conservation and management.

The main stated preference technique used for estimating non-market values, the Contingent Valuation method, has several perceived deficiencies and/or limitations (Kahneman and Knetsch, 1992; McFadden, 1994; Carson et al., 2003). As a result, economists have shown interest in the use of alternative stated preference techniques for estimating non-market values. One such alternative is Choice Modelling.

Choice Modelling was inspired by the Lancasterian microeconomic approach (Lancaster, 1966), in which individuals derive utility from the characteristics of the goods rather than directly from the goods themselves. As a result, a change in prices can cause a discrete switch from one bundle of goods to another that will provide the most cost-efficient combination of attributes.

The main purpose of Choice Modelling is to estimate the welfare effects of changes in the attributes. In order to obtain these, researchers have generally assumed a simple form of the utility function by imposing a constant marginal utility of income. Economists measure welfare using a monetary metric and define it in terms of the economic surpluses (or rents) that accrue to economic agents in their capacities as consumers and producers.

In this study, the surplus accruing to consumers was given by the difference between the benefit that people get from using public spaces such as Ningaloo Marine Park in its status quo and what they have to pay to increase the protection and conservation. In most non-market valuation applications, compensating surplus is defined as the
change in disposable income or expenditure that holds utility constant, given a change in environmental quality. The advantages of Choice Modelling are that values for each attribute as well as marginal rate of substitution between non-monetary attributes can be obtained.

This study used a new approach to Choice Modelling in order to elicit willingness to pay for conservation. The introduction of a separate section in the questionnaire, dedicated to the willingness to pay, instead of setting a fixed amount of money *a priori* (as done in traditional Choice Modelling format), has made it possible to estimate the WTP for conservation in all the scenarios presented to the respondents, including the *status quo*, which at the moment is free entrance. With this new approach to questionnaire design, respondents were also able to choose which type of payment vehicle they preferred, or explain the reason why they didn’t want to pay for the conservation of Ningaloo Marine Park. The aim of this different approach is to gather more information from the respondents about their attitude towards conservation and their willingness to pay for it.

In this way, the study attempted to fill the gaps in biodiversity conservation non-use values and to improve the information about Western Australians’ attitude towards conservation.

In summary the findings from the Ningaloo study are:

- There are positive and significant non-use values associated with environmental, economic, and social attributes of the increased protection scenario for Ningaloo Marine Park.
- The impacts of the social, economic, and attitudinal characteristics of respondents on their valuation of Ningaloo Marine Park obtained through Choice Modelling attributes are significant and conform with economic theory.
• Choice Modelling can produce valid non-market estimates of non-use value. The non-use values estimated in this study can be combined with direct and indirect use values of Ningaloo Marine Park to conduct a cost-benefit analysis. Inclusion of non-use values in benefits estimation enables policymakers to formulate more informed decisions on the efficient management of Ningaloo Marine Park.

• The flexibility to estimate values across a number of different scenarios was also notable. For instance, through the decomposition of values into their component “implicit prices”, policy makers are able to explore the potential of different policy options in achieving socially desirable outcomes.

This flexibility is not available from Contingent Valuation applications where single value estimate is produced. The application also demonstrated the use of Choice Modelling to estimate non-use values associated with social factors. The new approach to Choice Modelling allowed to generate accurate estimation of willingness to pay for each scenario, included the status quo.

8.2.3 Economic Valuation of Biodiversity Conservation

There has been little empirical work on economic valuation of non-use value in Australia but this analysis has been applied for Ningaloo Marine Park for the first time. The results indicate that positive non-use values exist for both environmental and social outcomes (i.e. respondents valued the environmental attributes of Ningaloo Marine Park protection and they also valued the non-use benefits of fish biomass protection created by conservation). These results reflected the pro-environmental trend among respondents that chose the scenarios with increased protection (75%) because these respondents were more concerned about the risk of
reduction of the coral reef coverage and fish biomass than the risk of income reduction for mining and fishing companies.

On average, a respondent is willing to pay $26.12 per person per annum, as entrance fees to contribute towards the protection and conservation of Ningaloo Marine Park. Generalising the results of this study and multiplying the average willingness to pay per person of $26.12 (the average WTP of Scenario II) for the 220,000 visitors of Ningaloo Marine Park (as in 2007), this option could be worth at least $5.7 million per year.

Considering the size of Ningaloo Marine Park, which stretches for about 300 km of the coastline, a conservation programme involves huge investment. Often, such steps are hindered due to lack of investment funds. The Ningaloo survey reveals that considerable funds can be generated from entrance fees, and an extra $5.7 million per year, could fund the needs for marine biological research, increase the control of commercial fishers entering Australian Commonwealth waters and fishing, create more visitors’ centres to provide information to tourists about coral reef conservation rules, control visitor numbers and minimise visitor impacts and overcrowding that usually occur during winter time (July and August), and furthermore, to protect these fragile ecosystems for the future.

8.2.4 Socio-economic-demographic Factors

When using Choice Modelling in environmental valuation, questions arise as to whether respondents have a tendency to remain at the status quo or move from the status quo to other alternatives to increase their benefits. The Ningaloo survey involved a hypothetical scenario in which an individual revealed his or her willingness to pay for conservation (Scenario II, increased protection). The aim of this part of the investigation was to understand the socio-economic-demographic
variables that affected the willingness to pay for conservation and determined what factors could explain or predict respondents’ WTP. The impacts of the socio-economic-demographic variables of respondents have on their valuation of Ningaloo Marine Park attributes were significant and conform with economic theory.

The variables that affected the willingness to pay are described below.

• The biodiversity knowledge of the respondents was tested with a specific section in the Ningaloo questionnaire. This result indicates that an individual with good biodiversity knowledge, possesses a higher probability of paying for a biodiversity conservation on Ningaloo Marine Park. The WTP probability increases by 6.27% (ceteris paribus) if the individual has good biodiversity knowledge. The probability decreases by 5.12% for average knowledge and 2.39% for poor knowledge. This result shows that the WTP is strongly affected by the level of biodiversity knowledge in this case.

• Respondents with high levels of education (university education) are more likely to choose higher payment levels related to the hypothetical Scenario II, increased protection. In particular, the WTP probability increases by 9.28% if the respondents have high level of education.

• Several studies have shown that people with higher income levels are more propitious to engage in environmental development programs (Berger, 1997; Owens et al., 2000; Rolfe and Windle, 2003), and income is generally a significant determinant of WTP. It means that people with higher level of income are positively associated with higher willingness to pay, compared to people with lower level of income. In this case, income is significant with a positive sign, indicating that respondents with a higher income were more likely to support the Scenario II option, with increased protection. The WTP probability increased by 4.56% if respondents have high level of income.
An interesting result, gained by this study, is that the level of education of the respondents is the most important factor affecting the WTP, while income appears to be of minor importance as a determining factor.

- The coefficient of the variable age was very low and no significant in relation to the willingness-to-pay of respondents, it means that respondents’ age doesn’t affects the WTP.

This study provides empirical evidence on non-use values for a marine park. In particular, there was high percentage of Western Australians respondents who held positive non-use values for biodiversity conservation of Ningaloo Marine Park. The information generated by this economic valuation is extremely valuable for future environmental management strategies for Ningaloo Marine Park.

8.3 Policy Recommendations

The aim of this section is to integrate the results obtained through the Ningaloo Marine Park non-use values analysis into a possible suite of policy recommendations for long-term planning and regional environmental management strategies. Specifically, the results of the previous chapters are targeted to aid policy makers by answering two specific questions: (i) what needs to be done to protect the coral reefs of Ningaloo Marine Park, and (ii) how to create economic incentive for funding a better conservation and protection programme.
8.3.1 Conservation of Marine Biodiversity

The proportion of a coastal area to be protected is usually determined through a compromise between the desire by some to protect all biodiversity and ecosystem function from human impact, and the socio economically valid goal of providing for continued use of the fishery and other resources in the area (Clinton, 2000). Sanctuary zones, where people can look but not take, are one of the most effective ways of protecting the nature conservation values within marine parks and this is their primary purpose. Such marine protected areas play a vital role in preserving marine biodiversity and an important role in the long-term sustainable use of the living resources of the coastal zone. As all of the components of the marine ecosystem are protected, from the seaweeds through to shellfish and table fish, it means that people can enjoy viewing completely unspoilt marine areas in such sanctuary zones. Scientists can also gain an understanding of the full range of species and their levels of abundance in such habitats.

In November 2004 the Western Australian State government formally extended Ningaloo Marine Park south to Red Bluff (covering a further 38,000 hectares) to include the entire 300-kilometre-length of Ningaloo Reef in the park and increased the sanctuary zone areas from 18% to 33% of the entire Park. However, even if the Department of Environmental and Conservation (DEC, 2008) has confirmed its intention to maintain and improve protection on the Ningaloo Marine Park, the new proportion of sanctuary zones may not be enough to prevent further environmental impacts on this fragile coral reef ecosystems, is the opinion of Ningaloo Marine Park users.

The primary purpose of sanctuary zones is for the protection and conservation of marine biodiversity. Successful MPAs have strong community support as well as sound ecological justifications. The results gained from this study, show that 75% of the respondents were in favour of the hypothetical scenario with increased
protection (66% of sanctuary zones). Policy makers should consider this result in future decision making management and increase the number and the size of sanctuary zones inside Ningaloo Marine Park.

As well as serving valuable biodiversity conservation roles, functioning no-take marine areas a portion of the fishery stock as insurance against commercial and recreational overfishing. Marine reserves offer a unique insight into the impact of human exploitation of marine resources due to the spatially explicit nature of their protection.

