Marine and Tropical Sciences Research Facility

Assessing the socio-economic implications of climate change (coral bleaching) in the Great Barrier Reef catchment

Synthesis Report

R. L. Miles, S. Kinnear, C. Marshal, G. O'Dea and L. Greer

Australian Government

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CQUniversity AUSTRALIA

Reef & Rainforest RESEARCH CENTRE

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Project 2.5i.4 Tools to support resilience-based management in the face of climate change

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The Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) supports world-class, public good research. The MTSRF is a major initiative of the Australian Government, designed to ensure that Australia's environmental challenges are addressed in an innovative, collaborative and sustainable way. The MTSRF investment is managed by the Department of the Environment, Water, Heritage and the Arts (DEWHA), and is supplemented by substantial cash and in-kind investments from research providers and interested third parties. The Reef and Rainforest Research Centre Limited (RRRC) is contracted by DEWHA to provide program management and communications services for the MTSRF.

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Reef & Rainforest
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We also thank Karen Chapman and Kylie James for assistance in project work and report editing.

Acronyms Used In This Report

ABARE.......... Australian Bureau of Agriculture and Resource Economics
AIMS .... Australian Institute of Marine Science
ABS............... Australian Bureau of Statistics
ACG .... Association for Corporate Growth
AGO .... Australian Greenhouse Office
ANZSCO .... Australian and New Zealand Standard Classification of Occupations
ANZSIC .... Australian and New Zealand Standard Industrial Classification
BMP .... Best Management Practice
BOM .... Bureau of Meteorology
CBA .... Cost Benefit Analysis
CM................. Choice Modelling
CSIRO .... Commonwealth Scientific and Industrial Research Organisation
CVM .... Contingent Valuation Methodology
CQU .... Central Queensland University
ENSO .... El Niño Southern Oscillation
EoP .... Effect(s) on Production
FTE................ Full-time equivalent
GBR .... Great Barrier Reef
GBRMP .... Great Barrier Reef Marine Park
GBRMPA ...... Great Barrier Reef Marine Park Authority
GCC .... Global Climate Change
GRP............... Gross Regional Product
GVP............... Gross Value Product
IPCC.............. Intergovernmental Panel on Climate Change
LGA(s) .... Local Government Area(s)
MTSRF .... Marine and Tropical Sciences Research Facility
NFI................. Net Factor Income
ISRD.............. Institute for Sustainable Regional Development
NRM .... Natural Resource Management
NRW.............. Queensland Department of Natural Resources and Water
OESR .... Office of Economic and Statistical Research
PIFU .... Population Information Forecasting Unit, Queensland Department of Local Government, Planning, Sport and Recreation
QPWS .... Queensland Parks and Wildlife Service
RC .... Replacement Cost
RWQPP......... Reef Water Quality Protection Plan
SOI .... Southern Oscillation Index
SP.................. Stated Preference
SST .... Sea Surface Temperature(s)
TC.................. Travel Cost
TEV .... Total Economic Value
US .... United States (of America)
UVB............... Ultraviolet light category (b)
WTP .... Willingness to Pay

Executive Summary

This report provides an integrated assessment of the potential socio-economic impacts of climate change (specifically coral bleaching) on the Great Barrier Reef (GBR) in Queensland, Australia. It covers three research phases, these being:

1. A literature review of:
   - Published research on the known and anticipated biological and productivity changes on coral reefs due to climate change;
   - The projected impacts of climate change on the GBR, specifically; and
   - An analysis of socioeconomic impact assessment methods that could potentially be applied to assess the climate change impacts (coral bleaching) on the GBR.
2. A socio-economic characterisation for three regions in the GBR catchment (Cairns, Townsville and Mackay-Whitsunday); and
3. The results of focus group workshops (with regional planners and local government), together with a business survey and with detailed phone interviews (for businesses in target regions). These aimed to assess the socioeconomic implications of climate change on the GBR.

The work presented in this report sought to answer three key questions:

- What is the current knowledge of and likely impacts from climate change on reef based communities? (via the literature review);
- How are communities currently placed with respect to potential risk and response? (via the socio-economic characterisation); and
- What are the perceived threats to communities and businesses and what are current stakeholder attitudes to risk and response to climate change? (via business surveys and focus groups).

The literature review highlighted wide gaps in published information about the impact of climate change (and subsequent changes in reef productivity) on reef-based ecosystems. This information is fundamental to assessing the socio-economic impacts of climate change at a regional level. The literature review also examined economic tools that have been used (or have the potential to be used) to assess the value of the coral reefs, particularly in the GBR region. Each tool was evaluated and the relative strengths, suitability, potential application and limitations were discussed. The analysis indicated that whilst a wide range of assessment tools are available, no single statistical or modelling technique appears suitable for this type of impact assessment.

The socio-economic characterisation of the target regions in the GBR provided information regarding the vulnerability of each area with regard to social and economic factors. Particular emphasis was placed on economic factors and sub-regional areas that are more reliant on the reef. It was concluded that Cairns region can be viewed as the most predisposed to climate change impacts, followed by the Mackay-Whitsundays and then Townsville.

The survey and focus group findings showed that businesses operating in the GBR region have a limited interest in, and/or awareness of, climate change. Subsequently, little or no action has been taken to address potential impacts. Possibly this is because business operators (in a general sense), do not necessarily reflect or consider the importance of underpinning economic, social and infrastructure prerequisites for their business to operate. Instead, operators tend to focus only on immediate factors likely to achieve the results for

their business. By comparison, local governments in the region are actively interested in climate change adaptation, but lack a detailed knowledge of their risks and exposure: this has resulted in there being no clear pathway forward to address climate change implications for business. This is of concern, since local governments are important stakeholders in assessing the socio-economic implications of climate change, given their focus on planning for infrastructure provision and services that support business and the wider community.

The surveys and follow-up telephone interviews also revealed considerable limitations in the knowledge and quality of climate change information that could be extracted from business operators. This directly results from a general lack of specific understanding of, and interest in, climate change impacts on the GBR. It was also evident that a gap exists in businesses understanding of the difference between 'mitigating' and 'adapting to' climate change. Unfortunately, this lack of knowledge somewhat limits the regional-level economic impact assessment that can be performed, since quantitative risk assessments for economic impacts (based on responses offered by business operators) may be unreliable.

Given the existing uncertainty surrounding regional-level climate change impacts, there was little scope to gather definitive answers to the question, 'How will climate impact on business?' Nevertheless, an indication of the likely responses of business operators was obtained by presenting them with the 'What if?' scenario:

> *If your business suffered a downturn in demand of 10%, 25% or 50% as a result of climate change impacts, what would this mean to your business?*

For each percentage level, respondents were asked to indicate whether they could absorb the downturn, would need to reduce staff, would look for alternative markets, would look for alternative products or close their business. None of the operators surveyed indicated that they would need to close as a result of a 10% downturn; and only 40% indicated that they would be likely to close in response to a 50% downturn. Instead, the preferred options to respond to a 25-50% demand downturn were reducing staff and diversifying by seeking alternative markets and/or products. This indicates that business owners believe they have the capacity to respond to changed conditions, once they have some sense of what those conditions are likely to be. The final step in the interview phase was to determine the future for business in the GBR region. Looking forward, half of the interviewed business operators could see opportunities resulting from climate change: while plans to take up these opportunities were generally not highly developed. This indicates operators are optimistic about their capacity to respond to the challenges of climate change.

This research forms one component of a larger research program funded by the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF). This 'parent' program is directed toward developing tools to support resilience-based management, as well as contributing to an atlas of climate change risk and resilience for the socio-economic and ecological systems of the GBR. Thus, the next stage of this work will be to synthesise the findings from this component with those from research projects carried out by the CSIRO and Australian Institute of Marine Science (AIMS) under the parent program. This will contribute toward the building a Bayesian Belief Network model and provide for the subsequent development and prioritisation of management responses to climate change, and ultimately, the creation of an atlas of climate change risk and resilience for the GBR social-ecological system.

1. Introduction and Review of Literature

1.1 Project background

The research was commissioned by the Marine and Tropical Sciences Research Facility (MTSRF) and contributes to a larger MTSRF program[1] that aims to "develop tools to support resilience-based management in the face of climate change". To support this aim, a team of researchers led by the CSIRO, and with participation by the Australian Institute of Marine Science (AIMS) and Central Queensland University (CQU), are developing an atlas of climate change risk and resilience for the GBR social-ecological system, as well as gathering integrative knowledge for prioritising management responses to climate change. The atlas of risk will provide place-based and regional-scale information about both the ecological and the social risks specific to communities, as well as their capacity (resilience) to manage these risks. This technical report is structured to reflect the three major stages of a socio-economic assessment of the impacts of climate change on the Great Barrier Reef (GBR), with a particular focus on coral bleaching. Given that the area under study (the GBR catchment) extends for thousands of kilometres, three major urban and industrial hubs of Cairns, Townsville and Mackay-Whitsunday were chosen as target regions to narrow the study (Figure 1.1).

The first chapter provides detailed contextual information on the state of knowledge on climate change and how this is likely to affect reef ecosystems and users. It also considers climate change implications for Australia and the GBR. An overview of published research is provided with respect to the effects of ocean temperature rises on coral bleaching, and implications for coral biology, reef fish and plant assemblages and productivity. This is followed by a review and critique of socio-economic assessment methods that might be useful in analysing the impacts of climate change on reef- dependent communities and economies.

The second chapter presents a detailed socio-economic characterisation of three target communities, including an analysis of the contributions made by the reef-dependent industries of tourism, commercial fishing and recreational fishing; as well as a characterisation of the business sectors of the target regions in general.

The third chapter builds on the contextual background presented in the first two chapters. It describes the results of a three-stage engagement process that aimed to determine (qualitatively) the level of impact that climate change will have on the economy of each target region, and the likely, consequent community impacts. The three steps of the engagement process involved:

- A survey and socio-economic analysis of businesses (Stage I);
- Focus group meetings with local government/planners in the target region (Stage II); and
- Detailed business and industry leader telephone interviews on the business impacts and implications are currently underway (Stage III).

Taken together, the information presented in this report provides a holistic insight into the socio-economic impacts of climate change (coral bleaching) on businesses in the target regions (Cairns, Townsville and Mackay-Whitsunday). The underpinning infrastructure and social fabric for businesses has also been considered, as this will heavily impact upon

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[1] MTSRF Project 2.5i.4 Tools to support resilience-based management in the face of climate change: http://www.rrrc.org.au/mtsrf/theme_2/project_2_5i_4.html

business continuity and competitiveness, as well as providing a more complete picture of the risks, exposures and vulnerability of the region to climate change. The report outcomes are designed to guide researchers and to contribute to the development of the risk atlas. Furthermore, the information will provide, to both government and industry, some considerations for policy development, institutional pathways and other strategies aimed at effectively raising the knowledge base of the business sector with regard to climate change impacts. Lastly, the report findings will be useful in securing the engagement of all stakeholders in managing the risks, exposure and vulnerability of reef-dependent business sectors in the GBR catchment for climate related impacts.

Figure 1.1: The Great Barrier Reef catchment area and the target regions used in this study (Source: GBRMPA).

1.2 Introduction

There is an emergent and serious need to understand and communicate the social and economic implications of the biophysical outcomes that will be driven by climate change on the GBR. This section reviews existing literature regarding global climate change predictions and their implications for the GBR, with a view to evaluating the socio-economic impacts consequent to coral bleaching and lost reef productivity. More specifically, this includes:

- A discussion of global climate change including past trends and future predictions;
- An identification of key implications of climate change, for both Australia and the GBR;
- An explanation of the biology of coral bleaching and its consequences, including changes in reef fish assemblages and reef productivity, in the context of climate change;
- An identification of the different social and economic values associated with a functioning reef community;
- A discussion of tools used to value the various market functions and services of coral reefs, including case studies of previous socio-economic valuation studies undertaken for coral reefs; and
- Suggestions for possible approaches to, and limitations on, the measurement of key socio-economic impacts resulting from climate change on the GBR.

In order to understand the implications that climate change will have on the GBR, it is important to note the difference between the anthropogenic effects on climate change and natural climate variability. Climate change can be broadly described as 'any change in climate over time, whether due to natural variability or as a result of human activity' (IPCC 2007). Natural sources of climate variability include modifications to ocean currents, continental drift and solar and volcanic activity: all these may result in random variation in climate along a continuing average. Such trends in climate are natural, pre-existing and have been experienced on a global scale for thousands of years (CSIRO 2006). However, more recent usage of the term 'global climate change' (GCC) typically refers to anthropogenically-induced changes to the global climate. In particular, it refers to excess greenhouse gas emissions, such as carbon dioxide (CO_2), methane and sulfates, which are produced by industrial activity and the burning of fossil fuels (CSIRO 2006). Plainly speaking, the release of these gases intensifies the natural greenhouse effect of the earth, resulting in the capture of more radiant heat originally sourced from the sun. This produces higher-than-normal levels of global warming via the enhanced greenhouse effect, a situation that has been associated with a number of detrimental consequences.

The Intergovernmental Panel of Climate Change (IPCC) was formed over a decade ago to research and enhance the global knowledge and understanding of climate change. The IPCC is an international cooperative body of leading scientists drawn from throughout the globe and is recognised as a leading authority on climate change. The sole function of the IPCC is to independently research and assess the state of knowledge on global climate with respect to observation, theory and modelling. This is being achieved via work on:

1. Understanding the science behind climate change and its causes;
2. Identifying the impacts of change in climate, including possible adaptation strategies; and
3. Working together to mitigate climate change impacts (IPCC 2001).

The work of the IPCC provides the underpinning science and scenarios used in this report.

1.3 Measuring and understanding global climate

Climate scientists have the ability to access a natural record of past climate trends: since CO_2 accumulates in polar ice caps, it is possible for scientists to take deep ice cores from the poles and hence obtain a record of global atmospheric CO_2 levels for approximately the past 400,000 years. However, in recent times, many scientists have studied global climate phenomena through the use of global (or general) circulation models, which track previous climate changes and use the collected data to extrapolate likely climatic conditions into the future. Such models account for components such as the effect of volcanic eruptions, the contribution of the biosphere, atmosphere, oceans and ice sheets and changes in the rates of greenhouse gas emissions (Hoegh-Guldberg 1999). An additional feature is that they also enable investigation – and prediction – of the likely impacts of (man-made) greenhouse gas emissions on the long-term stability of the global climate (CSIRO 2006).

It must be recognised that the natural spatial and temporal variability of climate is highly complex and this makes it difficult to model and/or predict climate with any degree of certainty (Houghton 1997). Global climate patterns are, by their nature, highly variable and this variability is sourced from quite fine-scale processes that may not be adequately represented in even advanced climate models. Furthermore, predictions of future global climatic conditions must rely on assumptions regarding the ability of the human population to curb greenhouse gas emissions. Nonetheless, our understanding of global climate patterns and their influences has been considerably increased in recent years, with the re-analysis of existing datasets, addition of new data and the ability to perform cross-comparisons between climate data collected from different sources (CSIRO 2006).

1.3.1 Current global climate trends

Based on existing data collected from global monitoring stations and advanced computer modelling, it appears that the global climate is currently undergoing a phase of immense change. For example, whilst levels of atmospheric CO_2 have varied considerably over past millennia; the scale of CO_2 increase in the immediate past 100 years has far exceeded any rate previously recorded (Figure 1.2). This CO_2 increase has been concomitant with an increase in global atmospheric temperatures, particularly in the last century (Figure 1.3). The CSIRO has reported a highly positive correlation between atmospheric CO_2 levels and temperature increases over the past thousand years (Houghton *et al.* 2001). Furthermore, detailed analyses of this CO_2 and temperature data, together with records of natural and anthropogenic climate variability, have suggested that there is a strong link between human activity and the current changes in global temperatures (Houghton *et al.* 2001) (Figure 1.4).

Unfortunately, rises in atmospheric CO_2 and air temperatures are just two of the many outcomes of the enhanced greenhouse effect. For example, combined temperature data collected by satellites, ships and buoys in the past thirty years indicate that tropical seas are also undergoing an average temperature rise of at least 1-2°C per century (Brown 1997; Hoegh-Guldberg 1999). Furthermore, the IPCC fourth assessment report has noted the oceans are becoming more acidic, with evidence that the average pH of surface sea water has fallen by 0.1 units in the last two hundred years, representing a thirty percent increase in the concentration of hydrogen ions (Hughes *et al.* 2007a).

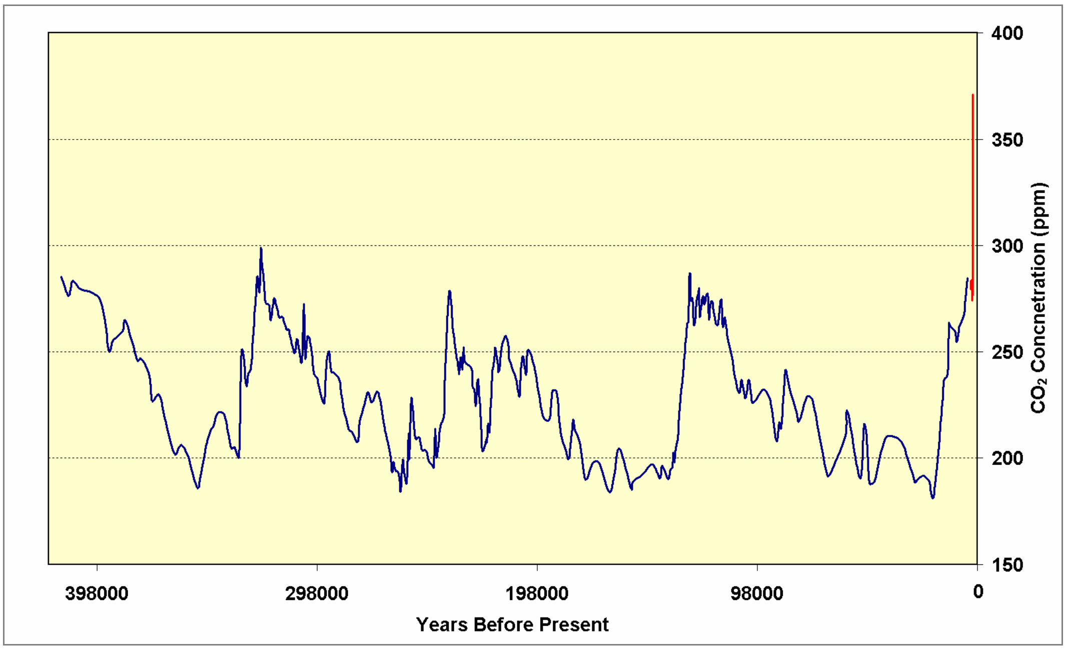

Figure 1.2: Atmospheric CO_2 levels recorded in the past 400,000 years. The current (2001) level is 371ppm – the highest ever recorded (Source: Pettit 2001; Keeling and Whorf 2000).

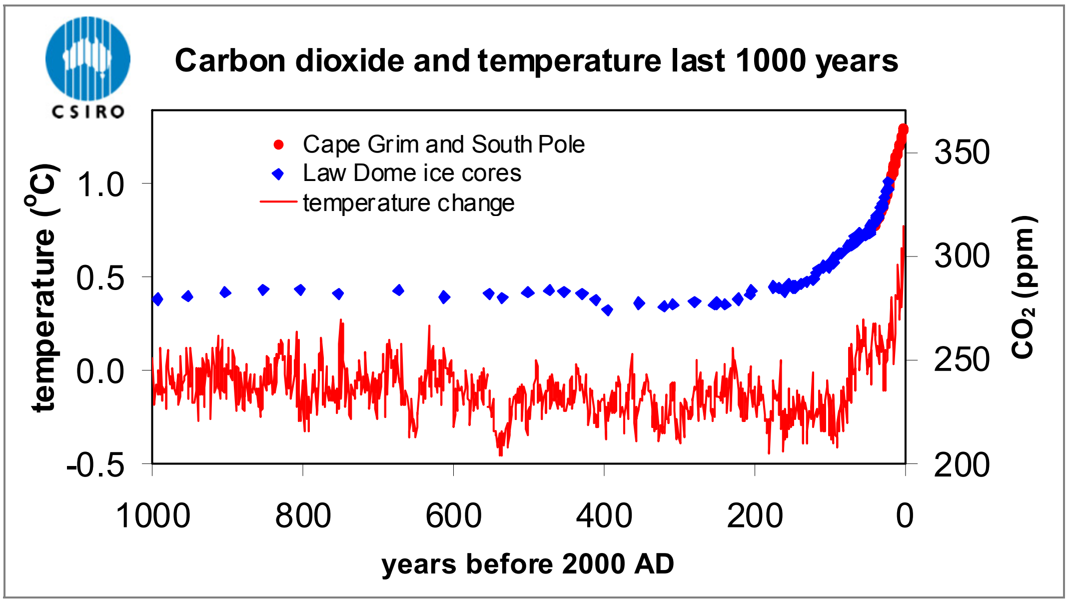

Figure 1.3: The correlation between temperature change and CO_2 levels over the past thousand years (Source: CSIRO 2006).

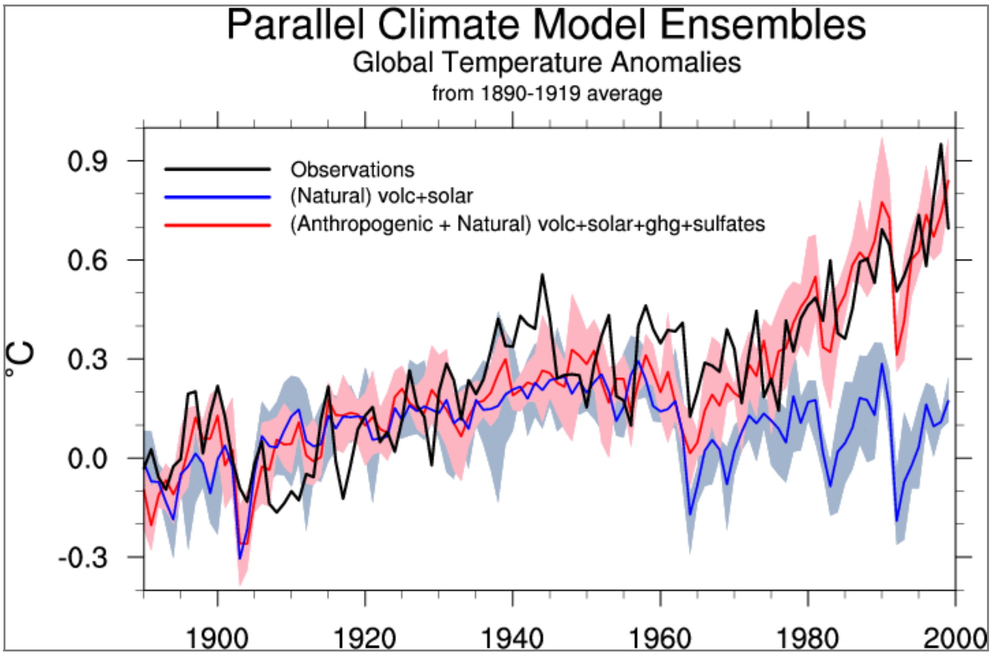

Figure 1.4: Parallel climate model ensembles of global temperature anomalies (Source: CSIRO 2006).

A snapshot of the current global climate shows that Earth appears to be in phase of rapid climate change, with rates of change almost certainly induced or accelerated by the contribution of industrial activity to the greenhouse effect. A précis of these changes can be found in the third IPCC assessment report, which contains detailed climate information and climate predictions. This report acknowledged the following key changes in global climate patterns:

- The global average surface (air) temperature has increased over the 20th century by about 0.6°C; however, there is much variability in average temperatures; 1998 remains the warmest year ever recorded (records began in 1861).
- During the past four decades, air temperature rises have been concentrated within the lowest eight kilometres of Earth's atmosphere. This is of considerable importance given that the atmospheric layers closest to the Earth's surface are also those that are most vulnerable to stratospheric ozone depletion, atmospheric aerosols and the El Niño phenomenon (discussed later).
- Snow and ice cover have decreased, with losses of about ten percent in the extent of snow cover since the late 1960s; mountain glaciers in non-polar regions have also retreated during the 20th century.
- The global average sea level has risen between 0.1 and 0.2 metres and ocean heat content has increased during the 20th century.

- A number of other key changes have also occurred, including:
  - Increased precipitation and an increased frequency of heavy storm events have occurred in tropical areas, especially in the Northern Hemisphere;
  - There has been a reduction in the frequency of extreme low temperatures;
  - Warm episodes of the El Niño-Southern Oscillation (ENSO) phenomenon have been more frequent, persistent and intense since the mid 1970s, compared with the previous hundred years;

- There have been relatively small increases in global land areas experiencing severe drought or severe wetness; and
- The frequency and intensity of droughts has increased in some land areas such as Africa and Asia.

(Houghton *et al.* 2001)

Along with the climate observations listed above, the third IPCC report also found that:

- There is new – and stronger – evidence that most of the warming observed over the last fifty years is attributable to human activities, compared with natural climate variation.
- Confidence in the ability of models to project future climate has increased.
- Anthropogenic climate change will persist for many centuries, since most emissions are slow to degrade and hence global climate is likely to take centuries to stabilize even if substantial changes are made to current greenhouse gas emissions.

(Houghton *et al.* 2001)

1.3.2 Future global climate predictions

According to the third IPCC report, the nature of the global climate in the future is expected to be as follows:

- Global average temperature and sea level are projected to rise under all IPCC scenarios;
- The globally averaged surface temperature is projected to increase by 1.4-5.8°C over the period 1990 to 2100;
- Global warming will contribute to a rise in temperature of 0.4-1.1°C by 2025, concomitant with a sea level rise of 3-14 cm;
- It is very likely that nearly all land areas will warm more rapidly than the global average, particularly those at northern high latitudes in the cold season; and
- Surface temperatures will become more El Niño-like in the tropical Pacific.

(Done 1999; Houghton *et al.* 2001)

The fourth assessment report from the IPCC was released in the second half of 2007 and reaffirms the information contained in the earlier assessment reports. The key findings in this report are:

- Stronger evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases;
- More evidence of other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers;
- A description of the vulnerability to climate change in the four key sectors (agriculture, forestry and ecosystems; water resources; human health; industry, settlements and society) can be exacerbated by the presence of other stressors; and
- The need to action sustainable development initiatives to reduce the world's vulnerability to climate change and that many impacts can be avoided, reduced or delayed by appropriate mitigation action.

1.4 Climate change challenges for Australia

1.4.1 Influences on Australian climate

Australia has a highly variable climate (Figure 1.5), characterised by a diverse range of climate zones, including tropical and subtropical regions in the north, arid expanses of interior and temperate regions in the south (BOM 2007). The country features typically low rainfall and high evaporation rates compared with other continents. A key driver of climatic conditions in Australia is the Walker Circulation, more commonly known as the Southern Oscillation. This phenomenon drives the frequencies of tropical cyclones, heat-waves, bushfires and frosts (BOM 2007). The Southern Oscillation Index (SOI) is a measure of the barometric pressure differential between Tahiti and Darwin, and is often used to detect, assess and predict changes to climate patterns in the Pacific Ocean (and hence, Australia). When the SOI is a positive value, the Pacific trade winds are stronger and northern Australia experiences warmer sea temperatures. As the sea surface temperatures on the eastern coast of Australia rise, there is a concurrent cooling in the eastern equatorial and eastern Pacific, and La Niña type conditions prevail. The La Niña system generally translates to above-average rainfall in Australia (Figure 1.6). In contrast, when the SOI is negative, the western Pacific cools the eastern coast of Australia. The result is El Niño-like conditions or generally lower-than-average rainfall on the eastern seaboard (Figure 1.7). The El Niño / La Niña weather patterns also have a significant affect on cyclonic activity: during El Niño years, cyclones form in the equatorial areas of the eastern sea-board, then track south and east, which moves them away from the Queensland coast, thus denying that state large quantities of rainfall (Figure 1.8). Conversely, during La Niña years, cyclones track south and west, bringing rain with them.

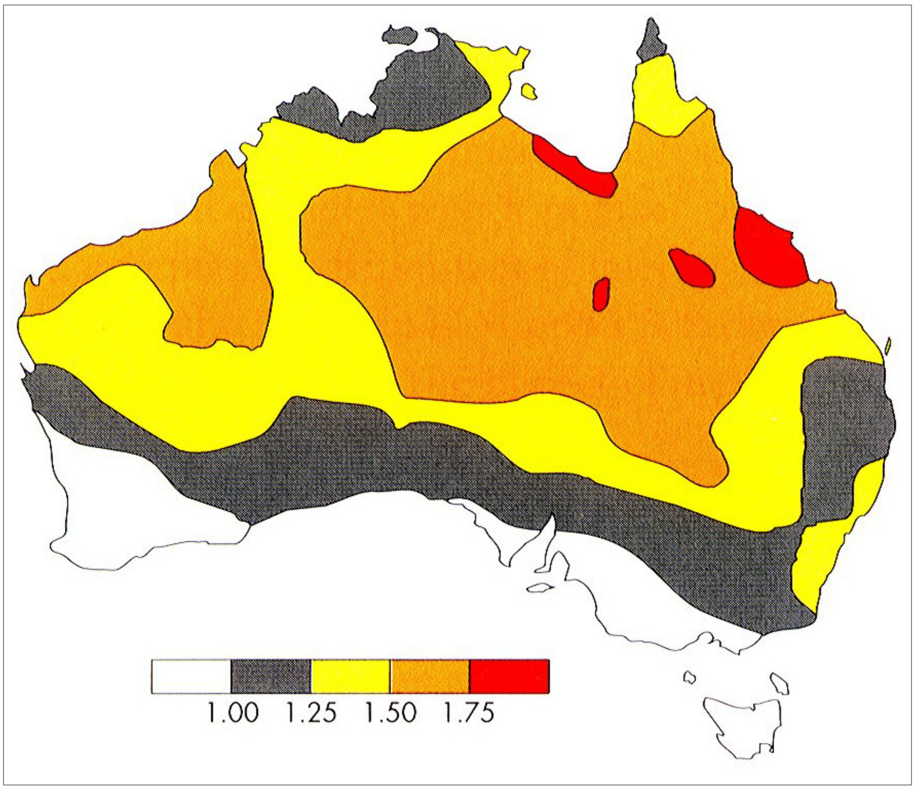

Figure 1.5: Australian climate variability expressed as the order of magnitude of variability (Source: Nicholls, Drosdowsky and Lavery, Bureau of Meteorology Research Centre, from a paper entitled *Australian rainfall variability and change*, yet to be published).

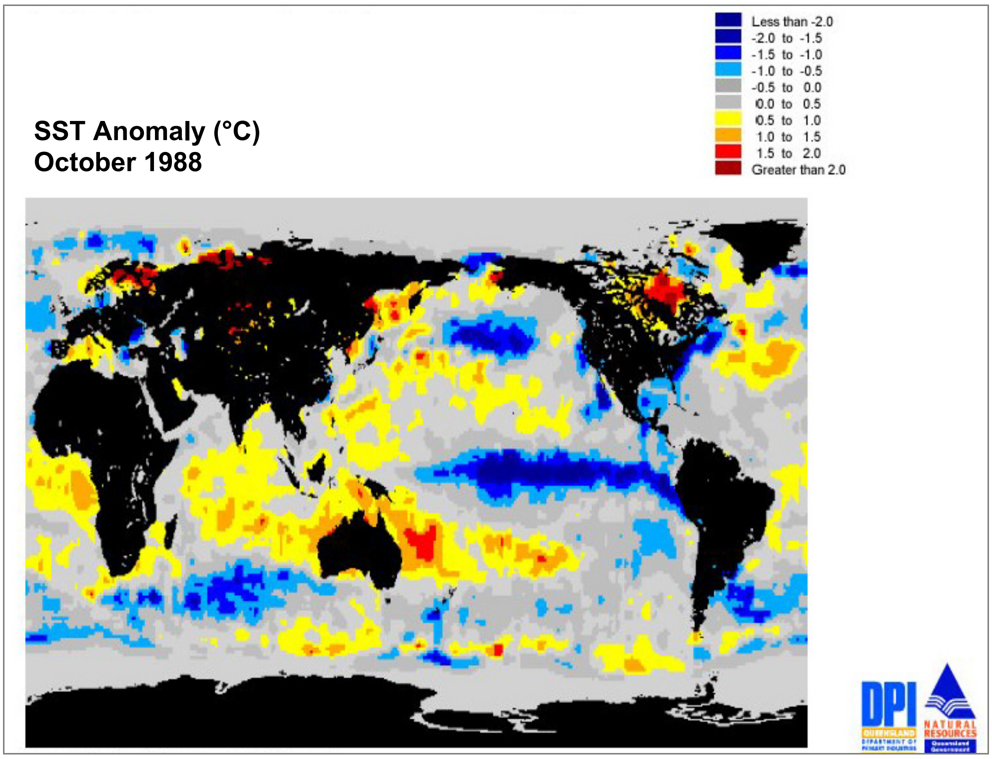

Figure 1.6: A classic La Niña condition, where above-average rainfalls would be experienced along the eastern seaboard of Australia. Ocean temperatures are expressed in degrees Celsius variation from the mean (Source: Steven Crimp, Queensland Centre for Climate Change Applications, Indooroopilly).

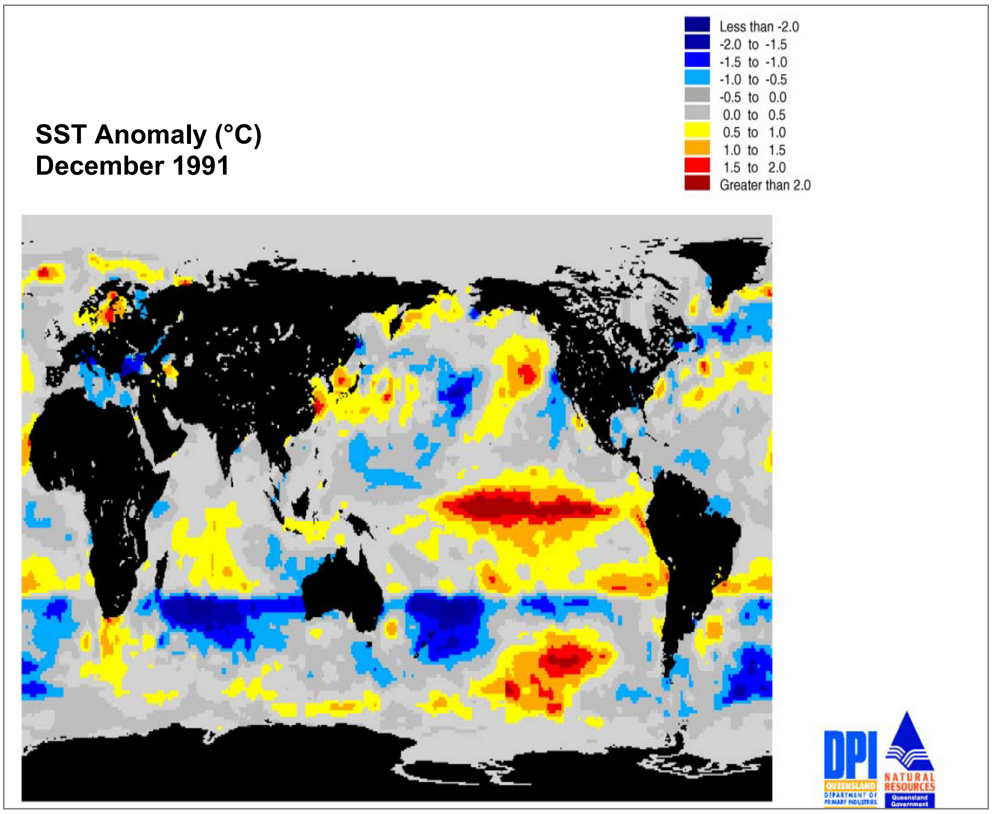

Figure 1.7: A classic El Niño pattern, where lower than average rainfalls would generally be experienced along the eastern seaboard of Australia. Ocean temperatures are expressed in degress Celsius variation from the mean (Source: Steven Crimp, Queensland Centre for Climate Change Applications, Indooroopilly).

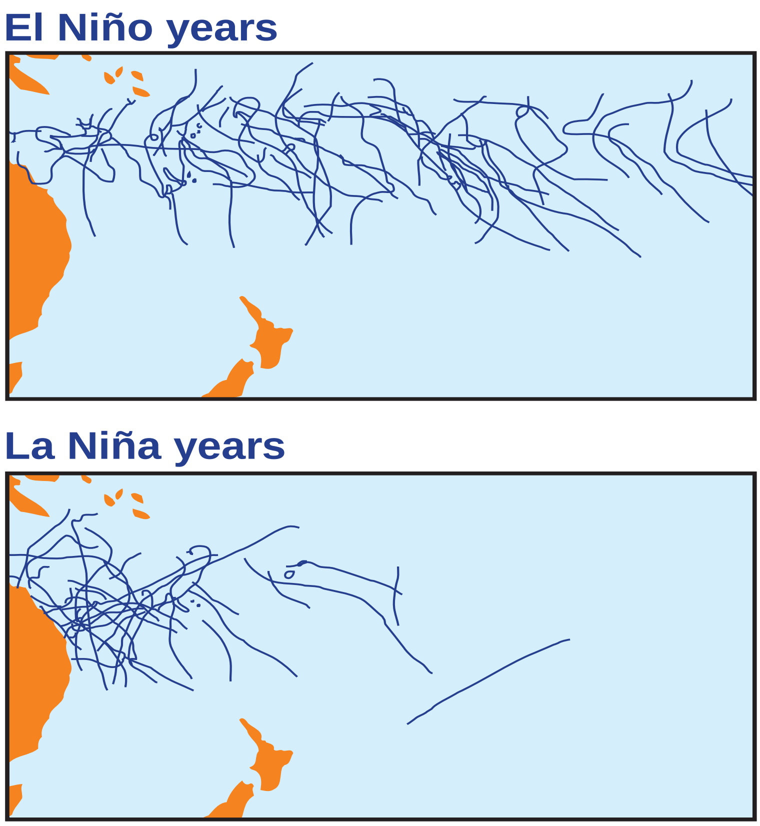

Figure 1.8: Patterns of cyclone movement in El Niño and La Niña years (Source: Peter Hastings, University of Queensland).

1.4.2 Past trends in Australian climate

Changes in the SOI index over the past thirty years and the consequent impact on rainfall patterns in Eastern Australia are presented graphically in Figure 1.9. A significant number of El Niño conditions have occurred in Australia during the past thirty years: these have correlated with the wetter periods experienced in the 1970s and late 1980s. Conversely, very dry conditions have prevailed in the intervening periods and particularly over the past decade. With respect to changes in global climate, it appears that the SOI underwent a threshold in the mid 1970s, with consistently negative SOI values being recorded almost every year since (Figure 1.10).

Australia's climate appears to be gradually becoming hotter, with significant regional changes in rainfall being experienced down the entire eastern seaboard. For example, Queensland has experienced a gradual, but significant, reduction in rainfall in the past hundred years (e.g. see Rockhampton rainfall in Figure 1.11). Similarly, periods of drought are evident for many parts areas of regional Queensland, a trend which becomes even more pronounced when data from the past fifty years are considered (Figures 1.12 and 1.13).

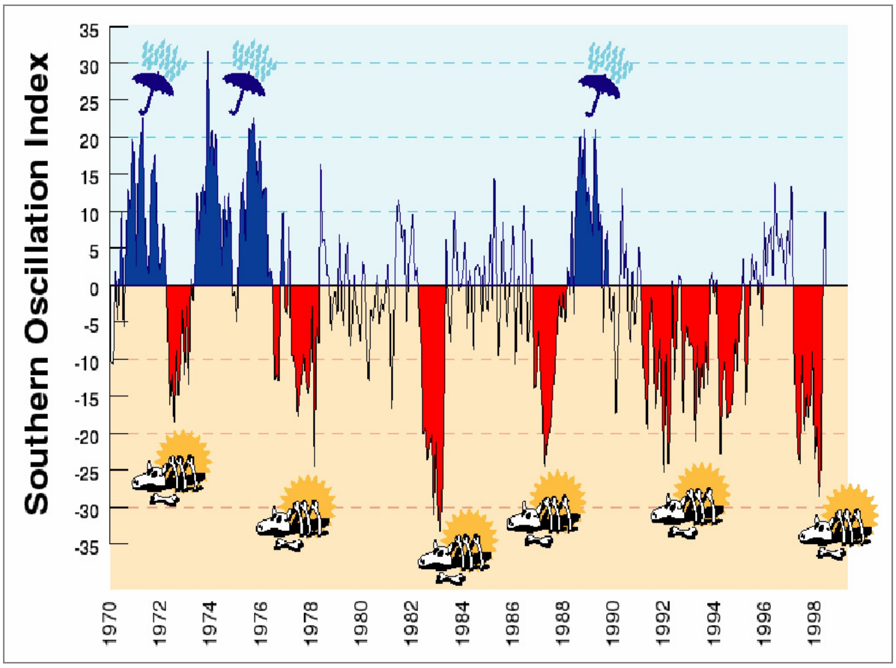

Figure 1.9: Changes in the Southern Oscillation Index (SOI) and rainfall patterns of Eastern Australia (Source: Steven Crimp, Queensland Centre for Climate Change Applications, Indooroopilly).

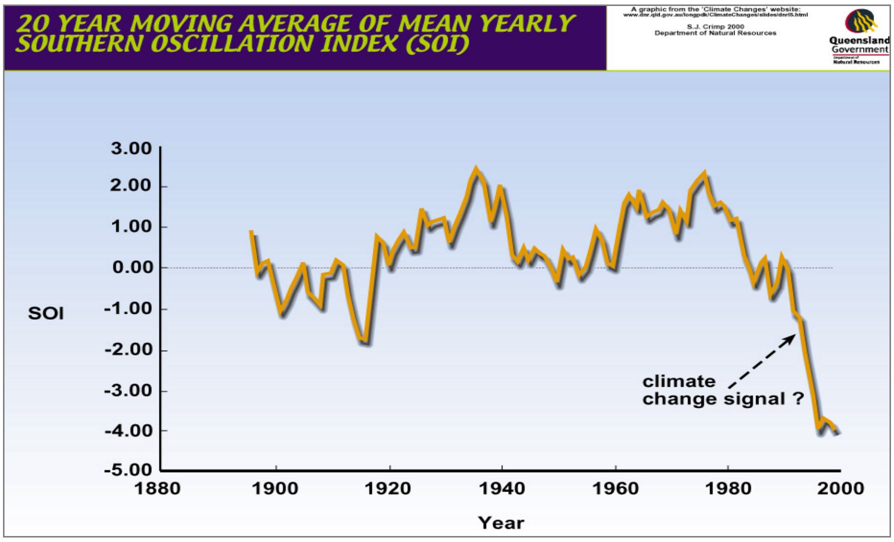

Figure 1.10: Long-term twenty-year moving average of the Southern Oscillation Index (SOI) since 1880 (Source: Steven Crimp, Queensland Centre for Climate Change Applications, Indooroopilly).