Considering that tourists are not familiar with coral reef ecosystems (only 27.6% of respondents revealed a good knowledge of the coral reef, in the Ningaloo survey), to reduce further potential threats caused by recreational activities, such as snorkelling, boating, solid waste, etc., an expanded information centre and new education campaign of NMP should be implemented. Information about coral reef fish habitat, endangered and vulnerable species, represents a key issue in reducing further impacts on these fragile ecosystems. Providing information on marine biodiversity conservation, also increases public awareness and appreciation of natural, physical and cultural values of Ningaloo Marine Park.

8.3.2 Creating Economic Incentives for Conservation

People’s economic decisions reflect their interests and preferences, which depend in turn on the information available to them and the incentives they face. Attempts to conserve nature without understanding the incentives that drive biodiversity loss are bound to fail. Economic instruments for environmental management such as the removal of distortionary subsidies, secure property rights, pollution taxes, user charges, tradeable emission permits, and refundable deposits aim to correct these
failures, reinstate full-cost pricing, and bring about a realignment of resource allocation.

Indeed, economic instruments can not only be used to reduce the apparent environment development conflict but, if properly designed and implemented, can actually make economic development a vehicle of environmental protection and vice versa. Economic instruments can be used to provide the kinds of signals concerning resource scarcity and environmental damage that induce efficient resource use and minimization of waste, which are needed to make sustainable development possible.

In this study the trend of the respondents in favour of the introduction of entrance fee and increase of protection for Ningaloo Marine Park, was very evident. The possibility to introduce an entrance fee could be considered by policy makers in two possible options.

**Option 1**

Generalizing the result of this study and multiplying the average willingness to pay per person $26.12 (the average WTP of Scenario II) for 220,000 visitors in Ningaloo Marine Park (Tourism, 2007) this option could be worth at least $5.7 million per year. The option of creating an extra 33% of sanctuary zone and an extra injection of $5.7 million per year, could be an interesting solution, and even more, protect this fragile and unique marine ecosystems for the future.

**Option 2**

This option reflects the present situation scenario from biodiversity conservation and protection view (33% of sanctuary zone), but introduces the hypothetical entrance fee of $9 per person (the average WTP of scenario I). This amount of fee, multiplied by the 220,000 visitors could be worth almost $2.0 million per year.
Introducing user fees in both options is a way to regulate access to the fragile ecosystems of Ningaloo Marine Park. It may therefore help to prevent overcrowding and other negative impacts on ecosystems due to excessive numbers of tourists, especially during the peak season (July/August). It may also be a way to capture part of the consumers’ surplus, in order to make the protected area self-sustaining, i.e. to finance management costs and conservation. Considering the long distance to reach Ningaloo Reef (1.270 Km from Perth which is the only international airport in WA) and the costs to drive or fly to Exmouth, the hypothetical entrance fee of $26,12 will not affect the tourist decision to choose this marine park for holiday.

Examples of successful user fee systems can be found in several locations, such as Bonaire (Netherlands Antilles), Sabah (Malaysia), Palau, Galápagos, and other sites in Africa, the Carribean, and Asia (Lindberg, 2001), Komodo and Ujung Kulon National Parks in Indonesia (Gallegos et al., 2005). For example, in Tubbataha Reef National Park (Philippines), after two years of fees collection, the total fees collected cover 28% of the annual recurring costs and nearly 41% of the core costs to protect the reefs (Tongson and Dygico, 2004). Some of the more significant lessons derived from these experiences are the importance of active participation by the tourism sector; information dissemination; awareness raising; transparency in fee collection and disbursements; need to monitor visitor arrivals both before and after fee establishment or fee increases, and earmarking funds for conservation activities (Gallegos et al., 2005).

Charging entrance fees allows more opportunity for individual users and consumers who directly appreciate and make use of the resources to contribute for the conservation of Ningaloo Marine Park. Fees not only generate revenues but also function as a permitting and regulatory instrument to control visitor volumes and activities. The permit serves as a license for dive boats to enter the park, and this allows authorities to monitor visitor arrivals and their activities.
Finally, further actions should be pursued to maintain the viability of tourism in Ningaloo Marine Park. These should include periodic reviews of existing fee mechanisms to control visitor numbers and minimize visitor impacts and overcrowding, obtain visitor feedback to assess customer satisfaction levels, and use part of the proceeds from the fees to promote the site and generate awareness.

8.4 Contribution to Knowledge and Theory

This research contributes to the development of knowledge and theory in two broad ways. First, it has developed a new methodological approach for valuing the marine ecosystems environment, and second, the new methodological framework has been applied to value biodiversity conservation on Ningaloo Marine Park. These two points are explained below.

8.4.1 Methodological Development

An alternative approach to elicit the willingness to pay for conservation with a Choice Modelling methodology was proposed and examined in this research. The willingness to pay section was not presented in the choice set as an attribute, which is the typical Choice Modelling format. A specific section called Elicitation was introduced in the questionnaire to elicit the willingness to pay, after the respondents had already chosen their preferred scenario. With the traditional approach of Choice Modelling, the researchers have to select a particular payment vehicle recognized as the most appropriate and then they have to choose an amount of dollars for each scenario that they retain feasible, credible and possible for everybody. Hence the respondents have very limited choice about the financial attribute (WTP) as they can only select their preferences from the choice sets, without being able to express any other preference about the amount of money they are willing to pay. Respondents in
this way cannot choose any payment vehicle, as the WTP attribute is fixed \textit{a priori}. With the developed new approach, the respondents have the possibility to express their preferences about the payment vehicles. In this case they were: \textit{Park entrance fees (user pays), donation (voluntary), increased income tax (from 0.15\% to 2.5\%), other (specify) and none.}

The advantage of this approach to elicit the WTP, is that it allows to gather more appropriate information about the WTP and the payment vehicle, something that with the traditional choice sets is not possible. Another important advantage of this new approach is that with a separate section dedicated to the WTP question, the respondents could express their willingness to pay for conservation also for the \textit{status quo} scenario, that in this case was free entrance. In fact, 23\% of the respondents that preferred the present situation scenario were in favour and put an amount of money in the WTP section, as entrance fees. It means that these respondents liked the way the Ningaloo Marine Park is managed and the size of sanctuaries, but they preferred to pay an entrance fee because they realized that the Park authorities and the management need more funds to control and increase the quality of protection in the Park. Using the traditional format of Choice Modelling it would have not been possible to elicit this information, which in fact is very important and significant for future considerations related to the strategic planning for the management of the Park.

The application of this different approach is much more flexible and capable to produce rich information about people’s WTP preferences and to generate statistically robust models of choice.
8.4.2  A framework for Non-use Valuation of Ningaloo Marine Park

The results from Choice Modelling provide important insights into methodological as well as practical policy issues. The case study reported here demonstrated the potential of the Choice Modelling technique for estimating non-use values in the context of policies involving environmental impacts. The technique was shown to be capable of yielding estimates that are cost-effective to obtain because an array of values can be estimated from a single application. The flexibility to estimate values across different scenarios is also notable. For instance, through the decomposition of values into their component “implicit prices” policy makers are able to explore the potential of different policy options or scenarios in achieving socially desirable outcomes.

The Choice Modelling application reported here could be used as a source of benefit estimates for Ningaloo management plans with only minor adjustment to the scenario information fed into the estimation model. This flexibility is not available from contingent valuation applications where single value estimates are produced. The application also demonstrated the use of Choice Modelling to estimate non-use values associated with social factors. This study is expected to provide useful information for management of other marine protected areas in Australia, as well as in other countries, and the application of this methodology can be used for other marine parks evaluation.

8.5  Further research directions

This study highlighted a vast range of issues that requires further investigation in order to reduce knowledge gaps. Suggestions for further research are targeted in two areas:
1) Valuation Techniques to Account Biodiversity Conservation

Considerable progress has been made in the last decades in developing reliable tools for the valuation of biodiversity resources and functions and associated ecosystem services. However, important opportunities for further research and development remain, particularly on coral reef ecosystems.

Further research on the conditions for validity and robustness of valuation techniques, in particular of stated-preference techniques, contribute to further the reliability of valuation information of non-marketed ecosystem services, in particular with regard to non-use values. Choice Modelling produces valid non-market estimates of non-use values, but further work will also be required.

Integrating techniques from the attitude–behaviour and economic valuation literature would be helpful to understand how socio-economic-demographic factors influence attitude towards conservations and also the willingness to pay. Specifically, studies integrating attitudinal measures and Choice Modelling methods are recommended to gain a better understanding of the influence of environmental attitudes.

The findings from this study suggest that implicit prices generated using Choice Modelling are extremely important for policy making decisions to explore the potential of different policy options in achieving socially desirable outcomes.

The new approach used in this study to elicit respondents’ willingness to pay for conservation is able to create valid and accurate results, however further research is needed to explore the potential of this approach.

2) Reduce the Gaps in Ningaloo Reef Biodiversity Knowledge

There are large gaps in Ningaloo Reef marine biodiversity knowledge. There is need for research to gain the missing biological information for target species (e.g. mobility, life-history, rates and patterns of settlement and recruitment, connectivity among neighboring populations, and the status of these populations as either sources
or sinks); as well as physical information about bathymetry, habitat and hydrodynamics at locations being considered for reserves.

The presence of deep (50 to >200 m) water over most of the Commonwealth Waters portion of the Ningaloo Marine Park imposes restrictions on research due to technical limitations and high costs. Research in deep open waters requires the use of larger vessels, heavy sampling equipment and sophisticated technical equipment such as side-scan sonar and remotely operated vehicles (AIMS, 2008).