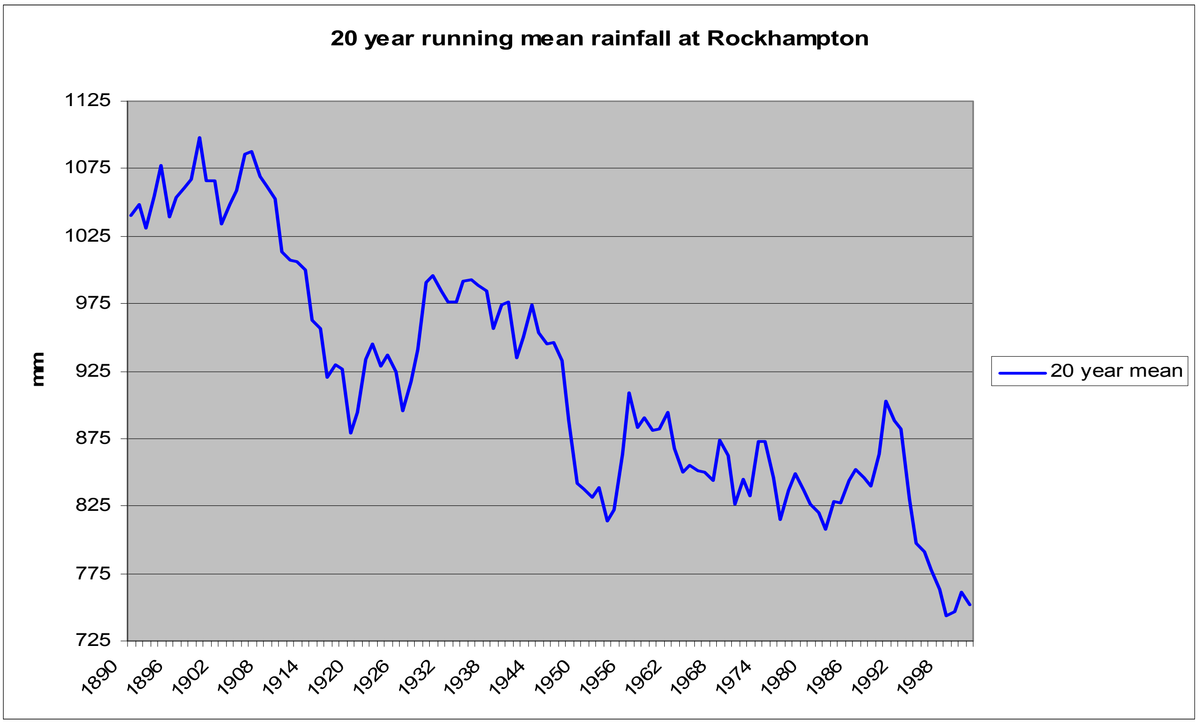

Figure 1.11: Twenty-year running mean rainfall 1890-2003 for Rockhampton, Queensland (Source: Bureau of Meteorology).

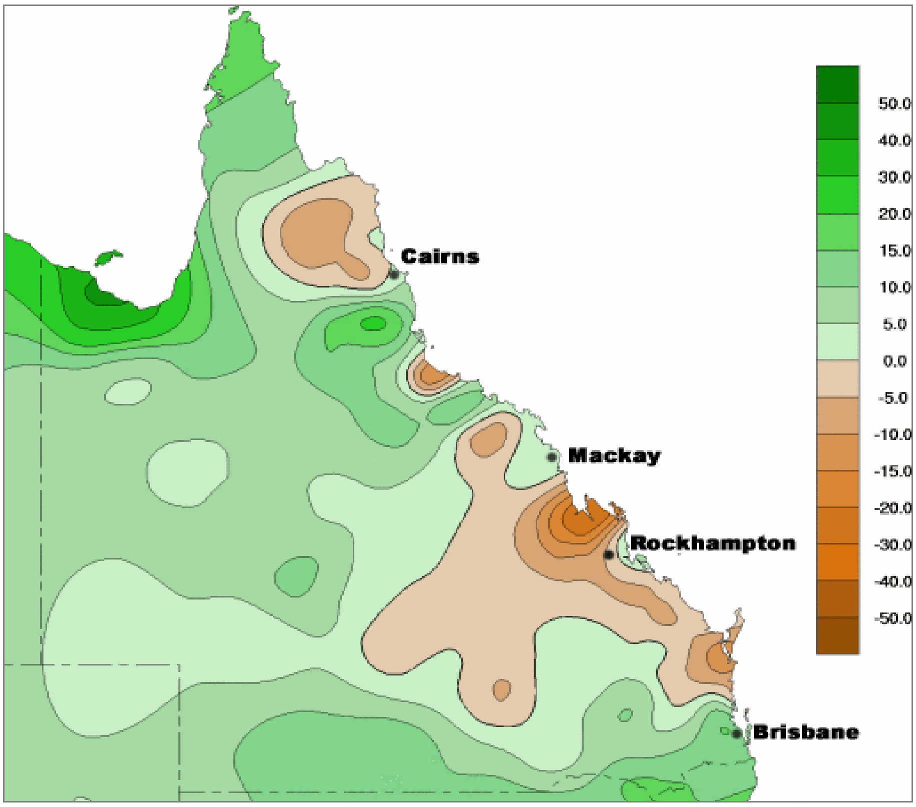

Figure 1.12: Changes in Queensland rainfall trends over the past century – isohyets are in millimeters per decade (Source: Bureau of Meteorology).

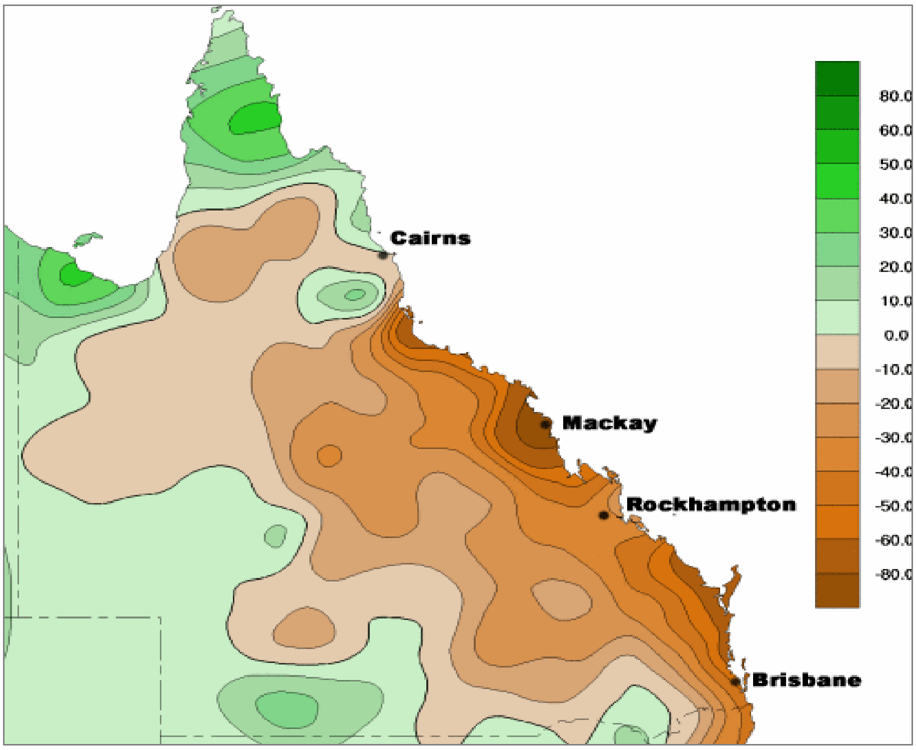

Figure 1.13: Changes in Queensland rainfall trends over the past fifty years – isohyets are in millimeters per decade (Source: Bureau of Meteorology).

1.4.3 Future predictions for the Australian and Queensland climate

Australia's relatively low latitude makes it particularly vulnerable to adverse impacts of climate change. There are also several other features of the Australian landscape which predisposes the country to climate change vulnerability: it has generally scarce water resources, a population that is largely concentrated in coastal areas, and many crops of importance are already growing near or above their optimum temperatures (IPCC 2001).

Several authors have concluded that Australia will face adverse impacts associated with global climate change in the next half-decade, irrespective of local, national or global efforts to reduce greenhouse gas emissions (ACG 2005). Furthermore, some Australian biological systems are more vulnerable to climate effects since the projected rates of change may exceed the natural ability of those systems to adapt (ACG 2005). Such systems include:

- Alpine regions;
- Reef systems (Ningaloo, GBR);
- Tropical rainforests;
- Healthlands in southwest Western Australia;
- Coastal mangrove and wetland systems (e.g. Kakadu); and
- Rangelands.

Based on the modelling and data reflected in the IPCC third assessment report, a range of possible outcomes for Australian climates have been suggested, as follows:

- Increased annual national average temperatures of 0.4-2°C by 2030, and 1-6°C by 2070;

- More heatwaves and fewer frosts;
- A likelihood that ENSO (El Niño-like) events will prevail, accompanied by a cycle of prolonged drought and heavy rains;
- Possible reductions in average rainfall and runoff in Eastern and Southern Australia, but rainfall increase in the tropical North;
- More severe cyclones and severe weather events (high-intensity storms, bushfires);
- Increased summer drying over the continental interiors;
- Change in ocean currents; and
- The CSIRO has predicted that the average number of days in summer over 35°C in Brisbane is expected to rise from an average of three to thirty by 2070.

(CSIRO 2006; Australian Climate Group 2005)

However, whilst these are considered indications of likely directions and the scale of changes expected, they are not necessarily forecasts (ACG 2005).

With respect to Queensland's climate, a report by the CSIRO (2001) described the following scenarios to result from global temperature increases:

- Significant warming in all seasons, particularly so in spring and summer;
- Summer rainfall decrease along the far north Queensland coast (ranging from +5% to -5% by 2030);
- An increase in the frequency of extreme rainfall events, based on the CSIRO high-resolution model (DARLAM-60); and
- An annual rainfall deficit in the GBR region of 245 mm ± 30 mm in 2030, to 340 mm ± 95 mm by 2070 (compared with current estimates of 200 mm).

1.4.4 Implications of climate change for Australia

For the past decade, scientists within the Queensland Government (Queensland Centre for Climate Applications), the CSIRO and the Australian Bureau of Meteorology have publicly expressed their concern over the significant and emerging trends in climate. Translating the IPCC findings to the Australian context, assessing the implications and identifying the adaptation strategies that are required are now priority tasks. Based on the IPCC third assessment report predictions, the changes to the Australian climate expected during the 21st century may have a number of important implications:

- Drying out of the Australian interior and generally lower rainfall levels is likely to be associated with decreased crop yields, decreased water resource quantity and quality and an increased risk of forest fires;
- Decreases in rainfall, together with increases in evaporation, may exert strong impacts on plant and crop growth and contribute to the loss of water from water storages (IPCC 2001);
- Much of Queensland is expected to experience an increased deficit in the water balance of the order of 40-130mm per annum caused by evaporation (CSIRO 2006; see Figure 1.14);
- Increased temperatures and a greater number of hotter days may have particularly serious implications, including in the context of providing health care for the aged and meeting energy demands for cooling without creating further greenhouse gas emissions (IPCC 2001);

- Temperature increases will have a significant impact on pest status; for example, the extent and spread of the mosquito borne diseases such as malaria and Ross River fever may be expected to increase (IPCC 2001); and
- Indirect local impacts from possible climatically driven changes in international conditions such as commodity prices and international trade have also been identified as major issues facing the Australian economy (IPCC 2001).

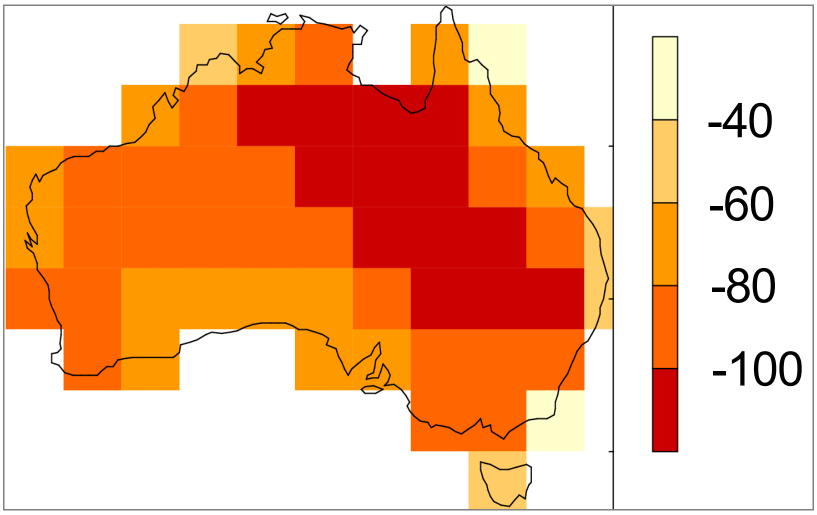

Figure 1.14: Annual water balance change for Australia by 2030. Figures are in millimeters per annum (Source: http://www.dar.csiro.au/publications/projections)

1.4.5 Implications of climate change for the Great Barrier Reef

Climate change is an emerging issue of critical importance to the Great Barrier Reef: changes in both mean and extreme climates will have positive and negative effects on the reef, including its biophysical functioning and the functioning of its socio-economic assemblages (AGO 2004). It cannot be ignored that the waters of the GBR are warming in tandem with increasing global temperatures, and that this upward trend is predicted to continue at an accelerated rate during the progression of the 21st century (Done *et al.* 2003). Consequent to global climate change, variation in sea levels, weather patterns, ocean currents, carbon dioxide concentrations and UVB radiation may all impact adversely upon the reef (Wilkinson 1999). Of course, the scale of these impacts will vary according to the actual temperature rises experienced in the coming decades, and according to the resilience and ability for adaptation in key ecosystems and socio-economic networks (IPCC 2007; see Figure 1.15). For example, whilst a mean annual temperature increase of 1°C may lead to increased coral bleaching only, a change exceeding 2.5°C may lead to widespread coral mortality (IPCC 2007).

The primary effects of global climate changes on the GBR can be summarised as follows:

- Rising sea temperatures may cause mass coral die-offs (Hughes *et al.* 2007a);
- Increasing water temperatures are considered likely to lead to depletion of reef biodiversity, as a diverse range of less tolerant species are replaced by a comparatively narrow suite of thermally adapted organisms (Done *et al.* 2003);
- Thermal stress may predispose some corals to disease (and thus decreased resilience). There has already been a dramatic emergence of coral diseases, some of which have

increased in observed area by five hundred percent in the past decade (Hughes *et al.* 2007a);

- Warmer temperatures may increase the incidence and growth of disease-causing organisms (such as bacteria and blue-green algae) and encourage plagues of predator organisms (Goldberg and Wilkinson 2004);
- Increased seawater acidity, which results from the word's oceans absorbing the excess carbon dioxide in the atmosphere, is of critical importance to reef-building capacity. This acidity results in a reduced capability for corals to form their limestone skeletons (Hughes *et al.* 2007a);
- Other impacts include increased cyclone intensity (but reduced frequency), increased drought and flood runoff from the land (Hughes *et al.* 2007a);
- Increased UVB radiation is not expected to cause a significant impact (Wilkinson 1999);
- Changes in sea level may have possible positive effects as low-lying habitats become inundated and provide more shallow, tropical waters for coral growth (Wilkinson 1999); and other effects as listed in Table 1.1.

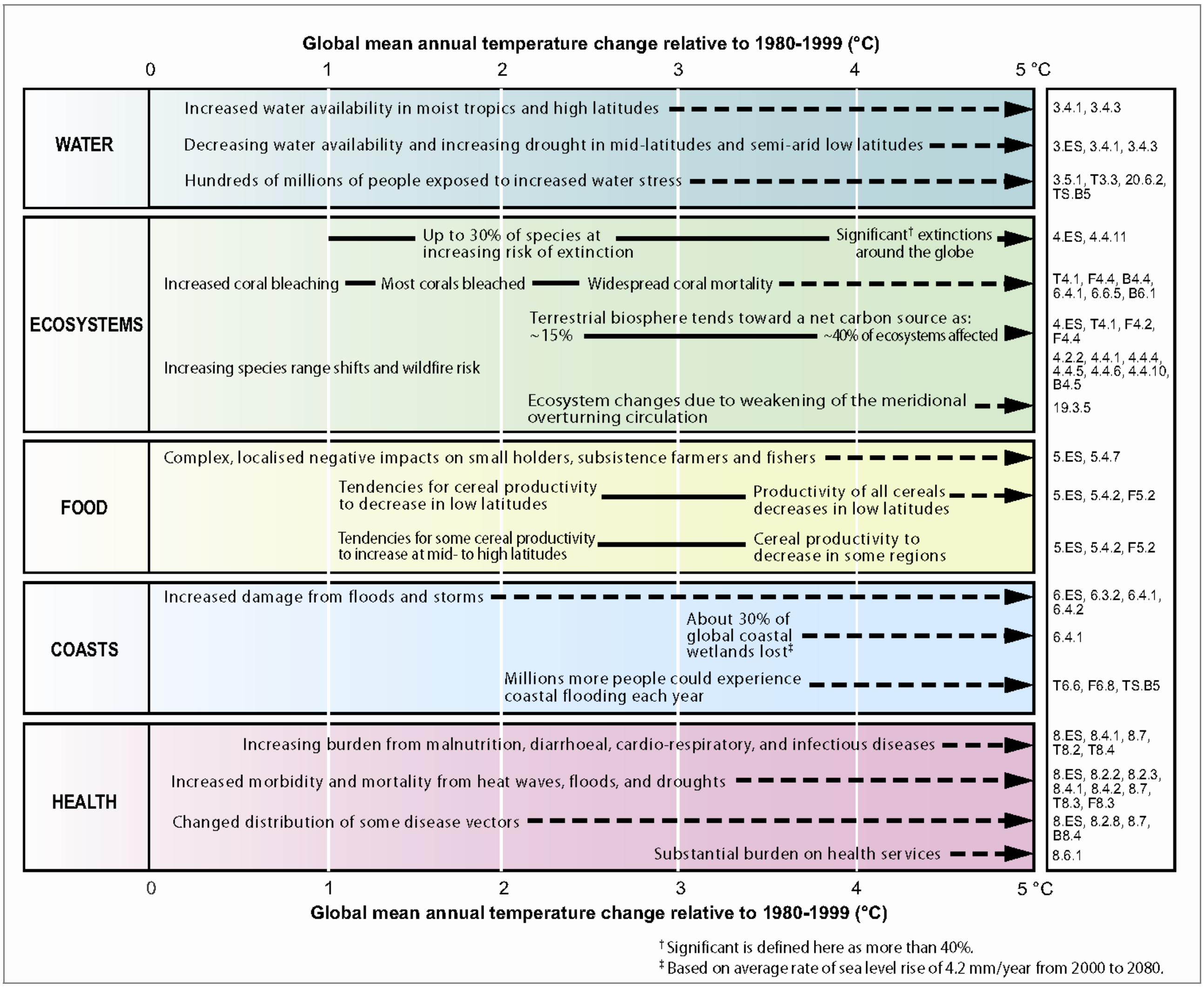

Figure 1.1.5: Key impacts as a function of increasing global average temperature change (Source: As presented in IPCC 2007).

Table 1.1: Implications of changing climate for coral reefs in the GBR region (Source: As presented in AGO 2004).

Increase In	Significance	2003	2030	2070
Temperature (days > 35°C)	Stress to corals and other symbiotic reef organisms leading to bleaching and death	3	3-8	9-?
Intensity of worst 25% of cyclones	Physical destruction worse		More	More
Streamflow	Extreme floods will kill corals at greater distances from river mouths		Less rainfall but increased extreme events	Less rainfall but increased extreme events
Sea level	May be beneficial to corals on some reef flats		+0.1m to 0.5m	0.2m + to 1.0m
Atmospheric CO_2 (global average ppm)	Increases rate of dissolution of reef limestone and weakens new growth	360	500+	700+

Finally, key findings contained in the IPCC fourth assessment report that are of relevance to the GBR include:

1. There is very high confidence (at least a 9 out of 10 chance of being correct) that reef corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1-3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals; and
2. There is very high confidence that significant loss of biodiversity will occur by 2020 in some ecologically-rich sites including the Great Barrier Reef and Queensland's Wet Tropics.

1.5 Climate change and the Great Barrier Reef: Coral bleaching

1.5.1 The biology of bleaching

Coral reefs usually predominate in shallow, tropical waters between 25°S and 30°N; where water temperatures range from 18-30°C, and where nutrient concentrations are generally limited (Hoegh-Guldberg 1999; Wilkinson 1999). Here, natural gradients of temperature, light, nutrients and trophic (food web) interactions all combine to create a functioning reef ecosystem.

The coral-like organisms found on reefs may be either hard (scleractinian) or soft (alcyonarian), but all belong to the Phylum Cnidaria, Class Anthozoa. Corals are relatively simple animals with a cup-shaped body plan; consequent to this primitive arrangement is the general simplicity observed in their life activities (e.g. methods of feeding, reproduction, locomotion and others). Corals obtain some nutrients by carnivorous feeding on planktonic matter; however this cannot entirely satisfy their energy needs. Subsequently, many corals also contain single celled algae, known as zooxanthellae, within their polyps (soft tissues). These algae are important in forming a mutually beneficial (symbiotic) relationship with their coral hosts. Here, the alga enjoys a relatively safe habitat in which it can exploit the coral's waste products (such as carbon dioxide) during growth; conversely, the coral benefits from photosynthetic sugar production and carbon fixation by the algae, which can provide it with over ninety percent of its total energy budget in addition to contributing key substances needed for skeletal growth.

Coral bleaching is the loss of symbiotic zooxanthellae due to the expulsion of the microscopic algae from their coralline hosts. The reasons for the eviction of the algae are various, but all relate to physiological stress in the coral host. For example, coral bleaching can occur in response to sudden changes in salinity, light irradiance or seawater temperatures (Gleason and Wellington 1993; Glynn and D'Croz 1990; Hoegh-Guldberg and Smith 1989; Jokiel and Coles 1990; Yonge and Nicholls 1931). There is also evidence that exposures to chemicals including herbicides and pesticides may trigger expulsion of zooxanthellae, particularly if this occurs in tandem with changes in water quality (Jones and Hoegh-Guldberg 1999).

Bleaching events can affect individual coral polyps, an entire coral colony, or large reef zones comprising may different colonial formations. Since it is the zooxanthellae (or more specifically, the photosynthetic pigments inside them) that are responsible for the bright colouration seen in many corals, bleaching typically results in discolouration or whitening of polyps: coral tissue is itself translucent and the absence of the algae allows the starched white coral skeleton to be visible. A range of other adverse effects are also associated with coral bleaching, including decreased reproductive capacity, increased susceptibility to diseases and energy depletion, which in turn leads to reductions in tissue growth and calcification rates (skeletal production) (Done *et al.* 2003; GBRMPA 2006).

Coral bleaching affects a diverse array of corals, and there is considerable variation in the thermal tolerance of different species and different reefs (Baird and Marshall 1998). Studies of bleaching on the GBR have recorded differential susceptibilities at different sites and depths: for example, reefs exposed to higher temperatures in the past appear less likely to bleach in future, compared with similar reefs inhabiting cooler environments (Marshall and Baird 2000). Differences in bleaching severity have also been observed between adjacent, conspecific (same-species) colonies (Atwood *et al.* 1992), although it is more common for differences to occur between geographically separate populations (Berkelmans and Willis 1999; Coles and Jokiel 1977) or for bleaching to be limited to susceptible species (Hoegh-

Guldberg and Berkelman 1997, in Saxby 2000). Variations in bleaching tolerance therefore appear to result from two primary factors: one, the prior thermal history of the reef – and hence its capacity for acclimatisation; and two, possible differences in the coral and zooxanthellae physiology (Berkelmans and Willis 1999; Jokiel and Coles 1990). Given these influences, it is not surprising to note the high level of individual and spatial susceptibility of coral bleaching observed on the GBR: representing fourteen degrees of latitude, 200km width and 10-200m in depth, the GBR is characterised by three thousand separate reefs of different shape, profiles, waves and currents, individual coral communities, symbiotic zooxanthellae and life histories (Done *et al.* 2003).

Although they take on a bleached appearance, corals that have lost their zooxanthellae are still alive. Hence, if the physiologically stressful conditions subside rapidly, the zooxanthellae can repopulate the coral's soft tissues, thereby enabling it to resume growth (GBRMPA 2006). This is possible because the symbiotic algae also exist in a flagellated form outside the coral and can therefore easily migrate back into the host (Wilkinson *et al.* 1999). However, whilst many corals survive short-term or periodic bleaching, most die where bleach events are prolonged. The immediate period post-bleach is particularly critical, since corals must rely on existing energy reserves and/or their own feeding strategies in order to capture sufficient nutrients, until such time as the algae repopulate their tissues (Wilkinson *et al.* 1999). Hence, corals that are simultaneously exposed to other stressors (e.g. pathogens, contaminants or sedimentation) during or immediately after a bleach event are particularly vulnerable since they are already energy-depleted and may easily die (GBRMPA 2006).

Coral recovery following a bleach event can occur over variable time periods. For example, a study of bleached coral in central atolls of the Maldives has shown the successful recruitment of many coral families within ten months, an unusually fast response (Edwards *et al.* 2001). This contrasts with slow-growing species and/or those with long generation spans, which may take decades or even centuries to recover. Studies have also indicated that vulnerable taxa take longer to return to their original status, if at all (Berumen and Pratchett 2006). Ultimately, the timing and extent of coral recovery following bleach events appears to be related to water quality conditions and other factors which influence the ability for corals to repopulate bleached areas. Example influences include:

- The presence of small patches of living polyps that have escaped bleaching (e.g. in shaded areas or on colony undersides), which may prompt coral tissue to regenerate;
- The survival of corals in other areas (e.g. deepwater or neighbouring reefs) which can provide a source of coral larvae and thus accelerate regeneration; similarly, these also represent a source of coral symbionts that can replenish zooxanthellae stocks and assist in repopulation of bleached tissues;
- Conversely, reefs separated from neighbouring reefs (by distance or strong currents) are less likely to experience re-seeding of larvae;
- Prevailing reef conditions that favour coral larval settlement (e.g. with respect to currents, temperatures, and available substrate) often stimulate and assist regrowth; and
- No repeats of high temperatures or other stressful factors (e.g. pollution, sedimentation, freshwater flushes) in the ensuing years prevents additive/synergistic stresses and provides the best chance for recovery.

(McClanahan *et al.* 2002; Wilkinson *et al.* 1999)

The resilience of coral reefs to bleaching also depends on their ability to adapt and acclimate to thermal gradients. Acclimation (or acclimatisation) occurs where a coral species is able to survive by changing its internal biochemistry, physiology and/or metabolism in an attempt to function better in the new conditions. For example, some corals possess the ability to change the balance of zooxanthellae present in their tissues, and thus can adapt to new temperature and light regimes. Acclimation is part of a natural process that may take hours, days or weeks, since sea temperature fluctuations regularly occur on diurnal, seasonal or yearly scales (Hoegh-Guldberg 1999). Ultimately, acclimation results in the same coral speciation compositions being present, though these may experience reduced growth rates and/or be more vulnerable to other stressors. By contrast, adaptation usually occurs where less tolerant species become dominated, or completely replaced by, individuals that are better suited to the new conditions (Hoegh-Guldberg 1999). The process of species-level adaptation is therefore often slow, in some cases taking many months or years. There is mounting molecular and genetic evidence that corals in the northern, central and southern GBR that have experienced prior exposures to elevated sea temperatures are better equipped to respond to warm water events in the future (Smith 2005). However, whilst corals and their symbiotic zooxanthellae have the ability to both adapt and acclimate to thermal gradients, evidence from the past two decades appears to suggest that they cannot do so quickly enough to match the short, sporadic thermal events that trigger bleach episodes (Hoegh-Guldberg 1999).

1.5.2 The role of temperature in bleach events

Multiple environmental factors have been acknowledged as triggers for coral bleach events (Berkelmans and Willis 1999; Brown 1997), but the single largest cause initiating coral bleaching appears to be warming ocean temperatures (Hoegh-Guldberg 1999). More than seventy percent of the global reported bleaching events have been associated with unusually high temperatures (28-34°C) (Goreau and Hayes 1994). Both field and laboratory studies have indicated that elevated sea surface temperatures (SSTs) are the principal cause of global bleaching events in the last decade (Done *et al.* 2003; Hoegh-Guldberg 1999; Hoegh-Guldberg and Smith 1989; Iglesias-Prieto and Matta 1992; Jokiel and Coles 1990; Lough 1999; Reaser *et al.* 2000; Wilkinson 1999). The "Hotspot" program run by the US National Oceanic and Atmospheric Administration also provides further evidence for elevated temperatures as one of the primary factors influencing bleaching events (Goreau and Hayes 1994; Hoegh-Guldberg 1999). Increased incidence of coral bleaching on the GBR correlates well with warming sea temperatures: 1998 was both the hottest year of the 20th century and also the one in which the greatest ever level of coral bleaching was recorded (Done *et al.* 2003; Lough 1999).

The importance of temperature in triggering coral bleach events is tied to the biology of coral organisms. Many reef-building corals – particularly tropical species – live near their upper thermal tolerance levels which make them sensitive to even minor temperature changes (Saxby 2000). Extended periods of hot, calm and clear conditions affect the photosynthesizing ability of the symbiotic zooxanthellae; this appears to ultimately prompt their mass expulsion from their host coral (Done *et al.* 2003; Iglesias-Prieto and Matta 1992; Lesser 1997). However, the exact relationships between temperature, coral susceptibility and zooxanthellae loss are not well understood: it appears that such interactions are complex and likely to be influenced by yet other parameters. For example, localised differences in bleaching can occur on the uppermost and underneath surfaces of corals, and this cannot be adequately explained by temperature anomalies (since the thermal capacity of seawater would almost certainly preclude differences in temperature over such small distances) (Hoegh-Guldberg 1999). Confusingly, bleaching has also been correlated with decreases in sea surface temperatures: a minimum thermal threshold of 16°C applies to most tropical corals, which is why reefs typically fail to form on the western sides of continents. Here, events such as cool water upwellings can easily affect open ocean reefs, with temperatures dropping several degrees with the tidal change (Glynn and Stewart 1973).

1.5.3 Consequences of seawater temperature increases in coral bleaching

Reports of coral bleaching have occurred since the 1870s (Brown 1997); however, bleaching events have occurred with increasing frequency and on much larger scales in recent decades. Six major (global) episodes have occurred since 1979 (Hoegh-Guldberg 1999). The most severe of these was recorded in 1998 following increased sea surface temperatures associated with the El Niño (Hoegh-Guldberg 1999; Wilkinson 2000), and resulted in the destruction of approximately sixteen percent of coral reefs worldwide, with half of the Indian Ocean and South Asian reefs losing their living coral (Goldberg and Wilkinson 2004). The linkages between wide-scale bleach events and continued global warming is now a topic of considerable interest and study. There is increasing concern that global temperature rises in conjunction with ENSO events will continue to have dramatic influences on reef communities (Jokiel and Coles 1990; Lesser 1997). This is considered likely given that bleaching is only one of a number of adverse effects associated with elevated temperatures; and that bleaching itself may result not only in coral death, but also a potentially wide-ranging suite of other biophysical effects. Some of latter are discussed below.

1.5.3.1 Coral death and declines in abundance

Both living and dead corals have important roles to play in the maintenance of reef structure and function, and all corals experience phases of natural population growth and decline over time. However, such episodes are usually small-scale and isolated. In contrast, the deaths of hard and soft corals that follow severe or prolonged bleach events typically occur at a significant scale. Furthermore, since the potential for coral recovery is limited in some circumstances (see earlier discussion), decreased growth rates and reduced reproductive success associated with bleaching often translates to major overall losses in coral cover and species diversity (Connell 1978; Saxby 2000). For example, near Sesoko Island, Japan, the 1998 bleaching event resulted in significant reductions in both coral species richness and coral cover (61% and 85% losses, respectively) (Loya *et al.* 2001). Added to this problem is the fact that increased temperatures are known to reduce the fecundity (= reproductive and regenerative capacity) of coral populations, even in the absence of bleach events (Hoegh-Guldberg 1999). In short, warming oceans and bleach events are considered highly likely to translate to fewer coral organisms being present on tropical reefs, with local or regional-scale extinction a distinct possibility for vulnerable taxa.

1.5.3.2 Reduced resilience

Bleached corals are likely to feature reduced growth and calcification rates, together with a decreased ability to repair damaged tissue, either in the short or long term (Hoegh-Guldberg 1999). However, even in the absence of bleaching, the increased sea temperatures and higher CO_2 levels associated with global warming can decrease coral calcification rates, making it more difficult for corals to recover from disturbances and to resist physical damage (Scavia *et al.* 2002). For example, slow-growing corals may be rendered vulnerable to invasions by boring organisms and other predators (Mokady and Loya 1998); they may be susceptible to storms or other physical damage (e.g. injuries caused by anchoring and/or contact by tourists); and they typically have a reduced capacity to compete for space against other, faster growing species, such as macroalgae, sponges or other invertebrates (Glynn 1993).

1.5.3.3 Declines in productivity and carrying capacity

The loss of key coral species due to climate change and coral bleaching can produce changes in reef ecology including altered resource use and decreased productivity rates. Coral reefs are amongst the most productive ecosystems on earth: coral-dominated landscapes may fix up to 40gC m^{-2} day^{-1}, and do so in otherwise unproductive waters

(Hoegh-Guldberg 1999). Since reef-building corals (and their symbiotic zooxanthellae) represent a substantive proportion of the productivity of reef ecosystems, their loss may severely limit productivity and carrying capacity overall (Done 1999; Hoegh-Guldberg 1999). This includes productivity related to coral growth itself and to the sustenance of other marine life. For example, reduced reef productivity may have substantial effects on birds and marine mammals, though few studies have examined this (Done 1999).

1.5.3.4 Changes in community composition and phase shifts

There are interspecific differences in the susceptibilities of corals to disturbances. These species variations effectively dictate the scale and nature of coral responses to bleach events (and other temperature-related disturbances) (Connell 1978; Hughes 1994; McField 1999; cited in Saxby 2000). However, it may also be the case that corals respond differently to bleach events at the community-level, as well as at the species scale. For example, areas of high species diversity may be better able to cope with change, since resource uptake and productivity can be stabilised or buffered (McClanahan *et al.* 2002). It has been suggested that climate change may be more detrimental towards specialist coral species, since these are typically slow growing, site specific and less abundant as a group, compared with ‘generalist’ species, which are less fastidious and more numerically abundant (Munday 2004). Vulnerability of corals (and other reef species) to the effects of climate change will vary according to the likelihood of exposures, sensitivity to changes and the adaptability of organisms to those changes.

According to Done (1999), variations in coral susceptibility to bleaching may produce one of four scenarios:

- Faster turnover: the rates of mortality and replacement in the pre-existing, resident coral species are accelerated due to reduced coral life expectancies;
- Tolerance / acclimation: pre-existing species remain and are able to respond to changes in temperature (within species limits);
- Adaptation / species replacement: hardier coral species replace those that are less tolerant to thermal changes; or
- Phase shifts: coral species become replaced altogether, for example, the community becomes algal-dominated. Phase shifts involve the loss of not just one species, but entire biological communities; occur over time and usually have significant and wide-ranging effects on a number of taxa.

A number of different ecological states may exist for coral reefs, according to the pressures and opportunities presented by ecosystem conditions at any one time. For example, such states may include:

- Dominance of fish, coral and coralline algae (the most desirable state);
- Turf algal dominance;
- Sea urchin dominance;
- Brown seaweed dominance; and
- Co-dominance combinations (e.g. simultaneous existence of high numbers of urchins, sponges and algae).

(McClanahan *et al.* 2002)

It is important to recognize that fluxes between these different reef states are entirely natural, since low-level disturbances and population changes are normal aspects of a healthily functioning reef (Done *et al.* 2003). Coral reefs are reasonably well equipped to deal with disturbances: this has been critical to their success in high-energy tropical locations. For example, reef ecosystems appear to be remarkably resilient to short term or 'pulsed' disturbances such as floodwater inundation or storm damage. In contrast, however, reefs cope poorly where pressures are significant, sustained and combined (Bellwood *et al.* 2006). The main factors which trigger a change from a coral-dominated reef to that dominated by other biota include:

- Reduced competition from corals due to growth inhibition
- Rapid increase in bare substratum area for colonization
- Reduction or disappearance of grazers such as fish and invertebrates
- Increased nutrient and sediment loads

(Moberg and Folke 1999)

Coral bleaching is implicated in the first three of these four factors, since stands of dead and dying coral have a decreased ability to compete with algae, may erode easily (thus leaving bare substratum) and represent considerable losses in habitat and food resources for many coral-dependent marine organisms. Coral reef communities appear to be very susceptible to phase shifts (Halford *et al.* 2004). Already, many coral reefs worldwide have undergone phase shifts to degraded assemblages in response to the combined effects of anthropogenic influences and direct and indirect climate change impacts (Hughes *et al.* 2007b).

It remains difficult to determine whether global climate changes will cause coral communities of the GBR to undergo permanent phase shifts, or simply to experience acclimation or adaptation and a continuation of change over time (including a possible return back to the original fauna) (Berumen and Pratchett 2006). For example, studies by DeVantier *et al.* (2006) have suggested that anthropogenic disturbances on the GBR's marine communities is likely to result in local removal of key coral species, rather than a species shift to other coral types. In contrast, in the late 1990s, it was suggested that climate change and its impact(s) upon community compositions could lead to a complete transformation of the GBR into a non-coral state by 2030, particularly in the inshore reef systems (Hoegh-Guldberg 1999). It seems likely, however, that phase shifts will be effected if climate change is persistent, since large-scale or severe disturbances, or those where multiple disturbances occur at once, are most likely to lead to permanent shifts in community structure (Berumen and Pratchett 2006). Furthermore, it is not only global climate change (and consequent coral bleaching) but also the added pressures of over fishing, habitat destruction and pollution, which may contribute to significant, long-term and permanent transitions in marine habitats on the GBR.

1.5.3.5 Changes in reef fish assemblages

There is a close interdependence between coral communities and reef fish. Coral reefs provide shelter, habitat niches, and suitable substrate for reproductive activities and larval settlement for reef fish. Coral reefs can also be an important determinant in population dynamics and population distribution of reef fish (Munday *et al.* 1997). In turn, many species of reef fish help moderate rates of coral settlement, health and growth, for example, by keeping natural populations of macroalgae and invertebrates in check (Birkeland 1997). In some cases, the associations between reef fish and coral are evident at fine taxonomic levels – for example, some 'corallivorous' (coral-feeding) fish forage only on the polyps of certain live coral species; other coral-dwellers reside in the polyps of only a limited number of corals (Munday *et al.* 1997). Furthermore, a number of other marine species, in addition to reef fish, are interdependent on reef ecosystems and may be equally affected by habitat and resource losses associated with coral bleaching. Many marine turtles (e.g. the endangered hawksbill) use reefs as a habitat and, like fish, are important in maintaining the overall health of the reef ecosystem. One study suggested that if turtles are unable to use hard corals as habitat and therefore become absent from the reef system, then glass sponges (which are a predominant part of turtle diets) may overpopulate the bleached hard corals, accelerating the destruction of reef architecture (Goldberg and Wilkinson 2004).

Given the close interdependence between reef fish and coral organisms, it could reasonably be expected that coral bleach events will have important implications for the health of fish populations (and other marine life). Reef fish assemblages have been generally poorly studied with respect to potentially adverse effects of coral bleach events. This is unfortunate since reef fish communities typically feature many small species which are habitat specialists and have restricted geographic ranges (Hawkins *et al.* 2000; Munday *et al.* 1997): thereby rendering them particularly vulnerable to stress. Ultimately, the consequences of coral bleaching with respect to reef fish can be separated into two main categories: firstly, effects on specific fish species that are closely linked with the reef via coral-feeding or other direct relationships; and secondly, effects on generalist fish species that use the reef as a habitat or indirectly, but which do not necessarily exhibit species-specific linkages with corals.

Effects on coral specialist fish

Declines in coral abundance often lead to corresponding declines in species-specific coral-dwelling and coral-feeding fish. This is particularly so for specialist fish species, since these typically have low population numbers, are less likely to recover from disturbance events and are most likely to be the first species lost from coral reefs (Munday 2004). For example, reduced abundance of Acropora corals on the northern side of Papua New Guinea was mirrored by an almost identical decline in abundance of coral-dwelling Gobiodon species (gobies) (Munday 2004). Similarly, changes in the distribution and recruitment of key coral-dependent fish at One Tree Island in the southern GBR were recorded after an extensive bleaching event (Booth and Beretta 2002).

Coral-specialist fish may not represent a large number of the overall reef fish population: surveys of reef at Kimbe Bay (northern Papua New Guinea) found that just eleven percent of the 538 reef fish species present had an obligate association with living coral (Munday *et al.* 1997). Furthermore, coral bleaching itself may not cause detriment to coral feeding and coral dwelling fish at all, unless the bleach event occurs on a scale which causes death of coral tissue (Sano 2004). Nevertheless, the biophysical and socio-economic effects of bleaching on specialist reef fish species are likely to be of major importance if:

- Bleach events are sustained and cause death of live coral tissue, in addition to lost zooxanthellae;
- Recovery periods are long (or the reef does not recover);
- Coral phase shifts or changes in species assemblages occur and this results in the loss of key coralline species (and their subsequent fish fauna);
- Key coral and coral-dependent fish species are amongst the ‘keystone’ organisms of that particular reef section (e.g. represent a dominant population or are intrinsic to the functioning of the food web); and
- Coral specialists have particularly special value for tourism, fishing, or both.

Effects on generalist reef fish

Long-term alterations in coral communities may lead to significant changes in the structure of reef fish communities, even those which are not directly coral-dependent (Berumen and Pratchett 2006). Several reef surveys have found that reef fish species experience a decline in abundance and changes in species composition following loss of coral cover (McClanahan *et al.* 2002; Munday *et al.* 1997). Changes in the abundance and suite of corals present on reefs will inevitably lead to changes in the composition of associated fish communities (Munday 2004, p. 1642), simply because habitat destruction – in marine communities and elsewhere – is often associated with species declines. In one bleach event, about 75% of fish species surveyed were found to have declined in abundance: in half of these cases, fish numbers were reduced by >50% (Munday *et al.* 1997). Nevertheless, in other examples, generalist fish have appeared to survive quite independently of reef damage (Jones *et al.* 2004). For example, recent studies by Wilson *et al.* (2006) recorded up to 62% decline in the abundance of reef fish species following a >10% decline in coral cover, but only in coral specialists: gross numbers of other fish that fed on invertebrates, algae or detritus actually increased. Similarly, during a twelve-year study of fish populations on reefs near Orpheus Island in the GBR, there were no decreases found in diversity, richness or abundance after a severe coral bleaching event occurred in 1998, despite an accompanying 75% mortality in Acropora species, the dominant coral (Bellwood *et al.* 2006).

Variations in the responses of generalist fish species to coral declines probably reflect the different nature and scales of bleach events. For example, in one study, a single, massive bleaching event resulted in a distinct shift in fish species composition whilst subsequent bleaching events were less problematic (Bellwood *et al.* 2006). In addition, there is evidence that non coral-dependent fish will experience limited impacts from coral bleaching, as long as the high structural complexity of bleached corals is preserved (Sano 2004). This is because dead coral skeletons may continue to provide valuable habitat to support adult reef fish assemblages for some time after a bleach event, until the architecture becomes eroded. Dead coral skeletons are also colonized quickly by seaweeds and other opportunistic organisms, many of which may continue to provide valuable habitat (Reaser *et al.* 2000).