There is a need for further evaluation of physical and chemical oceanographic processes in order to evaluate the potential effects of development within or adjacent to the Park. This will assist in assessing the potential for ‘trapping’ or recirculation of nutrients and other contaminants which may be discharged into the waters from the land, and for modelling the trajectory of potential oil spills that may enter the Park as a result of a shipping or oil production accident.

At the moment, the Ningaloo Collaboration Cluster, is playing an important part in addressing the challenge of integrating the knowledge of reef use, biodiversity and socio-economics into a management strategy for the Ningaloo Marine Park of Western Australia (CSIRO, 2008). The Cluster is delivering systems to predict the impact of different management decisions or development scenarios on both the ecological and socio-economic health of the region. It is also determining optimal approaches for monitoring the effectiveness of these options in maintaining a healthy ecosystem.

Considering that in this case study, biodiversity knowledge was a determinant variable which affected willingness to pay for conservation and willingness to chose protected scenario, future trust fund raising campaigns should target schools, colleges, and universities to improving general marine biodiversity knowledge and awareness towards conservation.
References


IUCN (1994). Guidelines for Protected Areas Management Categories. IUCN; Cambridge, UK.


Appendix I: Choice Sets from Questionnaire 1

NINGALOO REEF MARINE PARK
Questionnaire 1

SCREENING SHEET

Hello my name is Flavio Gazzani from ISTP (Institute for Sustainability and Technology Policy), Murdoch University, Australia. This survey is being conducted as an independent PhD research, to look at how Australia should use its marine protected areas. There are no right or wrong answers. Your answers will be confidential and your name will never be associated with your answers.

NINGALOO SURVEY

Choice Sets

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1 (Status quo)</th>
<th>Option 2 (Increased protection)</th>
<th>Option 3 (Decreased protection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>40%</td>
<td>3%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 60%</td>
<td>± 95%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose
### Choice set 2
Consider carefully each of the following three options. Suppose these options were the only ones available, which one would you choose?

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>50%</td>
<td>7%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 30%</td>
<td>± 90%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Very Low</td>
<td>High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose  

### Choice set 3
Consider carefully each of the following three options. Suppose these options were the only ones available, which one would you choose?

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>66%</td>
<td>0%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 30%</td>
<td>100%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Very Low</td>
<td>High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose  

276
Choice set 4
Consider carefully each of the following three options. Suppose these options were the only ones available, which one would you choose?

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>60%</td>
<td>10%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 60%</td>
<td>± 90%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Very Low</td>
<td>Very High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>Very High</td>
<td>None</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose

Choice set 5
Consider carefully each of the following three options. Suppose these options were the only ones available, which one would you choose?

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>75%</td>
<td>20%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 30%</td>
<td>± 75%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Extremely Low</td>
<td>High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose
### Choice set 6
Consider carefully each of the following three options. Suppose these options were the only ones available, which one would you choose?

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Status quo</td>
<td>Increased protection</td>
<td>Decreased protection</td>
</tr>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>90%</td>
<td>15%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 10%</td>
<td>±80%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Extremely Low</td>
<td>Very High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>Extremely High</td>
<td>Low</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose

- [ ]
- [ ]
- [ ]

### Choice set 7
Consider carefully each of the following three options. Suppose these options were the only ones available, which one would you choose?

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Status quo</td>
<td>Increased protection</td>
<td>Decreased protection</td>
</tr>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>80%</td>
<td>25%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 20%</td>
<td>±50%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Extremely Low</td>
<td>Very High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>High</td>
<td>Very Low</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose

- [ ]
- [ ]
- [ ]
**Choice set 8**
Consider carefully each of the following three options. Suppose these options were the only ones available, which one would you choose?

<table>
<thead>
<tr>
<th>Environmental Implications</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Sanctuary Zone</td>
<td>33%</td>
<td>45%</td>
<td>30%</td>
</tr>
<tr>
<td>Risk of reduction on coral reef coverage</td>
<td>± 50%</td>
<td>± 50%</td>
<td>±40%</td>
</tr>
<tr>
<td>Decrease of marine life biomass</td>
<td>High</td>
<td>Low</td>
<td>Very High</td>
</tr>
<tr>
<td>Decreased income of local fisheries</td>
<td>Low</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Loss of income for mining and petroleum companies</td>
<td>High</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>

Please tick one for the option you choose
Appendix II: Full version of questionnaire 2 schedule

NINGALOO REEF MARINE PARK Questionnaire No…….

SCREENING SHEET

Hello my name is Flavio Gazzani from ISTP (Institute for Sustainability and Technology Policy), Murdoch University, Australia. This survey is being conducted as an independent PhD research, to look at how Australia should use its marine protected areas. There are no right or wrong answers. Your answers will be confidential and your name will never be associated with your answers.

NINGALOO SURVEY

SECTION I   GENERAL LEVEL OF ENVIRONMENTAL CONCERN

I am going to ask you a series of questions. There are no right or wrong answers. Your answers will be confidential. Just tell me what you think.

Q.1 Some national priorities are more important to people than others. How important to you personally is a national goal of protecting nature, ecosystem conservation and controlling pollution?

1 Very important
2 Somewhat important
3 Not very important
4 Don’t know

Q.2 Do you think Western Australia needs to concentrate more on protecting the environment, or more on development (social and economic), or would you say we currently have a reasonable balance?

1 More on environment
2 More on development
3 Reasonable balance
4 Don’t know
Q.3 What do you think are the three environmental issues most important to Western Australia right now?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Combat pollution</td>
</tr>
<tr>
<td>2</td>
<td>Increase nature conservation of flora/fauna</td>
</tr>
<tr>
<td>3</td>
<td>Stop logging of old growth native forest</td>
</tr>
<tr>
<td>4</td>
<td>Prevent uranium mining</td>
</tr>
<tr>
<td>5</td>
<td>Sustainable planning of urban areas</td>
</tr>
<tr>
<td>6</td>
<td>Control soil erosion and soil salinity</td>
</tr>
<tr>
<td>7</td>
<td>Increase health of water ways</td>
</tr>
<tr>
<td>8</td>
<td>Secure sustainable water supplies</td>
</tr>
<tr>
<td>9</td>
<td>Decrease greenhouse effect</td>
</tr>
<tr>
<td>10</td>
<td>Dispose more carefully of waste</td>
</tr>
<tr>
<td>11</td>
<td>Make roads more environmentally sensitive</td>
</tr>
<tr>
<td>12</td>
<td>Increase biodiversity conservation of Ningaloo Reef</td>
</tr>
<tr>
<td>13</td>
<td>Increase number and size of National Parks</td>
</tr>
<tr>
<td>14</td>
<td>Reduce mining in environmentally sensitive areas</td>
</tr>
<tr>
<td>15</td>
<td>Better manage WA coastal environment</td>
</tr>
<tr>
<td>16</td>
<td>Promote renewable energy</td>
</tr>
<tr>
<td>17</td>
<td>Other (SPECIFY) .................................................................</td>
</tr>
</tbody>
</table>

SECTION II  NINGALOO REEF KNOWLEDGE AND VISITS

Q.4 In the last 12 months, did you spend time in a National Park or Marine Protected Area?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Unsure</td>
</tr>
</tbody>
</table>

Q.5 Have you visited Ningaloo Reef in the last 12 months?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Unsure</td>
</tr>
</tbody>
</table>

Q.6 What would you say Ningaloo Reef Marine Park is best known for? (Multiple responses possible)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A good fishing spot</td>
</tr>
<tr>
<td>2</td>
<td>As a tourist attraction</td>
</tr>
<tr>
<td>3</td>
<td>Wilderness/unspoiled environment</td>
</tr>
<tr>
<td>4</td>
<td>Coral reef wildlife</td>
</tr>
<tr>
<td>5</td>
<td>Whale sharks</td>
</tr>
<tr>
<td>6</td>
<td>Turtles</td>
</tr>
<tr>
<td>7</td>
<td>Remote attractive beaches</td>
</tr>
<tr>
<td>8</td>
<td>Aboriginal culture</td>
</tr>
<tr>
<td>9</td>
<td>Save Ningaloo Reef campaign</td>
</tr>
<tr>
<td>10</td>
<td>Others (SPECIFY) .....................</td>
</tr>
<tr>
<td>11</td>
<td>Don’t know</td>
</tr>
</tbody>
</table>
Q.7 On a scale of 1 to 5, how strongly do you agree or disagree with the following biodiversity statements.

Q.7a “I would like to see all species of Ningaloo Reef protected for future generations”
1 Strongly in favour
2 In favour
3 Indifferent
4 Opposed
5 Strongly opposed

Q.7b “It is my right to fish at Ningaloo Reef”
1 Strongly in favour
2 In favour
3 Indifferent
4 Opposed
5 Strongly opposed

Q.7c “There should be more opportunities for eco-tourism and recreational activities at Ningaloo Reef”
1 Strongly in favour
2 In favour
3 Indifferent
4 Opposed
5 Strongly opposed

Q.7d “I would like to see more commercial development at Ningaloo”
1 Strongly in favour
2 In favour
3 Indifferent
4 Opposed
5 Strongly opposed

Q.7e “The future of Ningaloo should be up to the local communities because it is their area”
1 Strongly in favour
2 In favour
3 Indifferent
4 Opposed
5 Strongly opposed

Q.7f “Ningaloo Reef is as ecologically valuable as the Great Barrier Reef”
1 Strongly in favour
2 In favour
3 Indifferent
4 Opposed
5 Strongly opposed

Q.8 What is your main source of information about Ningaloo Reef?
1 None
2 Television
3 Newspapers, magazines, and books
4 Internet
5 General word of mouth
6 School/education
7 Family/friends
8 Other (Specify)...............................
### SECTION III  ECOLOGICAL KNOWLEDGE

#### Q.9  Marine ecological knowledge

Please indicate true or false  

<table>
<thead>
<tr>
<th></th>
<th>T=True</th>
<th>F= False</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coral is an animal with tiny algal cells living in its tissues.</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>Mangroves are important nursery habitats for fish.</td>
<td>T</td>
</tr>
<tr>
<td>3</td>
<td>There are more turtles now than any time in the past 10 years at Ningaloo.</td>
<td>T</td>
</tr>
<tr>
<td>4</td>
<td>Parrotfish eat coral.</td>
<td>T</td>
</tr>
<tr>
<td>5</td>
<td>Grouper populations have increased in the past decade outside the Sanctuary Zone of Ningaloo Reef.</td>
<td>T</td>
</tr>
<tr>
<td>6</td>
<td>Sea snakes are dangerous to humans.</td>
<td>T</td>
</tr>
<tr>
<td>7</td>
<td>Whale sharks live only in Ningaloo Reef.</td>
<td>T</td>
</tr>
<tr>
<td>8</td>
<td>Global warming has caused sea levels to rise worldwide over the past decade.</td>
<td>T</td>
</tr>
<tr>
<td>9</td>
<td>Algal growth can cause coral damage.</td>
<td>T</td>
</tr>
<tr>
<td>10</td>
<td>In the past 10 years, cyclones have damaged Ningaloo Reef.</td>
<td>T</td>
</tr>
<tr>
<td>11</td>
<td>Marine Protected Areas will help increase fish numbers (inside the protected area).</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Oil spills cause damage to coral polyps.</td>
<td>T</td>
</tr>
<tr>
<td>13</td>
<td>The collection, trade and sale of most coral reef animals are not regulated in Australia.</td>
<td>T</td>
</tr>
<tr>
<td>14</td>
<td>Coral reefs are the breeding grounds for many commercial fish.</td>
<td>T</td>
</tr>
<tr>
<td>15</td>
<td>If current practices continue most of the world’s coral reef will be killed within 20 years.</td>
<td>T</td>
</tr>
<tr>
<td>16</td>
<td>The quality of Ningaloo Reef has declined over the last 10 years due to anchor damage.</td>
<td>T</td>
</tr>
</tbody>
</table>

### SECTION IV  NINGALOO SCENARIOS

Here are 3 different Hypothetical Scenarios for Ningaloo Reef (see also the maps)

#### Q.10  Which of the three Scenarios do you prefer?

1. Scenario I Ningaloo Reef in present situation (33% Sanctuary Zone) PRESENT IMPACT
2. Scenario II Ningaloo Reef with increased conservation (66% Sanctuary Zone) MINOR IMPACT
3. Scenario III Ningaloo Reef without conservation MAJOR IMPACT
**SCENARIO I**

**PRESENT SITUATION**

**NINGALOO REEF MARINE PARK**

Currently, Ningaloo Reef Marine Park is managed predominantly for conservation, recreation, science, education and 33% of the Marine Protected Area is Sanctuary Zone. Marine sanctuaries are fully protected waters in which all detrimental human activities are prohibited. They are often referred to as no-take zones or reserves since no extractive practices, including fishing, may occur in these areas. While many existing activities can continue, there are specific restrictions on activities in some zones (see the Map1).

**Activities prohibited**
- Mining along the coast
- Commercial fishing
- Recreational fishing allowed but not with underwater breathing devices or spear guns.
- Petroleum and mineral exploration (however, the North West Shelf, to the north of Ningaloo Marine Park is a major area for oil and gas production and exploration and the Ningaloo region is considered a prospective area).
- House and tourism infrastructure construction on Sanctuary Zone.

**Activities allowed**
- Access by boats is permitted throughout the marine park and marine management area.
- Recreational fishing is permitted in the recreational and general use zones in the marine park and in the unclassified area of the marine management area.
- Recreational shore-based fishing, for finfish only, is also permitted in the special purpose zone (shore-based activities).
- Commercial fishing is permitted in the general use zone south of Point Maud and north of Tantabiddi in the marine park, and in the unclassified area of the marine management area.
- Commercial shipping

**Benefits of marine sanctuaries**
- Increase biomass, abundance and population age of marine life
- Increase size of resident fish which consequently increases their productivity
- Increase catch per unit effort for fishers in areas surrounding reserves
- Can increase number and viability of species in surrounding waters through a ‘spillover effect’ (This ‘spillover effect’ occurs when marine life from within sanctuaries encroaches into the surrounding fishing grounds.)
- The highly mobile species such as cod, sharks, tuna and billfish may be offered protection from sanctuary zones if these areas encompass areas such as aggregation sites, nursery grounds or areas for spawning.
- Reduce probability of extinction of threatened species

**Impacts outside the Sanctuary Zone**
- Reduces the distribution and abundance of target species thus changing the population structure;
- Impacts on benthic communities including destruction of flora and fauna, and loss of demersal fish and other fauna through habitat modification (e.g. from trawling).
- Reducing population levels of non-target species through by catch.
- Fuel and oil discharges or spills e.g. from vessels (small or large scale).
- Sewage and other wastes from vessels including commercial shipping and waste associated with petroleum activities.

**Disadvantages in marine sanctuaries**
- Fishers are excluded inside marine sanctuaries
- Decrease income for fishing charters inside marine sanctuaries
- Changes sense of place for locals
- Restricted rights for fishers
- Restricted income of local communities of fishers
- Reduce income from mining
SCENARIO II

MINOR IMPACT INCREASED SANCTUARY ZONE

Let me describe to you how Ningaloo Reef Marine Park would be if in the Marine Park, the Sanctuary Zone is increased from the actual 33% to 66% (See Map2). Marine sanctuaries are fully protected waters in which all detrimental human activities are prohibited. They are often referred to as no-take zones or reserves since no extractive practices, including fishing, may occur in these areas.

Activities prohibited inside the Sanctuary Zone:
• Mining
• Fishing
• Petroleum exploration
• Dumping

Activities allowed inside the Sanctuary Zone:
• Tourism and recreation

Activities allowed outside the Sanctuary Zone:
• Mining
• Fishing
• Petroleum exploration
• Dumping
• Tourism and recreation

Positive benefits of marine sanctuaries
• Increase biomass, abundance and population age of marine life
• Increase size of resident fish which consequently increases their productivity
• Increase catch per unit effort for fishers in areas surrounding reserves
• Can contribute to increased tourism as the aesthetic qualities of the area increase
• Can increase number and viability of species in surrounding waters through a 'spillover effect' (This ‘spillover effect’ occurs when marine life from within sanctuaries encroaches into the surrounding fishing grounds.)
• The highly mobile species such as cod, sharks, tuna and billfish may be afforded protection from sanctuary zones if these areas encompass areas such as aggregation sites, nursery grounds or areas for spawning.
• Reduce the probability of extinction of threatened species

Disadvantages in marine sanctuaries
• Fishers are excluded inside marine sanctuaries
• Decrease income for fishing charters inside marine sanctuaries
• Changes sense of place for locals
• Restricted rights for fishers
• Restricted income of local communities of fishers
• Reduce income from mining
Map 2 Scenario of Ningaloo Reef with 66% Sanctuary Zone

Legend
- Sanctuary Zone
- Recreation Zone
- General Use Zone

Ningaloo Marine Park

Cape Perchor 

Arborek Point 

Green Island 

3 Mile Camp 

1 Mile Camp 

1 Mile Camp 

Cape Perchor 

Arborek Point 

Green Island 

3 Mile Camp 

1 Mile Camp 

Cape Perchor 

Arborek Point 

Green Island 

3 Mile Camp 

1 Mile Camp 

Cape Perchor 

Arborek Point 

Green Island 

3 Mile Camp 

1 Mile Camp 

Cape Perchor 

Arborek Point 

Green Island 

3 Mile Camp 

1 Mile Camp
SCENARIO III

MAJOR IMPACT  NINGALOO REEF WITHOUT CONSERVATION

In this Scenario we consider the hypothetical case of Ningaloo Reef without any kind of protection or conservation along the coast, except Cape Range National Park. In this case, any sort of human activities and industrial activities are allowed inside the reef and along the coastline (See Map3).

Activities Prohibited
None (except the Cape Range National Park)

Activities allowed:
• Mining
• Fishing
• Petroleum exploration
• Dumping
• Tourism and recreation

Benefits
• Increased income of commercial fishing
• Increased income from mining
• Increased income from industrial marine activities as harbours, cargo operations, transport, vessel movement
• Increased income from tourism activities and infrastructure constructions
• Increased job opportunities, related to the activities specified above
• Opportunities for international companies to invest in industrial and tourism activities

Disadvantages

Environmental Impacts of Industrial Activities
• Pollution from industrial activities, such as heavy metals and other toxic waste
• Handling of liquid bulks may require pipelines, which provide the potential for leaks, emissions and spillages.
• Biocides and bleach: Fouling of harbour structures, such as slipways, steps, jetties, pontoons, can result in surfaces becoming covered in layers of bacterial and algal slime that must be removed.
• The impact of chlorine on the marine environment is extremely toxic to shellfish and fish as well as causing the localised lowering of species diversity.