Several aspects of fish biology may also play a role in moderating effects from bleaching. For example, long-lived individuals may be resilient to change compared with populations of short-lived fish species (those with life spans of one year or less), since the latter may have their entire life histories (egg, larval, juvenile and adult stages) impacted by bleach events (Bellwood *et al.* 2006). Some reef fishes are able to disperse their larvae over long distances, consequently, their populations were often considered relatively robust to localised bleaching events. However, climate change has vastly increased the scale of disturbance of coral bleaching: it is now thought that buffering of local reef fish populations by other larval pools will no longer be sufficient to maintain populations, resulting in reduced resilience and recovery and local extinction (Halford *et al.* 2004; Munday 2004). The response of reef fish to losses of coral is also dependent upon stock replenishment, ecological niche of species, feeding rates and other sublethal responses (Wilson *et al.* 2006). Lastly, few long-term studies have been conducted of reef fish populations following coral bleaching; hence, changes to the fish fauna may not have been detected: one author has claimed that fish-related phase shifts resulting from coral damage may take between 5-35 generations to appear (Bellwood *et al.* 2006).

The precise linkages and influences between reef habitat, fish assemblages and coral bleaching continue to be debated (Sano 2004). Ultimately, however, the most severe changes will be restricted to those fish which are strongly coral-associated (e.g. corallivorous) (Bellwood *et al.* 2006), especially where coral bleach events are sustained and/or occur on massive scales. The impact of long-term coral declines on generalist fish populations in particular remains largely unknown and requires more study (Jones *et al.* 2004).

1.5.4 Future bleaching predictions

In 2001, it was estimated that eleven percent of all coral reefs had been totally destroyed or damaged beyond recovery due to combinations of pressures including climate change and other natural and anthropogenic impacts (Ahmed *et al.* 2002). Unfortunately, the impacts of global climate change – in particular, elevated sea surface temperatures – are predicted to result in yet more frequent and extensive bleaching episodes. Most of the Earth's past bleaching events have been correlated with the occurrence of El Niño – Southern Oscillation (ENSO) (Hoegh-Guldberg 1999; McCulloch and Alibert 1998). However, another potential threat to reef systems is the secondary impact of La Niña, which often results in cooler average winter temperatures that often drop below the lower thermal threshold of corals. Bleaching events caused by sequential El Niño – La Niña years may therefore have devastating impacts on coral growth and reproduction (Saxby 2000).

The frequency of bleaching events on the GBR is currently predicted to increase by 1.6-1.7 more events per decade, until annualised bleaching is experienced by 2030 (Hoegh-Guldberg 1999). In scenarios modelled for the Townsville section of the GBR, the inshore reef fared the best in terms of adverse effects of climate change, since it was considered that corals inhabiting this area are already acclimatised to warmer waters, compared with those living on the mid and outer reefs (Done *et al.* 2003). Elsewhere, episodes of coral bleaching are likely to become annualised events by 2050 in most oceans, with some areas experiencing yearly bleaching as early as 2020 (e.g. the Caribbean and south-east Asia) (Hoegh-Guldberg 1999). Since it is currently estimated to take ten to fifty years for a reef to recover from a severe bleaching event, these projections indicate a significant part of our corals could be replaced by seaweeds, unless the corals can evolve (= acclimate and adapt) incredibly quickly (Hughes *et al.* 2007a).

1.5.5 Other climate-change effects and sources of reef stress

The focus of this review is to discuss the implications of global climate change in the GBR with specific emphasis on coral bleaching. However, it should also be noted that global climate change may exert other impacts in addition to bleaching, which may be important in reducing the socio-economic values of the area. For example, variations in water temperature, ocean currents and upwellings may individually or collectively result in adverse effects on biological systems other than corals themselves. In estuarine and marine communities, the impacts of increased temperatures can include lethal effects for species having narrow temperature tolerance ranges, and/or acute or chronic sublethal effects for other species. Tropical fish are reasonably susceptible to climate change stress because these, like coral, usually live near their upper thermal tolerances. Thus, modifications to temperature regimes, such as those associated with thermal pollution, can easily be associated with changes in migration patterns, spawning cycles, and increased fish metabolism and growth (eventually resulting in resource exhaustion). Recruitment in fish populations, for example, has long been known to be strongly influenced by climate variability (Walther *et al.* 2002). Such effects are not limited to fish and may also include crustaceans, invertebrates or other marine species.

Secondly, it is important to acknowledge that the potential impacts of global warming (e.g. coral bleaching and other changes) will be superimposed upon, and in many cases intensified by, other ecosystem stresses. Reef ecosystems are continually affected by a number of natural threats including geological disturbances, storms, inundation by fresh (flood)water, air exposure during low tides, outbreaks of predators and disease (Wilkinson 1999). In addition, anthropogenic impacts on coral reefs have increased dramatically in recent times due to increasing development within coastal areas and altered land use patterns, leading to pollution by nutrients, sediments and pesticides, overharvesting and general habitat destruction (e.g. see review by Birkeland 1997). Furthermore, different reef regions may have variable susceptibilities to climate change and its biophysical manifestations. In broad terms, the GBR can be dissected into four quadrants, representing the tropical and temperate, and onshore and offshore environments, respectively.

These four reef sections may respond differently to seawater temperature increases for a number of reasons:

1. Organisms in tropical habitats already exist close to their upper thermal maximums: slight increases in temperature in these reef environments may exceed critical temperature ranges and cause decline in these species; whereas organisms in temperate environments have a 'buffer';
2. Onshore environments typically comprise shallow, fringing reefs that warm more quickly and are more vulnerable to changes in sea level; and
3. Due to their proximity to the coast, onshore environments are more polluted by runoff events, including a cocktail of sediments, nutrients and pesticides. These stressors can act in tandem with climate change to produce more serious environmental effects.

Ultimately, the adverse effects of climate change – and in turn, their social and economic consequences – are likely to manifest at much greater scales when the possibility (or more likely, probability) of these additive and synergistic effects are considered. As noted by the AGO (2004, p. 45): "The implications of [climate change] risk need to be considered within the context of other known influences on reef ecology and reef-based enterprises … including other negative and positive effects … The Great Barrier Reef, across its entire extent, is heterogeneous in relation to all these influences".

1.6 Assessing the social and economic values of the GBR

1.6.1 Identifying the goods, services, values and functions provided by reefs

The goods and services provided by coral reefs are variable by location and according to different coral reef types. For example, fringing reefs, barrier reefs, atolls and platform reefs are functionally different and each may be connected to other systems such as mangrove stands, seagrass and macroalgal beds, and coastal and estuarine communities (Moberg and Folke 1999). Different reefs therefore may have different stakeholder interests, but the key roles performed by coral reefs can be broadly summarised as follows:

- A resource for commercial marine harvests (finfish, crustacea);
- A source of organisms for the marine aquarium and curio trades;
- A source of potential pharmaceuticals and other novel bio-products;
- Social 'glue' – the reef may have a stabilizing effect on social structure especially in smaller fishing communities, where families and neighbourhoods are bonded by similar values and work (Birkeland 1997);
- Historical value (e.g. there are over 1,200 shipwrecks in the Great Barrier Reef World Heritage Area, in addition to other ruins and operating lighthouses of cultural and historical significance (Hand 2003));
- Recreational destination (fishing, diving);
- Scientific research and educational uses;
- Tourism, including fishing, diving and snorkelling, day tripping, resorts and onshore activity;
- Provision of ecosystem functioning and biodiversity (e.g. the storage and cycling of nutrients and organic matter);
- Coast buffering – protection against erosive wave action, particularly in regions that experience strong currents and severe storms (Spurgeon 1992); and
- Other environmental services (for example, by acting as a sink or dump for land-based runoff and pollutants: if the reef didn't exist, an alternative place would need to be found for sediments, pesticides and pollutants (Fürst *et al.* 2000)).

Additional goods and services are also listed in Table 1.2.

Table 1.2: Examples of goods and services provided by coral reef ecosystems (Source: As presented in Cesar and Chong 2002).

Goods		**Ecological Services**					
Renewable resources	**Mining of reefs**	**Physical structure services**	**Biotic services (within the ecosystem)**	**Biotic services (between ecosystems)**	**Bio-geochemical services**	**Information services**	**Social and cultural services**
Seafood products	Coral blocks, rubble / sand for building	Shoreline protection	Maintenance of habitats				
Raw materials and medicines	Raw materials for lime and cement production	Build-up of land	Maintenance of biodiversity and a genetic library	Biological support through 'mobile links'	Nitrogen fixation	Monitoring and pollution record	Support of recreation
Other raw materials (e.g. seaweed)	Mineral oil and gas	Promoting growth of mangroves and seagrass beds	Regulation of ecosystem processes and functions	Export of organic production, etc., to pelagic food webs	CO_2/Ca budget control	Climate control	Aesthetic value and artistic inspiration
Curios and jewellery		Generation of coral sand	Biological maintenance of resilience		Waste assimilation		Sustaining the livelihood of communities
Live fish and coral collected for the aquarium trade							Support of cultural, religious and spiritual values

Approximately fifteen percent of the world's population – about half a billion people – live within one hundred kilometres of a coral reef ecosystem (Hoegh-Guldberg 1999). Hence, on a global scale, reef ecosystems can represent considerable importance to livelihoods. Reefs provide direct financial value through the extraction and trade of resources and through recreation (both current and in the future). The two primary ways in which reef ecosystems can be used for employment and wealth generation are as a tourist destination and as a fisheries resource. In the case of small island nations, tourism is often the driving force behind the economy, with thousands of people depending on tourist expenditure for their livelihoods (Hoegh-Guldberg and Hoegh-Guldberg 2000). The contribution of reefs to the fisheries industry is similarly vast: the potential annual yield of coral reef fisheries worldwide has been estimated at nine million tonnes (Ahmed *et al.* 2002). The global standing stock of reef fish is staggering, with estimates as high as 93-239 metric tons in Pacific-based reefs alone. In the Philippines, coral reefs supply 11-29% of the total fisheries production (Ahmed *et al.* 2005b). The reef fisheries industry predominantly relies on a reef-based supply of food for wide-ranging pelagic or inshore species. Conversely, reef invertebrates play a somewhat minor – but nonetheless important – role, particularly molluscs (clams, oysters, squid, and cuttlefish) and other lobsters and prawns. In addition, seaweeds may be collected from reefs for food, medicinal components and agar, limestone can be used for building materials, cement, coral and other reef species can be used for jewellery and souvenirs, marine aquarium trade (Birkeland 1997).

It is widely acknowledged that coral reefs have a critically important role in the primary production of tropical oceans: they provide the basis for a complex food web and harbour thousands of species (Bryant *et al.* 1998 in Saxby, 2000). Despite this, studies that define and evaluate the ecological services of coral reefs are surprisingly few (Moberg and Folke 1999). A key function of coral reefs is inorganic and organic carbon production, which supports a diversity of species and complex food webs found in marine reef areas (McClanahan *et al.* 2002). Coral reefs also allow the formation of protected habitats such as mangroves and seagrasses, both of which provide nursery habitat for up to ninety percent of commercial fish species (Hoegh-Guldberg and Hoegh-Guldberg 2000). In addition, reefs represent important natural barriers and buffers to environmental hazards, which results in a protective function not only for coastal human communities, but also for vulnerable inshore and estuarine environments.

Whilst the fisheries and tourism industries and ecosystem services are the most easily recognised of the roles performed by reef systems, there are many other minor functions which are important in the overall contribution of coral reefs to social and economic functions. For example, in most coastal communities, coral reef fisheries are an important source of food and income for local populations. Reef fish and other marine life provide a significant source of protein for many third world countries, and it is thus possible to regard coral reefs as important to the maintenance of human health in poor coastal communities. Reefs can also deliver social and cultural values to coastal communities by aesthetic values, amenity arising from knowledge that wild and natural areas exist and perceived value for future generations. Incorporated in this are values from scientific research and by way of their educational, medicinal and pharmaceutical uses (Ahmed *et al.* 2002). For example, reefs can provide monitoring of pollution and stressors in the marine environment, and a record of global climate (Moberg and Folke 1999).

The Great Barrier Reef World Heritage Area is a multiple-use marine resource (Driml 1994). The key sectors of the GBR that contribute to economic output (e.g. commercial fishing, recreational fishing from private motor boats, charter boat tourism, island resort tourism, island camping, and research) have been studied for over twenty years (Driml 1987). Almost fifteen years ago, the total economic value of the GBR was estimated at $923 million, with the predominant categories being tourism ($682M), commercial fishing ($128M), recreational fishing and boating ($94M) and research ($19M) (Driml 1994). More recently, it was estimated that $US1 billion is generated by the GBR (Hoegh-Guldberg 1999). However, neither of these estimates includes the economic values of conservation, ecosystem services, and cultural and other social values: many economists argue that these non-use and intrinsic values provided by coral reef ecosystems should not be neglected (Bateman *et al.* 2002). This highlights a key problem in reef evaluation studies: the need to identify suitable methods to assess and value the variety of different services and functions represented by coral reef ecosystems. Similarly, few studies of the financial values of the direct uses of the Great Barrier Reef Marine Park have considered the flow-on impact on different sectors, nor the effects of linkages between key activities, with other industries in the state economy (KPMG 2000).

1.6.2 Methods and tools for reef valuation

Compared with its biophysical aspects, the social and economic environment of the GBR has been poorly examined. In fact, on a worldwide scale, the full economic value of coral reefs has hardly been studied. According to Spurgeon (1992), this has occurred for two reasons. Firstly, natural habitats – and the marine reef habitat in particular – may have a number of off-site benefits that occur away from the main ecosystem area, and are thus either forgotten, or made very difficult to identify. A simple example of this is the value that inshore coral reefs represent as a breeding ground for reef fish: as adult fish later migrate to other waters before being captured for recreational or commercial harvest, their value may be counted under another ecosystem (e.g. offshore deepwater environments), rather than under their reef of origin. The second is that reefs often have multiple benefits, of which many cannot (or have not) been readily accounted.

Natural resources such as coral reef ecosystems can be valued for both their use and non-use values (Figure 1.16). Alternatively, values can be grouped into marketable values (associated with products, functions and services), and non-marketable values (associated with opportunity, cultural significance, bequest and simple existence) (Ahmed *et al.* 2002). The latter includes values relevant to people who may never visit a reef, but who gain benefit from the fact that it exists in its natural state (Driml 1994). Either of these categories (use/non-use or marketable/non-marketable) can be combined to provide a 'Total Economic Value' (TEV), a figure that estimates the overall contribution of an asset or system to the social, economic and environmental functioning of society. The TEV is thus particularly useful because, unlike some other economic instruments, it can quantify the entire range of values represented by a natural asset. However, the TEV itself can only proceed once such values have been identified and appropriately measured. It is often difficult for the values of environmental assets to be measured, and traditional techniques (such as microeconomics) are rarely used (Cesar and Chong 2002). However, in recent decades, a host of new natural resource valuation techniques have been developed: the most common methods used to value coral reef ecosystems are summarised in Table 1.3, and discussed in detail below.

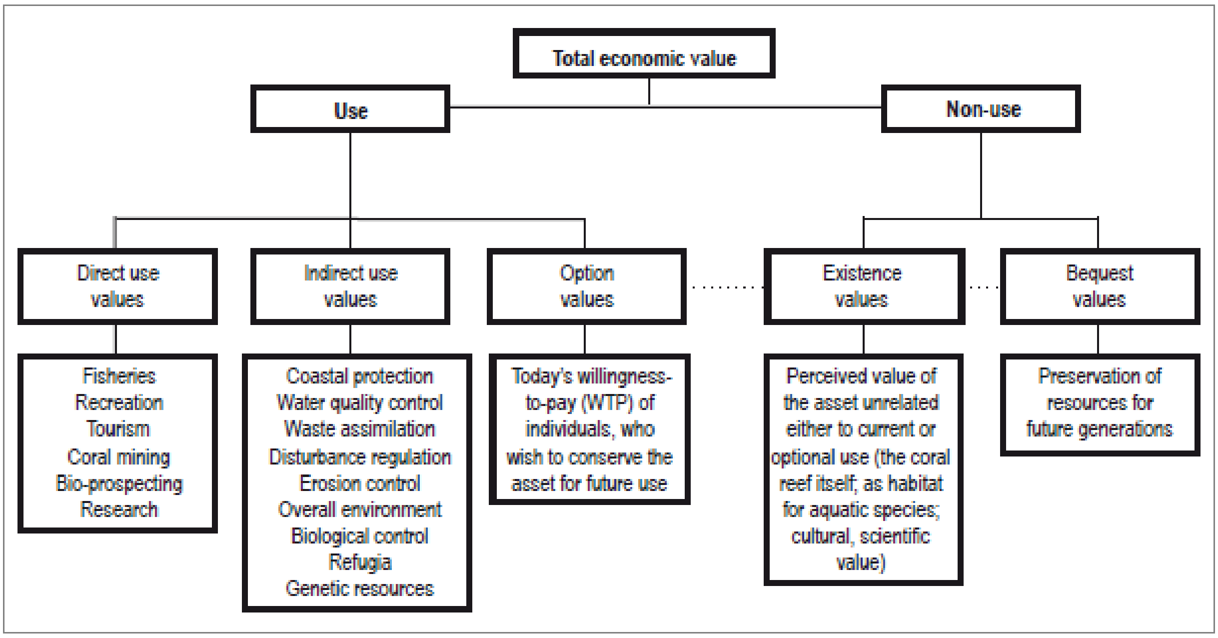

Figure 1.16: Economic values of coral reefs (Source: As presented in Ahmed *et al.* 2002).

Table 1.3: Types of values and corresponding valuation methods (Source: Cesar and Chong 2002).

Type of Value	Valuation Method
Direct Use Values:	
– Tourism (consumer surplus)	Travel Cost (TC)
– Tourism (producer surplus)	Effect on Production (EoP)
– Fisheries	Effect on Production (EoP)
Indirect Use Values	
– Coastal Protection	Replacement Costs (RC); Damage Costs (DC)
Non-use Values	
Option Values	Contingent Valuation Method (CVM)
Quasi-option Values	Contingent Valuation Method (CVM)
Bequest Values	Contingent Valuation Method (CVM)
Existence Values	Contingent Valuation Method (CVM)

1.6.2.1 Direct and/or economic values

Most studies on the direct use values of coral reefs focus on dollar figures generated from fish production (harvests), recreation, tourism, research and education. Purely economic valuations (for example, of trade or business) can be calculated using gross revenues and expenditure, however, these are also often combined with other methods that focus on measuring sociological and/or cultural benefits (Fürst *et al.* 2000). Ultimately, a variety of methods can (and should) be used to achieve a complete and comprehensive socio-economic valuation of the direct uses of coral reefs. Key tools for this are summarised in Table 1.4.

The economic value of an industry such as fishing can be measured simply as net revenue – that is, gross revenue minus costs of production. However, in a detailed economic analysis, the costs of production should also take account of the full costs of fishing including a component for management of the fishery to avoid environmental damage (Driml 1994). The Effect on Production (EoP) method is another approach that can be used to estimate values in terms of revenue generated (Ahmed *et al.* 2005a), and is particularly useful for assessments of readily marketable values, such as income from commercial fishing harvests. However, the EoP approach is limited by the need to first determine, and then model, the relationships between the condition of environmental resources and the services that they provide (Burke and Prager 2006). For example, to determine the effects of climate change on fisheries production, the EoP would require an understanding of how reef fish populations are affected by coral bleaching (e.g. which species may be lost).

Table 1.4: Key tools for measuring direct values of coral reef ecosystems.

Tool / Method	Likely application / direct value measured
Net revenue	Any reef-related market: tourism, fisheries, research, pharmaceuticals
Effect on productivity	Commercial fisheries
Net factor income	Commercial fisheries, tourism industry
Replacement cost	Fishing (commercial or recreational), tourism
Travel cost	Tourism, recreational fishing

Where goods and services traded in a market result in a net producer surplus, the Net Factor Income (NFI) method may be a more appropriate tool (Ngazy *et al.* n. d.). This method estimates the physical relationship between the coral reef area and economic activity (such as fishing or tourism). When estimating producer surplus, the Replacement Cost (RC) method can be used (similar methods include the substitution cost and/or damage cost approaches) (Ahmed *et al.* 2005a). These work by determining the costs involved in replacing a service provided by a natural resource, if the resource becomes damaged or lost and the service can no longer be provided (Burke and Prager 2006). Here, the costs associated with providing marketable goods and services by alternate means help to generate those values that are attributable to the reef. For example, when estimated via RC methodology, the 'coastal protection' value represented by a coral reef would be assumed to be equivalent to the cost of installing artificial barrier devices sufficient to prevent storm surges and beach erosion (Spurgeon 1992). However, there is some debate about whether or not this technique is misleading because producers do not necessarily use the alternative presented (Anderson and Rockel 1991; Woodward and Wui 2001). Furthermore, the figures created by the RC method can be misleading because such values may not ever be spent on the 'replacement': the protective capacity of the fringing reef on the Philippine coastline was estimated at US$22 billion in 1991, but it is unlikely that such an amount would ever be spent to replace it with an artificial device (Spurgeon 1992).

Another method commonly used to estimate the use values of coral reefs generated from recreational or tourism activities is the Travel Cost (TC) method (Freeman 1993). Here, expenditure on travel is used to estimate how much visitors would be willing to pay for entry, if entry fees were charged at market rates (Driml 1994). TC is often used to determine the recreational use values of a natural resource, but it needs considerably detailed data and analysis to perform properly (Burke and Prager 2006).

Finally, input-output analysis was used in early studies of the GBR by Driml (1987) and also more recently (Access Economics 2005). This approach provides information on the flow-on effects of an increase or decrease in output from a sector in terms of output, income and employment. This is important since economic activity in any reef-based industry (e.g. commercial or recreational fishing; tourism) will ultimately have 'leakage' or 'multiplier effects': that is, contribute to the creation of trades, goods and services for other sectors (AGO 2004). However, input-output analysis is somewhat limiting: it does not show whether a particular activity is generating net economic benefits or if a change in the activity will alter net economic benefits. Furthermore, many of the examined reef sectors represented only small industries in each of the studied locations, so results could be interpreted only on orders of magnitude (Driml 1987).