Environmental Impacts of Urbanization
• Sand mining and dredging lead to shoreline erosion and coastal alteration.
• Deterioration of water quality by sewage, sediment runoff, solid waste materials, high nutrient loads and pathogens
• Demand for construction materials (sand and gravel) can lead to disturbance and removal of benthic organisms at offshore extraction sites, (sensible choice of extraction sites can reduce the disturbances)

Environmental Impacts of Fisheries & Mariculture
• Dramatic decline in the abundance and diversity of marine life along the coast.
• Bottom trawls cause irreparable damage to coral reef.
• Fast decline of coral coverage.
SECTION V  ELICITATION

Q.11  Would you be willing to pay to protect and conserve Ningaloo Reef, insert the amount in all acceptable to you payment vehicles?

1  Park entrance fees (user pays)  from 0$ to 100$  ....................

2  Donation (voluntary)  from 0$ to 100$  ....................

3  Increase income tax  
   1  0.1%
   2  0.5%
   3  1.0%
   4  1.5%
   5  2.0%
   6  2.5%

(example: if your income is $15,000 per year, 0.5% is $75 per year)

4  Others (SPECIFY)................................................................................................................................

5  None

Q.12  If your willingness to pay is ZERO $ explain why.

1  There are already adequate levels of protections and conservation in Ningaloo Reef
1  I already pay enough tax
2  The Government has to increase its investment in marine conservation
3  The Shire of Carnarvon and Exmouth should increase their rates to fund the protection of Ningaloo reef
4  Other (SPECIFY)....................................................................................................................................

SECTION VI  DEMOGRAPHIC QUESTIONS

I have just a few questions about your background that will only be used for statistical purposes.

Q.13  Record sex

1  Male
2  Female

Q.14  Which of these age groups do you fit into?

1  18-28
2  29-38
3  39-48
4  49-58
5  59-68
6  68+

Q.15  What is the highest level of education you have obtained?

1  Primary only
2  Some secondary
3  Completed Year 10 secondary
4  Completed Year 12 secondary
5  Trade certificate
6  Tertiary degree, diploma or certificate
7  Higher degree
8  Other (SPECIFY)....................................................................................................................................
Q.16  Are you currently studying?

1  Yes, full-time
2  Yes, part-time
3  No

Q.17  What is your household gross income from all sources before tax or anything else is taken out?

1  Under $20,000
2  $21,000-$40,000
3  $40,001-$60,000
4  $60,001-$80,000
5  $80,001-$100,000
6  $100,001-$150,000
7  More than $150,000
10  Don’t know
11  Do not want to disclose

Q.18  What best describes your current work status?

1  Employed full-time
2  Employed part-time
3  Unemployed
4  Retired or aged pensioner
5  Other pension/other benefits recipient
6  Home duties
7  Other (SPECIFY)..........................
Thank you for your time and effort in answering these questions. If you are willing to be interviewed in further research, may I please have your contact details.

The information you provide below will be used only for you to be contacted if needed, this page of the survey will be detached from the other pages of the survey and in no way will your answers to this survey be associated with your name.

Respondent name:...........................................................................................................................................

Address:.......................................................................................................................................................................

Telephone No:............................................... 

Email:...........................................................................................................................

If you are interested in receiving information about outcomes from this research, please provide contact details

As above
Name........................................................................................................................................................................

Address:....................................................................................................................................................................

Telephone No: ............................................................

Email:...........................................................................................................................
Appendix III Coral Reef Ecology

Coral reef fishes are the shore fishes of tropical coastline. A few species are restricted to the topographically complex, biogenic habitats of coral reefs, but many of them occur also over seagrass beds, in shallow or deeper off-reef lagoons, and in mangroves and estuaries (Bellwood and Hughes, 2001). In all of these habitats, but especially on the reefs, coral reef fishes are notably abundant. Species lists for remote locations such as Easter and Ascension islands number less than 100, but most coral reef regions include from 500 to 1000 or more species (Thresher, 1991).

Biomass estimates vary considerably among regions, due both to levels of productions and harvest. This biomass is always distributed among many species, and fisheries therefore tend to include many species.

Reef fishes species fill a broad range of consumer roles; they are planktivores, carnivores on demersal invertebrates, piscivores, and grazing and browsing herbivores. In many systems, they are the most important participants in several of these trophic roles (in terms of energy or nutrient transfer). Further, because most species experience at least an order of magnitude change in size during their life span, trophic role can change substantially during life of the individual. Such ontogenetic niche shifts mean that individuals use their world in two or more quite different ways during the course of their life span, with the difference between the pelagic larval and the demersal juvenile and adult phases being the most pronounced (Sale, 1991).

With very few exceptions, reef fishes have the life cycle with a more or less lengthy pelagic larval phase followed by a demersal and usually strongly site-attached adult phase. The larval phase lasts from 10 to 100 days, more or less, and the sedentary phase lasts from one to several years (often to several decades in unfished systems). Until 1980s, ecological studies of reef fishes focused almost exclusively on the reef-
associated juvenile and adult phases, and our knowledge of the very different larval life has lagged seriously (Leis, 2006).

Immense differences exist among reef fish species in expression of sexual roles (gonophores and simultaneous and sequential hermaphrodites all exist), in fecundity, in frequency and periodicity of spawning, in duration of the larval phase, in survivorship during the first critical days in the demersal habitat, and in longevity of settled fishes.

Until recently, there has been relatively little attention to the differences. In addition, it is now clear that there can be substantial and temporal differences within species in these same life history features.

In one sense, the many different life history patterns exhibited by reef fishes are alternate solutions to the challenges of living in a spatially very patchy environment, bathed by waters that move in complex, no constant ways. The diversity of life styles means parenthetically that no single management approach will be optimal for all species.

Early ecological research on reef fishes made use of a rather narrow suite of species. Species that were used were small, easily caught, site attached, and reasonably abundant. As a consequence we know a lot about the commonest damselfishes, somewhat less about the most abundant parrotfishes, wrasses, and butterfly fishes, and next to nothing about the great range of species that each account for less than 1% of all individuals present in a site. A focus on common, small, easily caught species has permitted a strongly experimental approach in reef fish ecology, that has challenged several widely held paradigms of ecology (Sale, 1988). Our understanding however may not scale up easily to larger, rarer species (see the next section).

Although damselfishes are attractive animals with which to work, and will continue to yield important ecological insights, they cannot be representative of all reef fish species. It is important that recent attempts to work with logistically more difficult
groups continue. The demographic differences among species are particularly important in determining the spatial and temporal scales at which all individual species live out their lives, and we need a reasonable representation of “types” in our body of ecological data.

The pelagic larval phase and the patchy reef environment ensure that reef fish populations function as open systems of separate subpopulations interconnected by the recruitment of juveniles. However, perhaps the major unanswered ecological question at the present time is how open this population is. In the 1970s and early 1980s, when the prevailing ecological paradigm was one of closed populations, we emphasized the dispersive abilities of pelagic larvae. There was abundant evidence that fishes spawned in ways that facilitated export of larvae to open ocean (Johannes, 1978; Silvano et al., 2006). Larval lives were of substantial duration, and larvae were specialized morphologically, and in other ways, for pelagic existence (Leis, 2006).

During the 1990s, it became apparent that reef fish populations are less than totally open, and two empirical studies showed the “self-recruitment” of reef fish populations (Jones et al., 1999) by demonstrating that a substantial portion of larvae produced appears to be retained within an area measured in tens to hundreds of square kilometres. This area remains large enough to contain a substantial number of local populations of the species concerned (a damselfishes and a wrasse, respectively), and it is important that in emphasizing this evidence of control of dispersal, we do not fall into the trap of claiming that larval reef fishes do not disperse. The extent of larval disperse appears to be much less than the early enthusiasm suggested, but reef fish populations are still open.

At present, we do not know the magnitude of the interconnection among local populations on any spatial scale, and are unable to assess whether it is such that these groups of populations will function as metapopulations. At one extreme (low levels of dispersal among populations), the separate populations will function almost independently. At the other extreme (higher rates of dispersal among populations),
they may be so well interconnected that they will function as a single, if subdivided, population. Only at intermediate levels of dispersal will they operate as a metapopulation with the special dynamics that characteristically buffer such systems from both local and global extinction (Hanski, 2008). Because we have focused study of most reef fish species within the structurally complex reef environment, we are largely ignorant of the ecology of populations living in other habitats, the relative magnitude of reef and nearby non-reef populations, and the role, if any, of non-reef populations in sustaining populations on reefs. A full comprehension on the dynamics of reef fish populations will require far better information that now we possess on fish in non-reef habitats. There is need for much more research on coral reef ecology and it will need to be appropriately funded.

Rarity in Coral Reef Communities

One of the greatest challenges in ecology is to explain the inequality of abundance of taxonomic groups, and, in fact, why a majority of the species is any ecosystems are relatively rare (Gaston, 1998). Unfortunately, rare species are rarely studied, so relatively little information is available on the processes constraining their distributions or limiting their numbers (Kunin and Gunston 1993; Mora and Robertson, 2008). Although the ecological processes influencing rare species may not be fundamentally different from those affecting common species, this cannot be assumed. Direct comparisons of the ecology and life histories of common and rare species, in a range of different taxa, are only now beginning to reveal the essential causes of rarity (Gaston, 1998).

Many factors may explain why the issue of rarity has been avoided by marine ecologists. The taxonomic status of rare species in many marine taxa is uncertain (Ray and Grassle, 1991; Sheppard, 2006). It is always difficult to sample rare species
and this may be particularly true in aquatic environments. Published accounts of the geographic distributions of rare species may not be detected by the sampling method. Estimates of the abundances of rare species are almost always unreliable, because typical sample unit sizes and replications are usually appropriate only for common species (Andrew and Mapstone, 1987; Richard et al., 2007). However, there is no fundamental reason why studies on rare marine species cannot make a major contribution to our general understanding of the phenomenon of rarity.