1.6.2.2 Non-market, non-use and indirect use values

> "In considering the potential socioeconomic impacts of climate change and coral bleaching on the GBR, it is important to recognise that 'many of the things which are 'valuable' are not usually measured in dollar terms; the amenity derived from the existence of natural environments and cultural heritage features are important examples. It is also the case that many of the things we do to generate goods and services traded for dollars often have unpriced detrimental or beneficial side-effects (termed externalities)." (Driml 1994, p. 56).

Reefs offer many diverse values and benefits, many of which are non-market or non-use, and therefore unpriced (Ahmed *et al.* 2002). Non-use values are those that can be derived from a natural resource without the need for current human uses (Spurgeon 1992). Existence, bequest, option and quasi-option values are examples of non-use values arising from coral reefs: existence value is the value people place on ensuring an area remains as a natural environment; bequest value is the value they place on ensuring it is available to future generations; option value is the value they place on ensuring that it remains as a natural environment so that they may visit in the future; and quasi-option value is the value people place on conserving a natural environment so that new information may emerge from it in the future (Driml 1994).

In order to measure the economic benefits of indirect uses (or those direct uses where competitive markets do not exist), economists usually attempt to measure 'willingness to pay' (WTP) using a variety of valuation techniques. Common methods used for non-market ecosystem valuation include the travel cost, replacement cost and EoP methods (as discussed earlier) (Ahmed *et al.* 2005a; Nam and Son 2004 in Ahmed 2003). It is sometimes feasible to extrapolate non-use and indirect values by examining, for example, contributions to coral reef and marine life charity funds (Spurgeon 1992). Hedonic pricing is yet another option that requires all attributes or characteristics of a given resource to be identified, and then valued, based on the relationships between market prices and certain characteristics of goods and services. However, it often requires large data sets, which can be a disadvantage (Burke and Prager 2006).

In contrast to indirect or non-market uses, the non-use (sometimes known as intrinsic) values of coral reefs can be measured only by stated preference (SP) techniques (Bateman *et al.* 2002). The SP technique works by asking survey participants hypothetical questions in order to gauge their responses to a range of choices. A key outcome is to measure the collective 'willingness to pay' for a particular benefit, sometimes by using hypothetical payment scenarios. The need to use SP techniques to measure the non-use values of coral reefs arises because they are not associated with observable market transactions, and/or they have no "behavioural trail" – that is, they have no effect on consumption patterns that lead to observable changes in the price or quantity of a resource traded (Bateman *et al.* 2002).

There are two different approaches to SP evaluations: choice modelling (CM) and contingent valuation (CVM). Choice modelling is a valuation technique that relies dually on both stated and revealed preference data and can be used in the evaluation of environmental assets (Wielgus *et al.* 2002). CVM is the most commonly used of all the valuation techniques developed to estimate the non-use value of coral reefs. The challenge of CVM is usually to develop an appropriate and careful survey design and to apply suitable (usually complex) statistical analyses to collected data (Burke and Prager 2006).

There are several limitations associated with SP techniques: they are based on what people say rather than what they do, they can be complex and time consuming (both in execution and in statistical analyses), and the validity of the method often depends on the rigour of the survey technique (the type and style of questions asked and/or scenarios posed). Pilot trials are often useful to overcome the latter.

1.6.2.3 Cost benefit analyses

The last method being used to estimate the use value generated from coral reef ecosystems is Cost Benefit Analysis (CBA): this involves an evaluation of the different advantages and disadvantages that may be associated with alternative solutions which are compared, ideally in money terms.

1.6.3 Previous reef evaluation studies

Cartier and Ruitenbeek (1999) have already provided a review of literature which discusses various valuation studies conducted on marine and coral reef biodiversity during the 1980s and 1990s. The key findings arising from this synthesis were as follows:

- CVM, TC and WTP methodologies and CBA were amongst the most commonly used approaches to measuring the value of reef habitats;
- Studies evaluating existence and option values are rare (only one study available);
- Most studies are focused on recreational and tourism use values;
- Fisheries remain the most commonly valued ‘product’ of coral reefs; however, the natural systems that underlie fisheries harvests appear poorly explained, or ignored;
- Education and research values have been acknowledged, with their valuation based upon expenditure estimates or allocations from funding institutions;
- The only ecological function of reef habitats that has been appropriately valued is that of coastal protection; and
- No studies have evaluated the value of reefs as a genetic resource.

(Cartier and Ruitenbeek 1999)

More recent research on the economic value of coral reefs has been focused mostly on direct use values of coral reefs, with indirect use and non-use values studied to a lesser extent (Chong and Cesar 2004). There is a recurring theme to focus on changes to the tourism and fishing industries (Moberg and Folke 1999). This may be a function of commercial benefits being amongst the easiest reef values to measure, but also possibly because they are of most interest to stakeholders (in particular, policy decision-makers). By comparison, few studies have assessed the coastal protection role of barrier reefs or the cultural values of coral reefs in general. The additional case studies described below are examples of reef evaluation studies that have been conducted since 1999.

Fürst and others (2000) valued the costs and benefits of marine conservation in the Caribbean using a combination of WTP methodology and gross revenues and expenditure to value the reef. Heavy tourist visitation numbers, combined with the release of untreated sewage and intensive coastal development have resulted in reduced live coral cover and species diversity on the reefs surrounding the Caribbean’s Bonaire Island (Fürst *et al.* 2000). Divers were surveyed using a questionnaire that examined their environmental perceptions; visitors were surveyed on the motivational and expenditure aspects of their visits upon departing the reef, as dive operators and hoteliers were also surveyed before figures were cross-checked with existing tourism statistics.

Wielgus and others (2002) used a new approach to ascertain the economic costs of degradation to coral reefs with regard to loss of attributes important to SCUBA divers. This ‘dose-response function’ was able show a positive relationships between the number of SCUBA dives in an area per year and the percentage of damaged corals, in order to estimate the economic costs associated to the coral (and hence diver welfare). However, an important limitation of this approach was noted: there may be a discontinuity relationship evident, where an acute increase in coral damage occurs. This is particularly likely in the case of combinations or synergies of stressors (Wielgus *et al.* 2002).

A report by Hand (2003) assessed the economic and social impacts associated with the rezoning of the GBR as proposed by the GBRMPA, as well as reporting upon various studies that have attempted to calculate the TEV of different reef systems (Table 1.5). The study determined that the GBR is of considerable economic value to both the Queensland and Australian economies, particularly with respect to the tourism industry. Furthermore, the social value of the reef lies with its various Indigenous cultural, natural heritage and ecosystem and scarcity values, amongst others (Hand 2003). The overall conclusion of the report was that rezoning of the reef to increase the total protected habitat area had good economic grounds and was likely to contribute to improved environmental outcomes in the Great Barrier Reef World Heritage Area.

Carr and Mendelsohn (2003) examined both domestic and international travel as part of an extensive travel cost analysis of the value of the GBR. This study estimated that the annual recreational benefits of the GBR were worth between $US700 million to $US1.6 billion. However, the authors acknowledged that a number of problems were inherent with using international data for the calculation of TC values, since international air fares are not necessarily reflective of distance travelled; and many countries have no visitors to the GBR. Access Economics (2005) completed an economic contribution study of the GBR, which estimated the worth of market-related transactions only (see Table 1.6): non-market activities, including cultural and indigenous activities, were not included. The authors focused on key industries (tourism, commercial fishing and cultural and recreational activity) and concentrated on value added, gross product and employment values.

Table 1.5: Total Economic Value (TEV) estimates for reef systems (Source: As presented in Hand 2003).

Location	Annual Value per Hectare ($US)	Net Present Value per Hectare ($US)	Total NPV ($US)	Author
Galapagos Islands	120	2,400	2.8 billion	De Groot 1992
Montego Bay, Jamaica	23,820 – 61,200	0.4 million – 1.03 million	273 million – 702 million	Gustavson 1998
Indonesian coral reefs	1,373 – 11,619	22,883 – 193,650	N/A	Cesar 1996
All of the Earth's coral reefs	6,076	101,267	N/A	Costanza *et al.* 1998
Florida Keys National Marine Sanctuary	N/A	50,000	44.6 billion	NOAA 1995
Hanauma Bay, Oahu	N/A	N/A	1.05 billion	Cesar *et al.* 2002
Kihei Coast, Maui	N/A	N/A	522 million	Cesar *et al.* 2002
Kona Coast, Hawaii	N/A	N/A	389 million	Cesar *et al.* 2002
Hawaii – overall	N/A	N/A	9.7 billion	Cesar *et al.* 2002

Table 1.6: Total economic contribution value of tourism, commercial fishing and cultural / recreational industries in 2004/2005 (Source: Access Economics 2005).

Estimated value	GBR Marine Park Catchment	Queensland	Australia
Value-added	$3.5b per annum	$4.3b per annum	$5.1b per annum
Gross product	$4.1b per annum	$4.9b per annum	$5.8b per annum
Employment (full time equivalent basis)	51,000 persons	59,000 persons	63,000 persons

Most recently, Burke and Prager (2006) attempted to evaluate the socio-economic contribution of coral reefs to the Caribbean region by focusing on estimating values for food production, tourism and recreation, and shoreline protection, in a manner that was realistic and replicable. Several of the key non-market values of coral reefs were omitted from the estimates, but the authors concluded that this was acceptable since the complexities and difficulties associated with estimating obscure services (such as existence values) would thwart the overall evaluation process and render it inaccurate (Burke and Prager 2006). The project instead aimed to provide a rigorous, yet simple and cost- and labour-effective, methodology for the economic valuation of reefs, through the following approaches:

1. Tourism profiles were developed: what were the key features that attracted visitors – sun, sea, sand, ecotourism, diving? How much of the total tourist dollar spent in coastal areas should be subtracted or reduced because not all tourism is directly reef-related (such as miscellaneous shopping, recreation, accommodation)? The net economic benefits of reef-related tourism were then determined based on returned revenues minus costs.
2. Fishing profiles were developed: what revenues were derived from which fisheries related to reefs? The net economic benefits of reef-related fishing were determined based on returned revenues minus costs.
3. Shoreline protection services were gauged by making assumptions about probability and nature of storm events, natural erosion, and development of human settlements for a given coastal area. The 'avoided damages' approach was used to value shoreline protection services, which makes an estimate of the costs associated with repairing shoreline damage, should adequate reef protection not be present. This required the use of advanced formulae.

Finally, Kragt *et al.* (2006) have assessed the effects of reef degradation on the tourism industry on the GBR using a contingent behaviour model and a hypothetical reef damage scenario. The study suggested that decline in reef quality (defined as reduced coral cover, coral diversity and fish diversity) would lead to a reduction in tourist visitation and expenditure and loss of approximately $A136 million annually (Kragt *et al.* 2006). However, this figure did not take into account the possible flow-on effects resulting from a decline in the number of tourist trips to the GBR (e.g. businesses other than tourism).

1.6.4 Limitations of reef valuations

Despite the existence of several methodologies for valuing the goods and services provided by reef habitats, there are ongoing limitations on the ability to calculate TEV for coral reef ecosystems. The first of is that many reef uses are mutually exclusive or only partly compatible, such as use and non-use options. This means that even where separate benefits can be appropriately valued; it is not acceptable to simply sum the final figures together to obtain a TEV. For example, the economic benefits derived from the commercial fishing industry cannot necessarily be added to the economic benefits derived from the reef as a biological resource, since not all fisheries activities are sustainable – therefore, both values cannot be enjoyed simultaneously. However, this is not the case for all reef values, as many others can co-exist: for most businesses, opportunity costs for coral reefs are minimal since many activities can coexist on a reef (e.g. different types of tourism) (Fürst *et al.* 2000). Similarly, if one use is conservation and/or protection, then alternate uses may be limited (e.g. to research and education). However, Spurgeon (1992) circumvented the problem of valuing competing and co-existing values by assigning the six main economic uses of reefs, and then providing a separate reef valuation framework for each scenario (Figure 1.17).

Secondly, indirect use or non-use values are less easily quantified when compared with direct use values, since they are often 'intangible' to individuals (Fürst *et al.* 2000). Furthermore, most methods used to value non-market uses of reefs and other natural resources are subjective by nature and this causes substantial variability in outcomes (Ahmed *et al.* 2003). The major stakeholders related to coral reefs are those people living adjacent to the reef, whose livelihood revolves around the direct extraction, processing and sale of reef resources, and whose homes and land are sheltered by the reefs from wave action (Ahmed *et al.* 2002). Hence, non-use valuation approaches that rely on subjective indicators (such as data from interviews and surveys) may be complicated by the different values and opinions shared by this diverse group:

- Many stakeholders have different economic bases and thus attach very different 'economic' values to different components of the reef. This affects some measurements such as willingness-to-pay methodologies.
- Cultural differences between stakeholder groups may also affect the economic value placed on certain goods and services provided by reefs.
- There is no consistency of knowledge about the values the reef system supports: some stakeholders are better informed than others and this may influence their opinions
- Non-market valuations are also made difficult by the local, national and international scales by which coral reefs can be considered, since the types of goods, services and functions offered by the reef, and their associated value, differs at different spatial scales

(Ahmed *et al.* 2002)

Aggregation of Economic Values.

This illustrates the different proportions of each use and non-use value which could be added together in different reef use zones to give the Total Economic Value of a reef system. The relevant proportions for each value are indicated here as multipliers which are further explained in the text.

	Economic use zones					
	Preservation	Tourism	Multi use	Sust. Extr.	Mariculture	Non. Sust.
Financial benefits						
Direct Uses						
Fisheries	0	0	m	1	>1	0
Aquarium trade	0	0	m	1	s	0
Curio trade	0	0	m	1	s	0
Pharmaceutical	0	0	m	1	s	0
Other Industrial	0	0	m	1	s	0
Genetic material	0	0	m	1	s	0
Construction	0	0	s	1	s	>1
Tourism	s	1	m	s	s	0
Research	1	m	m	m	m	s
Social benefits						
Indirect Uses						
Biological support	1	m	m	m	s	0
Coastal zone ext.	1	1	1	1	1	0
Physical protection	1	1	1	1	1	0
Global life support	1	1	1	1	1	0
Social services	0	0	m	1	s	0
Indirect costs						
Navigational	−1	−1	−1	−1	−1	0
Other Economic Value						
Uses						
Product consumer surplus	0	0	m	1	s	0
Tourism consumer surplus	s	1	m	s	s	0
Social Value	0	s	1	1	s	0
Research Value	1	m	m	m	m	s
Educational Value	s	1	m	s	s	0
Non-uses						
Option Value	1	m	s	s	s	0
Existence Value	1	s	s	s	s	0
Intrinsic Value	1	1	m	m	m	0

Proportion of value which can be summed for each zone: s=some of the value (0.01–0.50) 0=none of the value.
1=full sustainable value. >1=increased value. m=most of the value (0.51–0.99) −1=negative value.

Figure 1.17: Possible method for aggregating economic values associated with coral reefs, as presented in Spurgeon (1992). Note: Reef zones were defined as follows: Preservation – no activities other than research and possibly some exclusive tourism; Tourism – reef devoted to non-extractive tourism; Multiple use ('Multi use') – a combination of extractive uses and tourism; Sustainable Extraction ('Sust. Extr.') – reef used primarily for extraction with some tourism; Mariculture – reef devoted to intensive but sustainable farming of reef organisms; Non-sustainable Use ('Non. Sust.') – destruction of reefs by a variety of uses would forfeit virtually all other reef benefits).

Non-market and/or indirect uses of coral reefs (such as the GBR) remain the most difficult to value in dollar terms yet they are the main reason for the special protection emphasis given to these areas (Driml 1994). Valuations of non-market and indirect uses are also vital in providing key information needed for management decisions. Thus, with consistent design and methodology, and careful attention to survey structure, coral reef valuation studies should be able to compare the relative value of non-market goods and services across sites, and better approximate the total value afforded by reef systems (Ahmed *et al.* 2003).

Thirdly, a poor understanding of relationships between climate change, coral bleaching, coral mortality and likely reef recovery rates represents a considerable impediment to any valuation of the socio-economic impacts of bleaching. The unpredictability of global climatic modelling and the lack of baseline biophysical information on which to estimate the likely effects of temperature increases on coral reefs mean that calculations of the resulting socio-economic consequences may be inappropriate. However, in one study, Wilkinson *et al.* (1999) tried to account for the uncertainties involved in predicting the biophysical effects on reef functioning by evaluating the economic costs of coral bleaching on the Indian Ocean using two different scenarios: one 'optimistic' prediction where reef damage is minor and recovery is rapid, and a second 'pessimistic' forecast where reef damage is significant and followed by very slow or no recovery. (This work was also later revisited by Cesar and Chong (2002) and Ahmed *et al.* (2005a)). Similar scenario-type modelling has been completed for the GBR, with the IPCC climate change predictions resulting in different consequences for the inshore, mid-shelf and outer-shelf regions of the GBR adjoining the Townsville region (Done *et al.* 2003). In Wilkinson *et al.*'s (1999) study, the socio-economic impacts identified with the 'optimistic' scenario were as follows:

- A slight decrease in tourism-generated income and employment, as some divers stay home or go elsewhere, and few tourists alter their behavior;
- Some change in the fish species composition. (e.g. an initial increase in fish productivity due to larger numbers of herbivores; balanced by catch reductions for rare ornamental fish); and
- No major change in the coastal protection function, as bio-erosion of dead reefs and coral growth of new recruits even each other out.

Conversely, the impacts aligned with the 'pessimistic' scenario were:

- Major direct losses in tourism income and employment, especially when charismatic marine fauna disappear as a result of bleaching and resulting mortality;
- Fish productivity drops considerably as the reef structure disintegrates, resulting in less protein in the diet, particularly for coastal communities; and
- The reef ceases to function as a protective barrier, resulting in increased coastal erosion.

The estimated economic damages associated with the optimistic scenario for the Indian Ocean coral reefs were $US706 million (Wilkinson *et al.* 1999). This compared with an estimate of $US8,190 million for the pessimistic option, resulting from a five-fold increase in lost food production; a ten-fold increase in lost tourism and recreation value, and the introduction of over $2,100 million in disturbance costs associated with coastal protection (Wilkinson *et al.* 1999). It is important to note, however, that this study did not account for losses in the environmental services of reefs (e.g. biodiversity functions), nor for non-use values of reefs (e.g. existence, bequest values). The high degree of uncertainty associated with predicting the biophysical aspects – and, in turn, the socio-economic consequences – of climate change on coral reefs thus remains a key limitation in measuring likely effects.

1.7 Linkages between climate change, bleaching and socio-economic impacts

The socio-economic implications of the biophysical effects of climate change on coral reef ecosystems – both on the GBR and elsewhere – are numerous, often hard to identify and usually difficult to value accurately. Furthermore, the 'limited reversibility' of many of the biophysical impacts of climate change signals a key concern, should key reef-based industries be adversely affected. Many reef industries can be said to have 'climatic dependency': agriculture, tourism, fisheries and forestries, recreation and others (AGO 2004).

1.7.1 Biophysical effects

The impacts of species losses, reduced species richness and local extinction are particularly difficult to determine. It is known that finely branched corals are often the most susceptible species, whilst massive and encrusting colonies survive (Loya *et al.* 2001). Hence, an understanding of how the discrete contribution that fine corals themselves make to the dive, tourism and/or marine aquarium trades is necessary, if one is to estimate the likely effects of climate change on the reef. By contrast, the economic impacts of reduced productivity and reef resilience are obvious: not only could the GBR could become limited in its carrying capacity for marine organisms used in commercial and recreational harvests (reef fish, crustacea, aquarium organisms), but the ability for the reef to tolerate high numbers of tourists may also be compromised, thus forcing limits on visitor densities.

Changes in the composition of coral communities on the GBR may be important in terms of socio-economic values if, for example, the specialist species that are lost play important roles in the generation of reef wealth (e.g. rare or attractive coral species that are keenly sought by divers). Phase shifts can lead to overall decreases in biodiversity, which is important in two ways:

- Biodiversity is a good indicator of ecosystem resilience, and in itself represents an important reef 'value'; and
- Many tourism-based activities place a high value on biodiversity, thus regions with reduced diversity may offer less in terms of tourism outcomes.

The implications of species replacements are far more difficult to determine. There are very few data available regarding the likely taxa which may replace the vulnerable coral, fish and other marine species that are lost due to increases in seawater temperature. Thus, it is impossible to predict whether new inhabitants therefore represent a greater, lesser, or equal value to the reef and its extended community (commercial fishing, tourism, etc.) in terms of socio-economic benefits. Phase shifts and species replacements can have important implications where new species have different social and economic values to the original flora and fauna. Fish, coral and other marine species (e.g. crustacea) of economic or ecological importance may be lost entirely. For example, studies by Berumen and Pratchett (2006) have shown that whilst highly disturbed reef communities appear to recover in terms of coral and reef fish abundance, the speciation patterns in the recovered reef sections were actually very different to the original reef.

Recovery rates of corals may also play an important role in influencing socio-economic impacts: if system recovery takes too long, tourism and fishing numbers may be severely impacted. This is particularly important where reefs in other, neighbouring regions remain unaffected, since a large proportion of the tourism trade may shift to those pristine locations, and not return. In addition, it is important to recognise that reef sections which have 'recovered' in the biological or ecological sense may differ considerably in the species composition, biological assemblages and reef-building capacity from the original landscape (Done 1999; Wilkinson 1999). This may have important implications where the socio-economic values of the reef are actually dependent on specific reef species assemblages (e.g. the presence of a particularly attractive or rare coral may attract divers).

Changes in fish communities may be significant, or not: conceivably, the new fish communities could have less socio-economic value than their reef fish counterparts; certainly the reduction in species diversity suggests lost ecological values. Key table species or sought-after sport fish may be important and cannot be satisfactorily replaced by others. The characteristics of a reef habitat (e.g. high coral cover, sandy lagoon floor, and the particular species assemblages present) will determine the species of fish caught, but also the requisite fishing gear needed by commercial fishers and the areas in which fishing effort is concentrated (e.g. known 'hotspots' for good catches such as large coral heads). Wholesale changes in the architecture of the reef and its fish and coral species assemblages may therefore impact in several ways on a commercial fishery. Firstly, loss of coral cover and reef fish carrying capacity may result in decreased catch rates. Secondly, changes in species assemblages may produce changes in catch composition, particularly towards herbivorous species which are lower in (commercial) value. Thirdly, if fishers decide to change their target species and/or the locations in which they fish, new equipment may be required.