Furthermore, we cannot assume that the processes leading to rarity in terrestrial organisms apply to their marine counterparts. The prevalence of species with dispersive larval stages and consequently an “open” population structure may require new explanations of rarity. Therefore, comprehensive studies of marine taxa are necessary before a general synthesis of this fundamental ecological issue can be attained.

Reef fishes exhibit the highest diversity of all the vertebrates’ communities on Earth and are therefore likely to contain a greater number of rare species as compared to their terrestrial counterparts. Among marine organisms, the taxonomic status and patterns of distribution and abundance of coral reef fishes are among the best known. Also, there is sufficient published information available to examine the patterns and potential causes of rarity in a number of reef fish families.

What is a Rare Species?

It is now widely accepted that there are two fundamental elements to rarity: low abundances and restricted geographic range (Harper, 1981; Gaston, 1998). Under these two definitions, patterns of rarity in coral reef fishes remain uncertain. Although there are many examples of reef fish species living in highly specialized habitats (e.g. anemone fishes, Amhiprion; coral gobies, Gobiodon), many of these
would not be considered rare. One can find examples of coral reef fishes with extremely small geographic ranges (e.g. the Banggai Island cardinal fish, *Pterapogon Kauderni*, restricted to a few small islands in the Indonesian archipelago (Allen, 2000), but much larger ranges are certainly the norm (McAllister, 1991). It may well be that coral reef fish are most often rare in terms of low local abundance, but patterns of abundances throughout a species’ geographic range have generally not been described. The possibility that all species are common somewhere in their range is an attractive notion, but establishing whether this is true could be a daunting task. To date there has been no comprehensive analysis of patterns in range size, abundance, and habitat specificity for any groups of coral reef fishes. Species conforming to such a pattern are subject to a “double jeopardy”, because either their restricted distribution or low abundance may increase their extinction risks (Gaston, 1998). Among terrestrial animals it is common to find a positive relationship between geographic range and population density, suggesting that these parameters could be linked by a common cause (Carrete *et al.*, 2007).

Therefore, although low abundance and restricted geographic range are two forms of rarity, they cannot a priori be assumed to be independent. To date, the relationship between range size and abundance for coral reef fishes remains unexplored. However, it may be useful in some situations to delineate rare from common. For example, it may be useful for pragmatic reasons to employ a rarity cut off when dealing with conservation issues or when unique qualities of rare species are to be emphasized.

Coral are invertebrates, and, therefore, a listing determination must be based on the species’ status throughout all or a significant portion of its range. The only information regarding the discreteness or distinctiveness of elkhorn coral (*Acropora palmata*) is a recent study that examined genetic exchange and clonal population structure in *A. palmata* by sampling and genotyping colonies from eleven locations in
the Caribbean area throughout its geographic range using microsatellite markers (NOAA, 2005).

Results indicate that populations in the eastern Caribbean have experienced genetic exchange with populations in western Caribbean. Within these regions, the degree of larval exchange appears to be asymmetrical with some locations being entirely self-recruiting and some receiving immigrants from other locations within the region. These results do not indicate source or sink areas, populations that are discrete or distinct, or any other specific geographic areas within the Caribbean Sea that should be considered more or less significant than another. Because there is no evidence indicating that any elkhorn population within the geographic range of the species is more or less important than others, they considered the entire geographic range in determining the status of these species (NOAA, 2005).

What Causes Rarity?

A large number of factors have been implicated as causes of rarity in terrestrial environments, both in terms of geographic range and abundance, but no one factor predominates among studies. Because the evidence for causes of rarity comes mainly from interspecific comparisons, our understanding in this area is based almost entirely on correlative information. Yet, many of the same trends emerge within and among a range of unrelated taxa, suggesting in some cases a common underlying cause. Body size in animals, for example, is frequently negatively correlated with abundance (Currie, 1993).

Even when the relationship is not clear-cut, large species tend to be rare, but small species can exhibit a range of densities. Range size appears to be an increasing function of body size, with large species nearly always within a large range (Brown
and Nicoletto, 1991). Again, small species can exhibit great variability in range size and it may be that body size just sets the possible minimum range size (McCoy and Mushinsky, 2007). Given that local abundance is positively correlated with range size, some of these patterns seem contradictory and worthy of more detailed analysis.

A number of other life history and ecological characteristics also correlate with rarity. Species with asexual reproduction, lower reproductive effort, and poor dispersal ability are often rare (Eriksson, 2008). Other ecological factors that correlate with rarity include specialized habitat requirements, resources availability, and a poor ability to establish in new areas and marginal habitats. The sheer range of correlated factors that may or may not be direct causes of rarity suggests that distinguishing among them will take considerable time and ingenuity.

The factors correlating with rarity are only just beginning to be examined for marine organisms (Hawkins et al., 1999). At this stage we can only speculate on their relative importance in marine environments. Although we are unable at this point to predict how rarity may be related in general sense to any of the variables previously identified for terrestrial organisms, many groups of marine animals and their terrestrial counterparts exhibit variation in the same parameters.

For example, differences in body size of several orders of magnitude are exhibited by some marine taxa, but body size - abundance-range relationships in those groups have not been widely addressed. A few studies confirm patterns for terrestrial species. For example, Marquet et al., (1990) found that population densities in rocky intertidal communities were inversely correlated with body size, and Reaka-Kudla (1997) found range size to be an increasing function of body size in coral-dwelling mantis shrimps. Caley and Munday, (2003) showed that coral reef fish abundance was only loosely related to body size, with large species seldom being very abundant.
In terms of environmental constraints, species associated with small seas separated by land barriers and species associated with islands that are isolated by great distances in oceanic areas may exhibit a tendency to have small geographic ranges, but this has not been examined. Depth ranges of some marine organisms appear to increase for deeper water species (Stevens, 2006), which may predispose them toward larger geographic ranges. Marine species with high fecundity and dispersing larvae often occupy greater geographic ranges compared to species with direct development. Marine organisms vary in the length of their larval life, but this has not been correlated with patterns of numerical commonness and rarity (Thresher, 1991; Benkendoff and Przeslawski, 2008). It has also been suggested that ecological processes such as habitat or dietary selection and predation pressure cause rarity. Clearly, for marine organisms there is a long overdue need to examine the strength of associations between rarity and this range of potentially important characteristics, both in terms of abundance and geographic range.

The factors correlating with rarity on corals were examined very recently in the Caribbean Sea by the Centre for Biological Diversity in Florida (2007). It lists 4 factors that cause reduction of abundance and rarity in coral reef communities. I briefly summarise these.

- **The Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range**

Seven stressors (natural abrasion and breakage, anthropogenic abrasion, sedimentation, persistent elevated temperature, competition, excessive nutrients and sea level rise) were identified as threats affecting both species through present or threatened destruction, modification, or curtailment of their habitats or ranges. This consists of both destruction or disruption of substrate to grow on, and modification or alteration of the aquatic environment in which the coral live. Although habitat loss has occurred, to date, the range of these two species has been reduced. However,
because of the species’ extremely low abundance, local extirpations are possible in the foreseeable future, leading to a reduction in range. Elkhorn and staghorn corals, like most corals, require hard, consolidated substrate (i.e., attached, dead coral skeleton) for their larvae settle or fragments to reattach. When the substrate is physically disturbed, and when the attached corals are broken and reduced to unstable rubble or sediment, settlement and reattachment habitat is lost. These kinds of coral also appear to be particularly sensitive to shading effects resulting from increased sediments in the water column. Because these corals are almost entirely dependent upon sunlight for nourishment, they are much more susceptible to increases in water turbidity and sedimentation than other species. Optimal water temperature for elkhorn and staghorn coral range from 25 to 29° C, with the species being able to tolerate higher temperatures for a brief period of time. Global atmospheric air and sea temperatures have been documented as rising over the past century, and shallow reef habitats are especially vulnerable. Water with sea surface temperatures above the optimal range does not provide suitable habitat for either of two species.

• Disease or Predation

Disease was identified as the single largest cause of coral mortality and decline. It is also the greatest threat to the two species’ persistence and recovery given its widespread, episodic, and unpredictable occurrence resulting in high mortality. The threat is exacerbated by the fact that disease, though clearly severe, is poorly understood in terms of etiology and possible links to anthropogenic stressors. Although the number or identity of specific disease conditions affecting Atlantic corals and the casual factors involved are uncertain, several generalizations are evident.
• **Inadequacy of Existing Regulatory Mechanisms**

Most existing regulatory mechanisms (not only in the Atlantic Ocean, but also in many other South Pacific States) are not specific to elkhorn and staghorn corals, but were promulgated to manage corals or corals reef in general. While the impact of many stressors were determined to be slightly reduced with the implementation of regulations, none were totally abated. In many cases, corals are incidentally destroyed during fishing practices, and therefore, the regulation does not fully abate the threat from damaging fishing practices. The major threats to these species’ persistence are severe, unpredictable, and have increased over the past 3 decades. At current levels of knowledge, the threats are unmanageable, and there is no apparent indication that trends will change in the future. The only way to avoid the kind of accidents are the establishment of Sanctuary zones.