Finally, reef fish that inhabit coral ecosystems provide many ecosystem services, such as the regulation of marine food webs and sediment processes; represent links to ecosystems (e.g. estuarine, mangrove and seagrass communities) and may perform a range of social, economic and cultural services (Holmlund and Hammer 1999). The economic value of these functions is difficult to pinpoint.

1.7.2 Focus: Tourism and other recreational activities

> "It is apparent that the very environment that makes the GBR region attractive for tourism may also increase its vulnerability to some or all of these [climate change] pressures … the close proximity of the reef to the coast that allows for short travel times, and the narrowness and shallowness of the continental shelf." (AGO 2004, p. 47).

Marine tourism has the highest commercial value of any activity in the GBR (CRC Reef Research Centre 2003). The tourism industry is the largest employer in many coastal Queensland towns (Hughes *et al.* 2007a) and the largest source of employment in the GBR catchment (almost 48,000 employed persons) (Productivity Commission 2003). In 2004/2005, marine tourism associated with the GBR generated over $US4.5 billion and provided around 63,000 full-time equivalent jobs. People employed in the tourism industry in the GBR lagoon and catchment represent 33% of Queensland's and nine percent of Australia's total employment in tourism (Productivity Commission 2003); with 85% of tourist activity centred on the Cairns and Whitsunday reef regions

The biophysical impacts of climate change on tropical reefs may significantly impact the tourism values of the GBR. Given that a large percentage of GBR tourism is based on exploration of the natural environment, the health of the reef and its surrounding waters is likely to be a key influence on tourist numbers (AGO 2004). For example, Moscardo and Ormsby (2004) listed the top nine drivers nominated by tourists as being important in their decision to visit the reef:

1. See the beauty of the GBR;
2. See coral in its natural surroundings;

3. See/swim with marine life;
4. Get close to nature;
5. Do something new and different;
6. To have a learning/educational experience;
7. Fun and excitement;
8. Rest and relax; and
9. Be with friends/family.

The first four ranked of these are dependent upon the ecological health of the reef. Similarly, when asked to rank the key features influencing their reef experience, many tourists nominated characteristics that are either directly or indirectly linked with climate change, coral bleaching, and the consequent decline in reef habitat and biological complexity (see Table 1.7) .

Table 1.7: Key features that influence the overall reef experience for tourists (Source: Shafer *et al.* 1998 in Moscardo and Ormsby 2004). Mean was calculated based on a seven-point response format, where 1 = very negatively; 2 = negatively; 3 = somewhat negatively; 4 = no influence either way; 5 = somewhat positively; 6 = positively; and 7 = very positively.

Condition Item	Mean	Standard deviation
Helpfulness of the staff	6.14	0.91
Types of fish I saw	6.12	0.95
Size of the coral I saw	6.11	0.95
Total amount of coral I saw	6.09	0.94
Number of different kinds of coral	6.03	0.98
Information provided by the staff	5.98	1.01
Colour of the fish I saw	5.90	1.08
Clarity (visibility) of the ocean water	5.88	1.22
Colour of the corals I saw	5.85	1.17
Appearance of the staff	5.81	1.05
Total number of fish I saw	5.80	1.18
Behaviour of the fish	5.64	1.15
Size of the fish I saw	5.62	1.12
Temperature of the air	5.29	1.44
Depth of the water	5.28	1.23
Temperature of the water	5.20	1.46
Number of animals other than coral or fish that I saw	5.16	1.39
Sea conditions during the trip from / to shore	5.05	1.60
Number of people on the main boat	4.65	1.33
Number of people snorkelling	4.65	1.40
Currents in the water around the reef	4.62	1.26
Number of people on the pontoon	4.61	1.35
Amount of wind	4.50	1.45
Number of human-made objects in the water	4.34	1.47

It has already been established that key biological factors such as species richness and coral growth rates are intrinsically important to the overall tourism value of the reef. Intimate linkages are present between biophysical attributes and the socio-economic value of a healthily functioning reef ecosystem. Wielgus and others (2002) determined that the most valuable attributes of coral reefs in terms of recreational and tourism services were coral-reef biodiversity, live coral cover and water clarity (Wielgus *et al.* 2002). A high bottom cover of coral, a variety of shapes, a kaleidoscope of colours and large colony sizes and 'appearance' values are all linked with tourism and diving values (Done *et al.* 2003). For the diving trade, Ngazy *et al.* (n. d.) found the most important reef characteristics to be overall reef condition, variety of fish, wilderness feeling and visibility. All these criteria are linked with the concept of reef aesthetics, which appears to a common theme for tourism satisfaction overall.

According to a scale developed by Done *et al.* (2003) (see Table 1.8), sublethal, very low and low impact bleach events on coral reefs that cause setbacks to coral appearance for less than one year are expected to have little detrimental effect on tourism amenity. The variability of different corals, and different fish, to coral bleaching, climate change and other stressors makes for a 'patchy' distribution of affected areas over the entire reef. This can be troublesome for tourism enterprises: though the reality may be only a localised area of reef affected in the short term, public perception may instead be a picture of prolonged and widespread devastation (Done *et al.* 2003).

Table 1.8: Description of bleaching impact levels on coral communities using the ReefState model (Adapted from Done *et al.* 2003).

Level	Effects	Number of years of setback
Sublethal	Whitening of coral tissue, but no mortality. No effect on percentage of reef covered by live coral, species composition, relative abundance	Zero-year setback
Very low level impact	Whitening occurs, some corals injured, vulnerable species die	3 years for ecology; 0.5 years for appearance
Low level impact	Less common, vulnerable corals die and become supplanted by survivors	5.0 years for ecology; 1.0 year for appearance
Medium level impact	Visually dominant corals suffer injury and death, though coral recruitment still likely	10 years for ecology; 5 years for appearance
High level impact	Dominant corals die *en masse*, few remnants available to stimulate regrowth	20 years for ecology; 10 years for appearance
Catastrophic impact	Ancient and dominant corals die en masse, regrowth takes longer than a decade	50 years for ecology; 10 years for appearance.

Other studies have shown that tourists are also interested in the conservation, biodiversity and other biophysical values of reefs, thus, some branches of tourism may be unaffected by coral bleaching. For example, a large proportion of reef tourism deals with 'sun, sea, sand'– the location and the lifestyle. In areas such as the Wet Tropics (Daintree, Cape Tribulation), tourism is based on a suite of experiences that may include resort lifestyles, rainforest and reef activities, foods and beverages, and other attractions. Hence, damage to small sections of the reef may not overly affect tourism numbers, as visitors come not only for that small component, but also others. Thus, to a large extent, species-level changes may not be of consequence so long as the overall reef experience remains.

The AGO (2004) raised the following key questions during their study of impacts of climate change, coral bleaching and amenity for tourism in the GBR community:

- Are the reefs in the GBR region uniformly at risk of exposure to the conditions that promote coral bleaching?
- If so, will all places respond equivalently, or will there be some places where the impact is merely cosmetic whilst in others it is catastrophic?
- If not, can we identify reefs that will systematically escape exposure to bleaching conditions as a function of their local environmental settings (e.g. in relation to currents and surrounding sea floor depths)?

There is the possibility that mild bleach events, where coral tissue is discoloured but coral mortality does not occur, could even be used as a novel tourism attraction in the short term (AGO 2004).

There is also an indirect contribution of tourism to the GBR: some of the goods and services provided by the reef are actually used as inputs into businesses other than reef-based tourism operators: e.g. businesses directly supplying goods and services to tourism outside the GBRCA (Access Economics 2005). Accommodation costs indicate that recreational fishing overlaps a little with tourism and the estimated overlap is 25% (Access Economics 2005).

1.7.3 Focus: Recreation and recreational fishing

Recreational fishing is an important lifestyle activity for residents and visitors to the GBR lagoon and catchment. Unlike commercial fishing, there is no requirement for recreational fishers to record fishing catch and effort. This makes the productivity of recreational fishing much more difficult to quantify and survey methods are often used to estimate the economies of recreational fishing and fishing-related expenditure (Hand 2003). Nevertheless, the Queensland Fisheries Services estimated expenditure on recreational fishing in the GBR lagoon and catchment at $240 million in 1999-2000 (almost half the total spent on recreational fishing in Queensland) (Productivity Commission 2003, p. 93).

The exact implications of coral bleaching on the recreational fishing sector are hard to quantify. The quality of recreational fishing in the GBR is likely to be affected by coral bleaching. However, this is not necessarily constrained to the prospect of returning home empty-handed because target fish species were not available. Indeed, much of the enjoyment derived from fishing may not, in fact, be related to actually catching fish: ‘to rest and relax’, ‘to enjoy nature’ and ‘to be outdoors’ are all motivations of recreational fishers (Moscardo and Ormsby 2004). In addition, localised differences exist in the recreation values of different reef sections. Hand (2003) highlighted this through his summary of GBR-related willingness-to-pay studies, which reported values of:

- $8 per adult visitor to unnamed coral sites;
- $15.12 to visit Green Island; and
- $36.29 to experience Heron Island.

1.7.4 Focus: Commercial fishing / marine harvests

The commercial fishing sector contributes both economically and socially to the functioning of the GBR, including its regional communities and townships, and is expected to increase in terms of annual gross value of production in the next few decades (Productivity Commission 2003). Similarly, the aquaculture industry in the GBR has consistently contributed approximately $50 million for the past several years (Access Economics 2005).

There are several uncertainties regarding the precise correlation between bleaching and temperature change, and between bleaching and reef fish assemblages. Hence, at this stage, it can only be said that the effects of climate change coral bleaching on reef fisheries appear most likely to be observed in the long-term through changes in the habitat complexity and associated speciation changes. This could involve, for example, the loss of key target species and/or replacement by less desirable or undesirable species. A simple example of this would be a gradual trend towards dominance of herbivorous fish that feed on turfing algae (which themselves would dominate due to lost coral cover), possibly combined with an increase in predatory pelagic fish species.

1.7.5 Views of the community

Gauging the capacity of reef communities to identify, understand, predict and adapt/react to the stresses of climate change and its biophysical effects on the reef is an important part of socio-economic studies. In a study by the AGO (2004, p. 6), stakeholders identified water quality impacts resulting from climate change as the key priority, followed by the impacts of global warming on the reef itself – particularly the physiological effects and their secondary impacts on tourism in the Cairns-GBR region.

1.7.6 Potential trade-offs and advantages

Thus far, this review of literature has examined the likely negative consequences of climate change and coral bleaching on the socio-economic health of reef-based communities on Queensland's eastern seaboard. Certainly, the adverse implications of reef degradation are of uppermost importance. However, it is also possible that some advantageous outcomes would arise. For example:

- What tradeoffs may there be between protecting biodiversity and then using those protected areas to generate income (e.g. charging higher rates to take tourists to limited-access areas)?
- Job creation for persons involved in reef research and reef protection / regeneration; and
- Given that coral bleaching is known to be highly variable (both spatially and temporally), it is conceivable that reef degradation may be limited to particularly vulnerable regions (e.g. tropical, inshore and densely-populated environments in the Whitsundays). Hence, whilst lost trade from tourism and other reef-based industries may affect the immediate area, there is the potential for those industries to be shifted to other locales where they can stimulate regional economies and development (e.g. Cairns, elsewhere).

1.8 Limitations in measuring the socio-economic impacts of climate change on the Great Barrier Reef

AGO (2004) suggested that a key limitation of many climate change impact assessments is their focus on system interactions between non-human components of climate systems. This was considered a downfall since "future changes in land use, demographics and economic development are likely to have as great, or greater, indirect impacts on regional ecosystems and on socio-economics than the direct impacts of climate change". To overcome this, an integrated assessment approach for the GBR was suggested, incorporating with the following steps:

- Development of climate change projections specific to the region;
- Development of regional models of land use and socio-economic change;
- Development of spatial vulnerability and/or hazard maps;
- Integrated assessment models for the key sectors in the region;
- Cost-benefit analysis of different adaptation options; and
- Expansion of monitoring to reduce knowledge gaps.

This would contribute to an overall integrated assessment and monitoring and management plan as shown in Figure 1.18.

1.8.1 Identifying critical gaps

There are a number of barriers that limit the current understanding of climate change impacts on the reef and consequently, the ability of reef-based sectors to adapt and respond to the challenges of coral bleaching in their respective industries. The Cairns community identified the several key knowledge gaps, including the need to:

- Enhance/improve long-term monitoring programs;
- Improve regional climate change scenarios;
- Improve the existing knowledge base regarding a variety of natural systems;
- Improve socio-economic knowledge for the region; and
- Improve integration of climate change studies currently under way in the region.

(AGO 2004, p. 6)

Following their economic valuation of the GBR, Access Economics (2005) identified a number of impediments to economic studies:

1. The need to make available up-to-date and consistent data on which a foundation can be built for economic analyses;
2. The need to quantify the value of scientific research and monitoring in the GBR, since this is an important activity; and
3. A lack of data for scuba diving, snorkelling and boating.

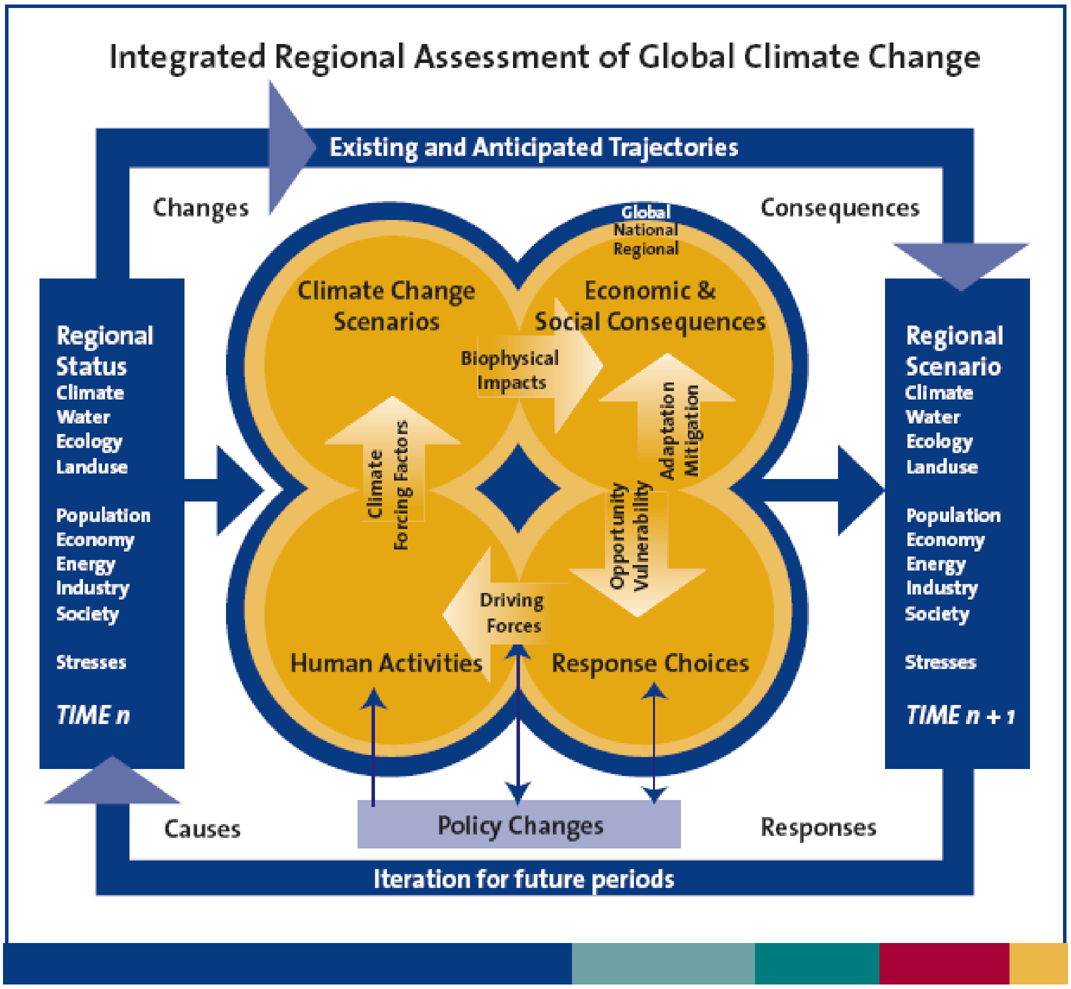

Figure 1.18: Suggested method for measuring impacts of global climate change (Source: As presented in AGO 2004).

The ability to predict the likely socio-economic impacts resulting from reef degradation under different climate change scenarios is hampered by three critical gaps:

1. **Uncertainties surrounding global climate change predictions**, particularly for Australia and on the GBR specifically. For example, an expected increase in average surface seawater temperatures may be available to within 1-5°C, but this interval covers a wide range of bleaching scenarios.
2. **A lack of understanding of the biophysical processes involved in reef functioning**, particularly species-level effects, the possibilities for phase shifts and species replacement following mass coral bleaching events, the ability for system recovery under different degradation scenarios and its extrapolations to for whole-of-reef productivity; and the likely socio-economic implications associated with each of these aspects, for example:
   - How turf-algal or phytoplankton-based species assemblages are compare with coral-based systems in terms of biodiversity, ecosystem and socio-economic values; and
   - Whether the replacement fish species assemblages associated with highly disturbed (or completely destroyed) coral systems are of comparable value to recreational and commercial fishers and the wider tourism industry.

3. **A lack of sufficient baseline data and/or methodology related to the measurement of potential socio-economic losses** associated with bleach events in the GBR, given the paucity of previous reef evaluation studies conducted worldwide.

Currently, the world's understanding of the underpinning biology of tropical reef systems with respect to coral bleaching, change in coral and reef fish community assemblages and species replacement scenarios is in its infancy:

> "How coral reefs ecosystems will change in response to the reduced viability of reef-building corals [e.g. due to climate change] is a complex question. In theoretical terms, a huge number of endpoints are possible, given the number of interactions that make up a coral reef ecosystem" (Hoegh-Guldberg 1999, p. 857).

An understanding of the key aspects of the biophysical nature of the reef could be obtained by answering questions relating to:

- Species-specific information on the types of corals affected; estimates of extent of mortality; and potential for recovery (if any);
- Species-specific information on the types of reef fish (and other marine species) that are affected, either directly or indirectly, by coral decline; the extent of such effects and potential for recovery (e.g. expect a complete loss of red emperor);
- Expectations for species replacement following bleaching (coral, fish, other organisms), including species-specific information about the likely new, adapted species assemblages (where possible); and
- An indication of the productivity, economic and social value(s) associated with key reef species that are, or have the potential to be, affected by bleaching (e.g. coral, fish, other), particularly with respect to key sectors such as commercial/recreational fishing and tourism.

In essence, this information (when collated) would become an inventory of key species, their thermal stress susceptibility, their potential for replacement by other species, and the socio-economic values associated with the 'existing', 'disturbed' and/or 'replaced' species and systems. Differences in the original biophysical conditions of reefs within the target study locations (e.g. Cairns, Townsville and Mackay-Whitsunday) may also contribute to uncertainty. The reef habitat is very different in these locales and hence may respond differently to the challenges of climate. For example, when surveyed in 2004, reefs in the Keppel region (near Rockhampton) featured much lower hard coral biodiversity than those of the Whitsundays (Sweatman *et al.* 2004).

Data that link biophysical changes in the GBR occurring due to climate change with key economic and social impacts are conspicuous in their absence from existing studies, with the notable exception of a recent analysis conducted by Fenton and Beeden[2]. The climate change scenarios that have already been modelled for the GBR allow for a prediction of the extent of loss, but not its specifics in terms of affected coral species, and, in turn, affected reef fish species. This makes the job of predicting socio-economic impacts very difficult. Until these at-risk coral and reef-fish species can be identified, it will not be possible to make a comprehensive determination of changes to reef productivity and aesthetics, and hence to assess properly the socio-economic impacts of climate change on the GBR with regards to tourism, fishing and other key activities. Furthermore, such scenarios may need to be

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[2] Unpublished report to the Great Barrier Reef Marine Park Authority.

modelled separately for target study areas (e.g. Cairns, Townsville, Mackay/Whitsunday) since different tourism, recreational and commercial values are present in each, and because different reef ecosystems and tolerances/stressors are expected (e.g. predicted scenarios for tropical/subtropical/inshore/offshore reefs). Furthermore, as noted by Done *et al.* (2003, p. 2), 'the implications of [climate change] risk need to be considered within the context of other known influences of reef ecology and reef-based enterprises … adverse effects of crown-of-thorns starfish, runoff of pollutants, freshwater, silts and nutrients, diseases, fishing and harvesting … and the benefits of integrated management of the reef as a world heritage and marine park area'.

1.9 Creating climate change scenarios to assist in assessing the socio-economic impacts of climate change on the GBR

The degree of sensitivity of corals to bleaching in the Great Barrier Reef (GBR) varies spatially and with species type. Bleaching is exacerbated by stressors such as sediments, pesticides and nutrients. Land management practices are thus key variables influencing the spatial and temporal resilience of the reef. Whilst the biophysical responses of the coral (bleaching) to climate are now known and spatially mapped, the impact of bleaching on productivity, species diversity (including linkages to reef fish assemblages) and aesthetics is not well known, nor extensively researched. In order to properly evaluate the socioeconomic impacts of climate change on the reef with respect to coral bleaching, an understanding of these direct and indirect impacts is required. As evidenced from the above review, the data needed to support this analysis are yet to be systematically collected. Given the potential number and depth of socioeconomic impacts likely to occur from climate change resulting in coral bleaching on the GBR, some form of preliminary assessment is required. Clearly, an assessment is needed to underpin the development of appropriate policy and institutional frameworks to ameliorate, adapt or mitigate the risks faced by government, the business sector and the community. In addition, this information is required to ensure management practices are optimised to encourage reef resilience and to adequately address socioeconomic concerns.