• **Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes**

Only one stressor under this section was identified as a potential threat to elkhorn and staghorn corals: over-harvest for curio/aquarium demand. Over-utilization does appear to be a significant threat to either of these two species given current regulation and management in Caribbean Sea. In Florida identified by the Centre for Biological Diversity, all of the above factors are associated with human presence and activities. Similarly, we’ve seen the gradual death to coral life on the Great Barrier Reef (Pandolfi et al., 2003). Ningaloo Reef is even closer and more accessible and thus far more vulnerable to human impacts. While there is considerable information on the status of the Great Barrier Reef, there are still gaps for some significant parts of the Australian coastline, such as Ningaloo Reef. For these reasons we pay particular attention is paid to the concept of abundance reduction and species rarity as they relate to this fragile fringing reef. The Ningaloo Reef front receives the full force of swells from the Indian Ocean, so corals tend to be compact, although cover may reach 40%. Coral cover behind the reef crest and in channels varies from 5-40% with
an increase in coral cover to the south. Outbreaks of a coral-eating snail (Drupella) killed much of the coral in some areas in the 1970s and 1990s, and other areas have been damaged by low oxygen conditions when coral spawn decomposes (Maniwavie et al., 2000). Now, new corals are recruiting and restoration of coral cover is progressing, but many areas are still dominated by dead coral and rubble. A broad-scale monitoring program has recently been established. The conservation of biodiversity at Ningaloo Reef requires careful protection from human activities in order to allow for the complex ecological relationships to be maintained.

**Stock-Recruitment Relationships on Coral Reefs**

The relationship between the stock of a marine population and the level of recruitment to that stock has always been recognized as one of the aspects most difficult to investigate, but most important, in the management of that population (Kellner et al., 2008). It is one of the keystone concepts of fishery science, since the parameters for this function translate directly into management reference points and set the ultimate limits on sustainable fishing (Quinn and Deriso 1999, Bravington et al 2000). However, it is also one of the most problematic: data are difficult to measure and generally noisy, the relationship is surely non-linear over a range of stock sizes, and a variety of plausible biological mechanisms are consistent with very different functional relationships between spawning stock and recruitment. There is, of course, general agreement about the properties a stock-recruitment model should possess. First, any extant stock must be able to replace itself, so that recruitment should be greater than stock size over some range of stock sizes. Second, we expect there to be density dependence; recruitment may be nearly proportional to stock close to the origin but per capita recruitment is expected to decrease at large stock sizes. Third, for closed populations, recruitment should tend to zero as stock
goes to zero, passing through the origin (Munch, 2005). However, the spatial scale on which the population is closed is often unclear. Many models may be derived from this set of principles and the data are frequently insufficient to distinguish among them. Consequently, selection of a parametric model is often rather arbitrary. Over the last decade, parametric Bayesian approaches have been increasingly applied in fisheries (McAllister and Kirkwood 1998, Millar 2002). One of the great advantages of the Bayesian approach is that it allows a statement of model probability to be made in cases where there is no a priori biological basis for model selection. However, this approach will not work if the appropriate model is not included in the set of candidates. Moreover, even if the model is appropriately specified, important management parameters such as the slope at the origin, may be unduly influenced by points far away (Ludwig, 1995). Consequently, several authors have proposed non-parametric approaches. Brodziak et al. (2002) divide the stock-recruitment plane into several regions and estimate transition probabilities among them from the observed time series. Non-parametric density estimators have also been used to construct the distribution of recruitment given stock biomass. Non-parametric regression and spline methods that fit some locally weighted smoothing function to the stock-recruit data have also been used.

The chief benefit of these non-parametric approaches is that they allow the data to speak for themselves. This is a highly desirable property, once we recognize that the available biological information is typically insufficient to specify a functional form a priori. (Rideout and Morgan, 2007). However, there are several drawbacks to existing methods. First, they all require the ad hoc specification of a smoothing parameter. Although cross-validation methods may be used to circumvent this problem to some extent, they do not perform well on the relatively small data sets available in fisheries. Second, uncertainty bounds for estimates from these methods rely heavily on asymptotics; given the relatively small samples available in fisheries, these uncertainty bounds will be unreliable (Needle, 2004). Third, these methods lack
biological underpinnings and this makes results hard to interpret and sometimes biologically unreasonable. Bravington et al. (2000) have made some progress in this regard by developing a smoother that is forced to pass through the origin and producing diminishing gains in recruits as spawning stock size increases. Although elegantly incorporated, these biological constraints are by no means certainties and the inclusion of hard constraints is at odds with the nonparametric philosophy of letting the data speak for themselves. Despite these modelling attempts, we still lack a method that allows prior information about the biology of the stock to be incorporated while simultaneously allowing the data to determine the overall shape of the fitted relationship. This is another aspect of coral reefs that requires serious investigation.

**Coral Reef Community Dynamics: Competition versus Abundance**

Another fundamental goal in ecology is understanding the processes that influence the composition of ecological communities. A key factor influencing community structure is the relative abundance of juveniles entering the community. In relatively closed communities, most incoming juveniles are a product of reproduction within the community, and thus the relative abundance of incoming juveniles is directly related to the current structure of the community. In contrast, relatively open communities (e.g., most marine communities, as well as plant and insect communities) have also outside sources for most incoming juveniles (Connolly and Roughgarden 1999, Knowlton and Jackson 2001). Because juvenile supply is often spatially and temporally unpredictable in open systems, there is commonly little relationship between the relative abundance of incoming juveniles and the current structure of the community (Almany, 2003).

As a result, the initial composition of open communities is partially determined by
stochastic juvenile supply. However, once juveniles have entered the community, a variety of others factor influence their persistence. Understanding how such factors affect the persistence of colonizing juveniles could provide insight into the mechanisms that influence the structure of open communities (Almany, 2003).

Assemblages of coral reef fishes are classic examples of open communities. Like most marine species, reef fishes produce planktonic larvae that spend weeks to months in the pelagic environment (Victor, 1991). Larvae disperse from their natal reefs in oceanic currents, although recent studies provide evidence that some larvae are locally retained at the scale of oceanic islands (Swearer et al., 1999). Larvae typically make a nocturnal transition from the plankton to reef or near-reef habitats, a process called “settlement” (White, 2008). After settlement, counted juveniles are called “recruits,” and the net process of settlement minus subsequent mortality until census is called “recruitment.”

One factor that may have a strong influence on juvenile persistence is the types of organisms already present in the community. Interactions between newly arrived juveniles and established residents may affect juvenile survival in a species-specific manner, and thus can alter initial patterns of abundance generated by juvenile supply. For example, residents may consume or compete with incoming juveniles, thereby preventing or inhibiting their establishment in the community. These “priority effects,” in which established individuals affect those that arrive later, are a common feature of ecological communities and have been documented in coral reef fishes (Steele, 1997), and amphibians (Lawler and Morin, 1993). Determining how species-specific priority effects influence juvenile persistence may prove useful in understanding temporal changes in community composition (Guidetti, 2007).

A much debated issue concerns the extent to which patterns of relative abundance at settlement are reflected in recruitment and later community structure (Hixon, 1991). Since population densities of predators and conspecifics typically vary in space and time, it is not surprising that their effects do too (Fairweather et al., 1984; Vincent et
In particular, there can be strong seasonal variation in the effects of predators and competitors (Beal et al. 2001), but how such seasonal variation influences the relative importance of the two processes is poorly known. For example, it is not known whether the two processes typically covary, such that competition is intense when predatory effects are intense, or whether the intensity of each process varies independently (Steele, 1998).

In a recent research, Steele and Forrester (2005) found that predators reduced the growth of blackeye gobies during much of their study. Prey often grew more slowly in the presence of predators in other systems, but few studies have explored this phenomenon in marine animals. The few published studies that have tested for predator-induced reductions in growth of marine animals have found them (Nakaoka, 2000). Furthermore, marine animals are well known to alter their foraging behaviour in response to predators (Steele, 1998), so they suspect that sublethal effects of predators on prey growth may be widespread in marine systems. Certainly, such effects merit greater attention in marine systems than they have received to date.

In conclusion, there are wide gaps in our knowledge about coral reef ecology and more research is needed to build up the scientific knowledge that can allow better protection and conservation of coral reef biodiversity. Notwithstanding this, coral reef are experiencing already significant negative impacts caused by climate change and human activities. In fact, it is not an overexaggeration to state that they are in crisis.
Appendix III Marine Ecology

Introduction

Ecology is a holistic science that seeks a broad understanding of the relationships among organisms, their environment, and, increasingly, humans. Though the science of ecology has its own specialties, ecologists must remain well versed in methods, goals, and knowledge accumulated in other fields. In the past decade or so, rapid developments in instrumentations, techniques and analytical approaches, and in general knowledge in fields as remote as molecular biology and physical oceanography have made keeping up with progress in these allied fields ever more difficult (Bellwood and Hughes, 2001). Yet, more than ever, the challenges facing ecologists can be answered only by using the knowledge gained by workers in other fields, and building collaborations that go beyond the boundaries of ecology (Sale and Tolimieri, 2000).

What information do we need in order to tackle current problems to do with biodiversity, chiefly its dramatic loss? What basic knowledge do we have and how can we assemble different aspects of this knowledge to gain new insights? Where is there a lack of perhaps even very basic data?

These questions provide the background for the identification of gaps and deficits in current biodiversity research. Collaboration should be strengthened in the following areas and between the following levels: different systematic and taxonomic areas, taxonomy and molecular systematic, organism interactions and species distributions, observation, theory and experiment, ecosystem ecology and population biology and ecology and human welfare, ecology and environmental economics (Sale and Kritzer, 2004).
Knowledge regarding interactions between different levels of organization, for instance, interactions between genetic and species levels or between population and ecosystem levels, is often lacking. So far, these processes have only been investigated in very specific individual cases.

Generally, these areas can be categorized according to the following criteria: levels of organization (genes, species, populations, ecosystems), types of research disciplines (natural, human and social sciences), types of research instruments (observation, theory, experiment), levels of classification of organisms (taxonomic and functional units), types of interventions (environmental management, unintentional human impacts, natural disturbances) and types of importance to humanity (welfare, risk, health, food supply etc.) (Hixon, 1998).

Interactions within these categories as well as among different categories deserve more attention in biodiversity research. However, not all possible combinations among the categories can be addressed.

Another major gap in knowledge concerns the impact of different types of interventions on ecosystems and their functioning. One challenge will be to integrate real impact scenarios into research projects, in order to gain knowledge more directly applicable in practice. For instance, harvesting practices concentrated towards large fish can lead to evolutionary shifts within species and subsequent shifts in species composition (Grafton et al., 2004).

These changes may bias an ecological community in a different way from that simulated in experiments with random extinction events and may negatively affect future harvesting potential. Establishing strict nature reserves where no harvesting takes place may be an answer to this problem, but we do not know this for certain and we do not know what size such reserves should be (Sale and Tolimeri, 2000).

Combining recent molecular methods with traditional taxonomic and systematic methods may result in new fundamental knowledge regarding the relationships and evolutionary aspects of organisms and may thus serve as a base for further research.
topics. Recent research approaches in the field of biodiversity and environmental issues unite experts from different disciplines, in order to tackle complex problems that concern environment and society in an inseparable way. Concepts of integrand transdisciplinarity have been developed, with a variety of experts and stakeholders involved in the whole research process.

Similarly, basic research into ecosystem services can help justify and put real price tags on compensation areas in managed terrestrial landscapes. This requires close collaboration with economists, managers, and politicians. These considerations will be useful to better understand the important ecological and environmental biological diversity and rare species habitat of Ningaloo Reef.

**Ecology and Management**

Here I discuss in turn each of the three reasons for the lack of representation of ecologists at the management table:

- Ecologists have tended to explore questions using convenient species and systems rather than those that are economically important.
- Academic ecologists until recently actively avoided “applied” questions in favour of “pure” research.
- Ecology is not a profession with membership limited to those accredited by national or international bodies that certify qualifications.

**Use of Economically Less Important Species**

Academic ecologists for many years have explored questions using systems that were convenient rather than economically important. The ecology of 1960s was
developed through work on songbirds, small mammals, insects (butterflies as open as pest species), intertidal invertebrates, the fishes of ponds and streams and herbaceous plants. True, there were ecologists working on big game, on commercial fisheries, on crop plants, and on insect pests. However to a very large degree, these individuals were not the ones who developed the underlying principles that drove ecology. There are two reasons for this (Sale and Kritzer, 2004).

First, working with many of the economically important organisms is difficult. When working with game mammals, it is not easy to replicate well, or even to do field experiments, and a great portion of work about these larger organisms has been descriptive. This difficulty of replications and experimental design shows up even in studies of small rodents (hardly game mammals), which have turned out to be quite mobile and difficult to manipulate. Methodologies using large cages (e.g. 250m$^2$) of sophisticated design have been required (Valone and Brown, 1996) in studies spanning several years, simply to explore competitive interactions. Ecologists wishing to work on commercial fishery species have been drawn to fishery management agencies, and to a strong interdependence with the fishery simply for access to data on the fish populations.

Fishery-independent sampling is expensive, and opportunities to manipulate the fishery in order to run field experiments have been rare. It is far easier to do innovative work with guppies, sticklebacks, or host of other small species.

The consequences is that not enough good science has been done on economically important species, and also that the science has tended to move in directions compatible with the logistic constraints, and to address features specific to particular species of populations, rather than to tackle general ecological questions.

Second, many of the ecologists who worked on the more “important” species have been directly employed by management agencies. Their freedom to explore new ideas has been constrained by the need to do the work the agencies had a legal responsibility to do, and to a considerable degree they have worked in an
environment that is pragmatic, and problem solving, rather than one that encourages the building of general scientific principles (Sale and Tolimeri, 2000).

Carer advancement has derived from solving particular problems, rather than from publishing these solutions in high-profile journals, and extensive “gray” literatures have been developed and used (Sale, 1998).

This has further isolated many agency ecologists from the academic ecologists who published their exciting, but often esoteric, new ideas about economically quite unimportant organisms in the peer-review literature.

_Active Disinterest in “Applied” Questions_

Ecology did not evolve as a practical science (Lubchenco et al., 1991). There has been a long period of active disinterest by the academic ecological community in “applied” questions. Ecologists frequently prided themselves on working on systems that were not economically important, or on systems largely unimpacted by human activities (Doak and Mills, 1994). Indeed, human impact was seen frequently as an “un-natural” disturbance making a system less suitable for ecological study. In academic institutions, well into the 1970s, work that was ecologically relevant was often disparaged. It was “applied” rather than “basic”. Now, with human impacts substantially greater and more widespread, it is difficult to find “unimpacted” systems, and academic ecologists seem much interested in the systems that our species are impacting severely. This is a recent development, and the major advances in ecological understanding over the past 100 years have come about because of work on economically less important organisms.
Lack of Professional Status for Ecologists

Ecologists do not wear rings or insignia, and are not licensed or certified (until recently and only on application). Anyone who seems to be “interested in” natural systems can identify as an ecologist, and in many people’s minds, an individual who practices the science of ecology is not different from one who espouses a conservationists ethic. The distinction between ecologists and conservationists has not been clear to the public (Sale, 1998).

Although ecologists have busily been avoiding research that would have ensured we sat at the table where management goals, policies, and practices were developed, the conservationists have been eager to take places there.

The conservationist ethic is not science, despite having many scientific elements. It is an ethical perspective on the world and our place in it. Although most conservationists have sought ecological evidence to support their arguments, and while many have formal ecological training, there are necessarily delays between discovery and dissemination, and ecological concepts have been evolving rapidly. Conservationists should not be expected to provide a sound ecological basis for management action in addition to providing their important ethical perspective.

To get back to the management table, the ecologists need to demonstrate that their science can help improve management, and they need to become better informed about the management process and the other kinds of expertise that contribute to it. Also, despite progress in our ecological understanding, management decisions are based on a combination of factors, economic considerations being quite significant among them.
Holism and Reductionism in Ecology

Ecologists often discuss what should be the ‘fundamental’ unit of ecological research and what research strategy should therefore be followed. This is mostly described as a dispute between a holistic school of primarily systems ecologists and a reductionistic school of primarily population ecologists (Simberloff, 1980; McIntosh 1985; Hagen 1989; Cabin, 2007). The former argue that the ‘functional’ level of organization in ecology is formed by ecosystems and that research should therefore be holistic and directed at these systems. The latter, who take modern evolutionary theory as a starting point, argue that populations should be the fundamental units of ecological research. The question thereby is not so much whether systems ecology can be reduced to population ecology, but rather whether there is any use at all in doing systems ecology (and community ecology) besides population ecology (Looijen, 1998).

Reductionism seeks to understand phenomena by "reducing" them to their parts, essentially looking for explanation at the lowest scales of organization. This is the traditional approach of Western science, and it has lead to some breathtakingly impressive explanations for numerous phenomena. Physics and chemistry are largely reductionist sciences, and reductionism is generally the main approach in molecular and cell biology. The alternative scientific approach has traditionally been called holistic science, a term which suggests the idea that "the whole is larger than the sum of its parts." Holistic science looks for explanation at the same or larger scale than the phenomenon in question (Orland, 2004).

Unfortunately the term "holistic" is also used by many by non-scientists to indicate all kinds of "fuzzy" thinking and pursuits that have very little to do with the highly technical scientific search for principles of causality from higher organizational scales. Scientific understanding of holistic causality and emergent phenomena is a new approach in contrast to reductionism, and as such is not as well-developed as a
method (Fryxell et al., 1999). The cutting edge of theoretical research in this area can be quite complex and quantitative, involving teams of mathematicians and scientists and large computing facilities, very remote from the birds singing in mountain forests, or fish swimming (Orland, 2004).

Holistic scientific explanations are particularly important to include in ecology because ecological systems provide the larger scale context in which many biological processes occur, and hence serve as the basis for the holistic explanations of many phenomena at organismal and lower scales. In addition, emergent phenomena, which arise from complex high-order interactions among organisms, likely are quite important within ecological systems. Thus the structure observed in discrete assemblage of animals is the result of interactions (predation, competition, disease, symbiosis) among them on both long-term (evolutionary) and short-term (ecological) scales. The emergent property often is an apparently stable (persistent through time) community in which each member has a distinct niche with little overlap with other community members. In California streams, for example, two small fishes that live in fast water, speckled dace and riffle sculpin, live in different parts of the stream and feed on different invertebrates. When sculpins are removed, however, the dace take over the places where sculpin lived previously and develop a broader diet. They are constrained by the aggressive behaviour of sculpin who drive them away from the prime habitat. The pattern of segregation, however, is predominant in most streams (Orland, 2004).

It is important to emphasize again that both reductionist and holistic explanations are important to biology and ecology because the causes of scientific phenomena can occur at both smaller and larger scales. The degree to which either holism or reductionism is sufficient to explain something may be dependent upon the system in question, and for some questions reductionism may be all that is needed.
However, if we want to reserve the health of the marine and coastal ecology at Ningaloo Reef we need to be able to holistically grasp its importance for current and future generations.