1.9.1 Method for creating scenarios

The socioeconomic impacts of coral reef bleaching cannot be comprehensively determined unless the biophysical responses of coral are evaluated with respect to their implications for reef-based and reef-related industries. In order to address this deficiency, a technical expert panel was formed to report on the published work that relates to this field of interest and to draw on well-credentialed scientific expertise to map the likely or expected responses. This considered analytical perspective has distilled a suite of foundation scenarios that will enable a socio-economic analysis to be completed based upon key levels of risk and uncertainty. Each scenario has been purposely developed to be both plausible and generic in nature: this will accommodate incremental improvements in future analyses as scientific knowledge of climate change and the biophysical responses of the reef matures. The framework of the analyses is also designed to ensure that the short term responses, long term implications and intergenerational interests can be evaluated.

1.9.2 The scenarios

The scenarios developed for the socioeconomic assessment exercise are illustrated in Table 1.9. It should be noted that these were prepared as discussion items and to enable the social and economic implications of climate change to be assessed. As such, the scenarios should be regarded only as first approximations of the biophysical outcomes expected on the reef, given increases in water temperatures. Each scenario is based on current expert knowledge and published research regarding the impacts of temperature on coral bleaching, in addition to other relevant studies of various perturbations on reef productivity and the associated responses of marine assemblages. For example, climate shifts resulting in temperature rises of between two and three degrees are expected to have a catastrophic impact on coral reef assemblages: these rises are at the lowest end of the changes projected by the IPCC. Thus, there is a reasonable degree of confidence that serious biophysical impacts on the reef due to climate change will occur in the future.

The overall aim of socioeconomic analysis is to achieve a better understanding of how changes on the reef will affect users and other individuals dependent on the GBR ecosystem, particularly:

- The understanding and perceptions of climate change amongst different reef users;
- Management needs – both for 'here and now' and for each of the four degradation scenarios;
- Expected changes in the way of doing business, as prompted by each scenario;
- Social obligations and improved adaptive capacity of social systems;
- Management support for climate change mitigation;
- Contributing to identifying support for GRB management;
- How important coral is to tourism, commercial and recreational fishing;
- How easy will it be to change in terms of the adaptive capacity of the target industries;
- The extent that coral bleaching will impact on the tourist industry (given that the reef is only one component of the overall package offered to tourists);
- What behavioural changes are expected or needed and how these translate economically;
- How coral bleaching will affect the region's global market share of tourism;
- The influence of the media, and the influence of the biophysical changes on the media;
- The potential to expand or exploit new and emerging industries (either reef-based, or based on the likely replacement ecosystems);
- The current extent of knowledge of the impacts of climate change on the GBR by SMEs within the GBR catchment area;
- The relationship between the extent and source of knowledge of climate change impacts and possible SME strategies for mitigation against the possible impacts;
- Estimations of likely impacts of climate change scenarios on the profitability of SMEs in the GBR catchment area;
- Intergenerational intentions of SME owners in response the climate change scenarios;
- An estimation of the level of trust and credibility afforded science and institutional knowledge of climate change impacts on the GBR;
- Increased understanding of the impacts of climate change on the GBR and SME size, structure and relationship to the GBR;
- Requirement for targeted technical expertise focused at SMEs; and
- SME adaptive capacity and preferred business strategies for mitigation of perceived impacts of climate change.

Table 1.9: Four scenarios of the biophysical responses, and consequent socio-economic impacts, that could result from climate change pressures on the Great Barrier Reef.

Scenario	Key change	Likely biophysical responses	Impact(s) on Tourism, Recreational Fishing and Commercial Fishing
1. Minor (as expected from a 1° temperature rise)	Coral bleaching events occur, on average, ***less than once every ten years***	• Some increase in the adaptive capacity of reef organisms due to the loss of some of the more sensitive species • Some short term shifts in coral species composition and visual appeal (< 2 to 5 years before recovery) • No major structural decay in the hard coral • Minor short term impacts on the obligate fish species (e.g. those dependent upon the sensitive coral species) • No major changes to remaining reef fish assemblages • Ecosystem function regeneration remains likely due to local recruitment of coral and zooxanthellae, with subsequent habitat restoration expected • >80% retention of species diversity expected • No major long term decrease in aesthetic appeal	*Tourism* – short term but recurrent losses of visual amenity, particularly of onshore and shallow fringing reefs (deeper, offshore sites least likely to be affected) *Recreational fishing* – short term recurrent losses in catch *Commercial fishing* – short term recurrent losses in catch
2. Moderate (as expected from a 1-2°C temperature rise)	Coral bleaching events occur, on average, ***more than once every five years***	• 25% loss of total coral cover • 50% loss of the cover of 'iconic' coral species • Significant shifts in coral species composition, with a trend expected toward crusting organisms as opposed to soft and branching coral • The long term structural integrity of the reef is affected as coral degrades to rubble • Moderate increases in turfing algae • Obligate reef fish species are strongly affected; representing 10% of the total fish speciation found on reefs. (Obligate species typically include the highly colourful small fish species such as damselfish) • Increase in herbivorous fish species (and consequent impact on fishers, given that these species cannot be captured on baited lines) • Some decline expected in the predatory fish species which existed prior to bleach events • The inherent or quasi long term stability and regenerative ability of the reef declines	*Tourism* – enduring loss of visual amenity of onshore and shallow reefs (deeper and offshore reefs may be less affected) *Recreational Fishing* – sustained loss in catch *Commercial Fishing* – sustained loss in catch

Scenario	Key change	Likely biophysical responses	Impact(s) on Tourism, Recreational Fishing and Commercial Fishing
3. Major (as expected from a > 3°C rise)	Coral bleaching events occur, on average, ***at least annually***	1. Complete loss of all existing coral species, resulting in one of two major pathways (a) ungrazed and over fertilised; and (b) over grazed • Total loss of reef structure (reduced to rubble) • All carbonate accretions gone • Area colonised by turfing algae • Loss of all obligate fish species • 70% decline in the total number of pre existing fish species • decline in species richness and diversity across the entire reef ecosystem (coral, fish, invertebrates, others)	*Tourism* – total loss of visual amenity of reef *Recreational fishing* – inability to catch fish due to replacement by herbivorous species; focus switches to spear fishing only *Commercial fishing* – complete loss of line fishing of reef species; some accompanying shifts in pelagic species expected
4. Alternative estate	A total decline in reef structure and a replacement ecosystem develops	• Replacement ecosystem becomes based upon on seagrass and turfing algal plant communities • Concomitant increase in herbivorous species of fish and invertebrates • Consequent species composition changes of predatory fish species to in response to increased herbivorous prey	*Tourism* – some tourist interest in decaying coral and replacement seagrass species *Recreational Fishing* – long term scenario may see some replacement in non-reef predator species *Commercial Fishing* – shift to netting of herbivorous species as basis for catch – some shift in pelagic species expected

1.10 Conclusion

Global warming is a serious and significant concern for the health of biological communities worldwide. Degradation of coral reefs due to global climate change and bleaching will have profound effects worldwide. The consequences of climate change on the GBR are numerous and potentially include losses in, and changes to, reef biodiversity, ecology, appearance and flow-on effects to the many recreational and economic activities that are dependent on a healthy and functioning reef ecosystem.

The GBR region is heavily dependent on the fisheries and tourism sectors. Since these sectors are likely to be adversely affected by climate change, the vulnerability of the entire GBR region to climate change is high (AGO 2004). However, the extent to which increased temperatures and coral bleaching will affect key industries will be tempered by (a) the exact nature of global and local climate changes and (b) the way(s) in which the communities of the GBR (both biological and social) responds and/or adapts (AGO 2004).

The costs of coral reef degradation are expected to exceed billions of dollars annually, and to have extensive economic and social impacts for millions of people (Dunstan 1998 in Saxby, 2000). However, to date, there have been insufficient studies to provide estimates of the socio-economic impacts of coral reef decline associated with climate change and coral bleaching. This review has provided an overview of the range of techniques that can be employed in valuing the range of both direct and indirect uses of coral reefs, as well as identifying some of the key impediments to the measurement of socio-economic impacts associated with climate change and coral bleaching. By providing information relating to the socio-economic losses from coral reef degradation, and the different values reefs provide, the current and future management of coral reef resources can be improved, despite the uncertainties associated with climate change. In the interim, the biophysical and socio-economic loses may be minimised by effective management of human impacts for reductions in global climate change and an optimisation of the reef's considerable powers of recovery (Wilkinson 1996).

2. A Socio-economic Characterisation of Three Target Areas within the Great Barrier Reef Marine Park

2.1 Introduction

This chapter presents a socioeconomic characterisation of three target regions (Cairns, Townsville and Mackay-Whitsundays) located within the Great Barrier Reef Marine Park catchment, including regional variations where appropriate. The characterisations are followed by an analysis of the economic contributions made by the reef-dependent industries of tourism, commercial fishing and recreational fishing. This information has been derived from the latest available data at time of writing, from sources including the Australian Bureau of Statistics (ABS), the Queensland Office of Economic and Statistical Research (OESR) and the Population Information Forecasting Unit (PIFU) of the Queensland Department of Local Government, Planning, Sport and Recreation as well as other reputable statistical publishers such as the Productivity Commission. The information provides a framework for assessing the socio-economic impacts of coral bleaching in the Great Barrier Reef.

2.2 Delineation of target regions in the GBR

Given the geographic size and the socioeconomic complexity of the GBR catchment, this socioeconomic characterisation has been focussed on only three target areas; the Cairns Coastal region, the Townsville Coastal region, and the Mackay Coastal region. These targets were chosen because each represents a key regional centre, and, taken together, the three areas represent a good geographic cross section of the communities fringing the GBR. The characterisations for each region include the thematic areas of:

- Demographics;
- Income;
- Education;
- Employment; and
- Regional socio-economic indices.

These fields can be used to understand the diversity and robustness of the communities and their economies. In addition, the socioeconomic characterisation also represents a simple measure of the degree of resilience those economies might have in offsetting the impacts associated with a given climate change scenario, particularly any decline in productivity due to lost 'attractiveness' of the reef. For example, those communities that feature economic diversity, healthy age-sex structures, a diversity of skills and employment, are well educated and display above average socioeconomic indices are, generally speaking, more likely to have the ability to rapidly adapt and/or mitigate climate impacts to the benefit of their social wellbeing.

2.3 Target Area 1: The Cairns coastal region

The first target area is Cairns Coastal region, which is a major tourism area and economic service hub for the northern portion of the GBR. For the purposes of this report, the Cairns Coastal region includes the local government areas (LGAs) of Cairns (C), Cardwell (S), Douglas (S), Johnstone (S)[3]. This region covers 9,007 km^2 or 0.5% of the State's area.

2.3.1 Population and population growth to 2026

The estimated resident population as at 30 June 2006 was 180,066, which represented 4.4% of the State's population. Population projections from OESR (2006) indicate that the Cairns regional population will increase by fifty percent in the next 25 years, from 160,847 people in 2001 to 240,512 people in 2026. The average annual growth rate for the region between 2001 and 2026 will be 1.6%, slightly less than the Queensland average of 1.7% over the same period (OESR, 2006).

Cairns City is predicted to remain the most populous area in the region, with a projected population of 188,532 persons by 2026 (Figure 2.1); and Cairns City's share of the region's population is expected to rise from 53.9% in 2001 to 59.8% by 2026. The area surrounding Innisfail and Mission Beach (formerly, Johnstone Shire) will be the second most concentrated area of population, with 20,145 persons expected by 2026 (OESR, 2007).

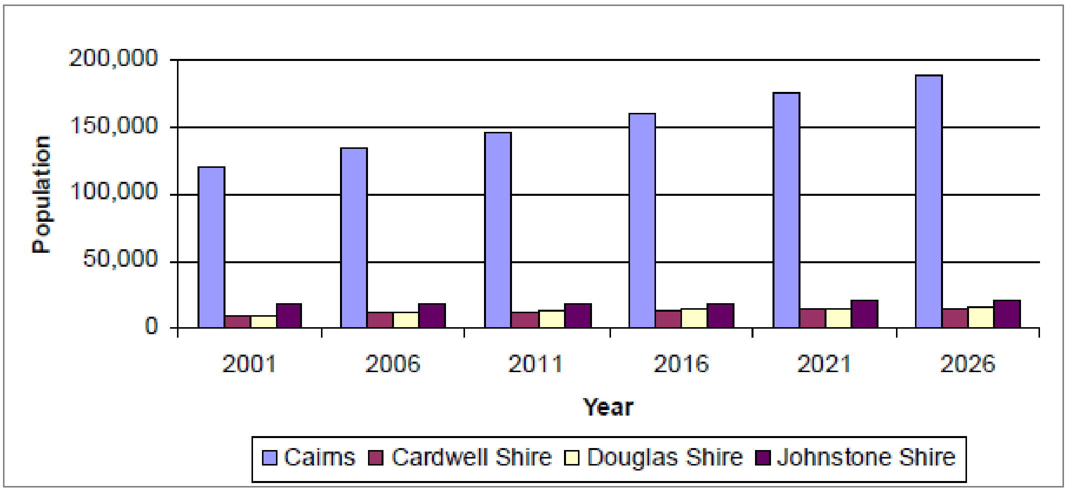

Figure 2.1: Projected population growth for 2001-2006 in the Cairns region, based on Local Government Area (Source: OESR 2006).

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[2] These LGAs were separate entities at the time the socio-economic characterisation was conducted. However, following local government amalgamations during early 2008, Johnstone and Cardwell Shire Councils combined into the Cassowary Coast Regional Council, whilst Cairns and Cardwell became Cairns Regional Council.

2.3.2 Cairns Region age structure

Cairns coastal region has a median age of 37 years, slightly older than Queensland's median of 36 years. The age structures of the five LGAs within the target region are summarised in Table 2.1. The region is dominated by the Cairns population, which accounts for nearly three-quarters of the entire region's population. Generally, about forty percent of the Cairns regional population is represented by adults in the 25-54 years age bracket, and usually with less than ten percent being aged (65 years or greater) (Figure 2.2). One exception is Johnstone shire, where approximately fifteen percent of residents are aged 65 years or older.

Table 2.1: Age structure of Cairns coastal region, 2006, according to Local Government Area (Source: ABS Census of Population and Housing 2006).

LGA	Population by Age				
	0-14	**15-24**	**25-54**	**55-64**	**65+**
Cairns	28,077	16,530	58,533	12,961	11,338
Cardwell	2,024	999	3,970	1,263	1,272
Douglas	1,950	1,109	4,809	1,326	1,000
Johnstone	3,909	2,091	7,316	2,149	2,790
Cairns Coastal Region	37,273	21,362	77,062	18,694	17,385

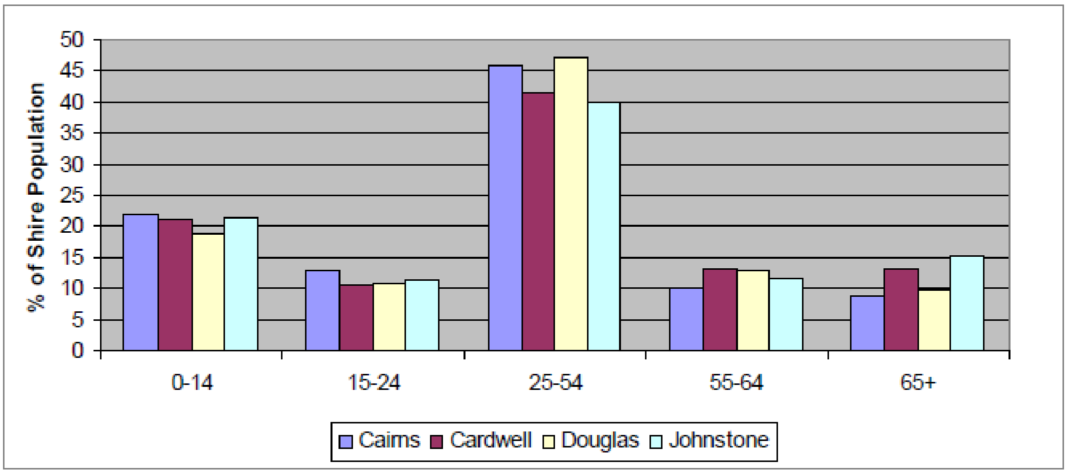

Figure 2.2: Age categories in the Cairns coastal region, as a percentage of the total population of each Local Government Area (Source: ABS Census of Population and Housing 2006).

The overall age structure for the Cairns region is graphically presented in Figure 2.3. This clearly illustrates that the largest age cohort in the region is the 25-54 year cohort. However, there is also a strong base of population aged 0-24 years, which is indicative of growth in the region, together with a narrow band of residents aged 65 years and older. The loss of youth, as demonstrated in the low percentage of the 15-24 year age cohort, is also of note for the community (Figure 2.3).

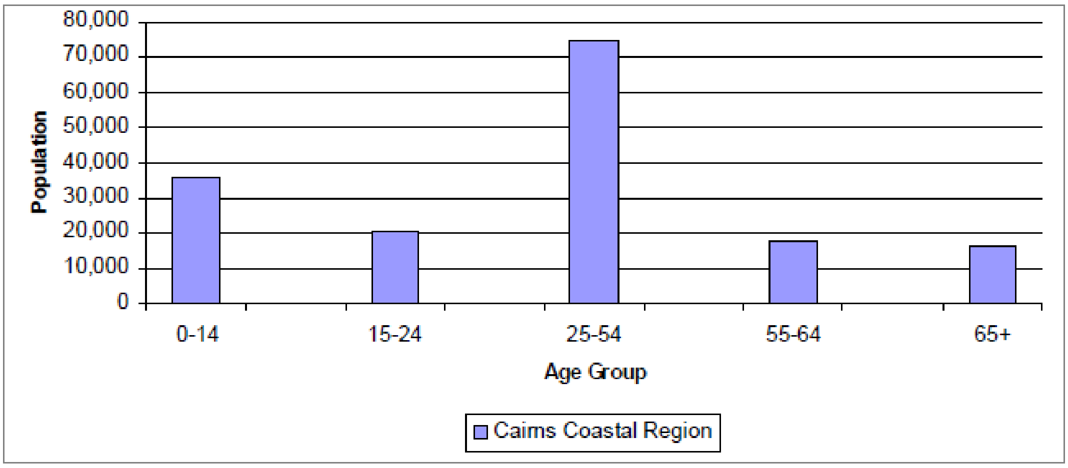

Figure 2.3: Age structure of the Cairns coastal region (Source: ABS Census of Population and Housing 2006).

2.3.3 Selected socio-economic characteristics

Income is important in predicting economic activity and as an indicator of regional welfare[4]. Statistics from the ABS 2006 Census illustrates considerable income variability across the Cairns coastal region, with the median weekly household income ranging from $1,051 in Cairns (higher than the Queensland average) to just $817 in Johnstone. The average income figure for the Cairns coastal area was $924 per week, which was $109 a week less than the state figure ($1,033).

Table 2.2 summaries a number of other selected socio-economic indicators for the five local government areas within the target region. These indicate that the Cairns region can be characterised as one with a median age similar to that of the State, but with a disproportionately high number of Indigenous persons (some areas have well over double the usual rate of Indigenous residents). Median weekly rents and housing loan repayments are in some cases, similar to the state figure (e.g. in Cairns and Douglas); yet in other areas, prices appear comparatively cheaper (Cardwell, Johnstone).

2.3.4 Post-school education qualifications

An indication of a community's capacity to respond and adapt to change can often be obtained by examining the proportion of community's population that hold post-school educational qualifications. In 2006, 20.2% of the Cairns region with post-school educational qualifications held a bachelor degree or higher; this compared with 26% for the State as a whole (ABS 2006) (Table 2.3). The proportion of the labour force holding graduate and postgraduate degrees was also slightly lower than the Queensland average. However, of those that held formal qualifications, the Cairns coastal region had a slightly higher proportion of its labour force holding advanced diplomas and certificates than the rest of the state (Table 2.3).

[4] In economics the term welfare is used to measure an individual's wellbeing. For the broader community social welfare reflects the wellbeing of the broader community when consideration is given to a range of variables affecting the state of the economy and the overall quality of life enjoyed by its residents.

Table 2.2: Socio-economic characteristics, Cairns coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Category	Local Government Area				Queensland
	Cairns (C)	Cardwell (S)	Douglas (S)	Johnstone (S)	
Population (Place of usual residence)	127,438	9,529	10,193	18,256	3,904,532
Median age (years)	35	39	37	40	36
Indigenous persons (% of total)	7.8	8.4	8	8.2	3.3
One parent families (% of total)	18.4	14	14.1	16	15.9
Lone person households (% of total)	21.4	20.5	18.2	21.2	21
Median household income ($/weekly)	1,051	842	984	817	1,033
Median rent ($/weekly)	195	135	190	135	200
Median housing loan repayment ($/monthly)	1,268	953	1,200	867	1,300
Dwelling fully owned (% of total)	22.9	36.8	25.8	39	30.4

Table 2.3: Post-school educational qualifications, Cairns coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Qualification	Cairns coastal region		Queensland
	# population	% population	% population
Postgraduate Degree	1,589	2.3	3.9
Graduate Diploma and Graduate Certificate	1,291	1.9	2.3
Bachelor Degree	10,998	16.0	19.8
Advanced Diploma and Diploma	8,414	12.3	13.1
Certificate:			
Certificate nfd*	1,906	2.8	3
Certificate III and IV	22,564	32.9	30.2
Certificate I and II	1,523	2.2	2.3
Total	25,993	37.9	35.5
Level of education inadequately described	2,077	3.0	2.7
Level of education not stated	18,183	26.5	22.7
Total	**68,545**		

2.3.5 Labour force

At the time of the 2006 census, the overall unemployment rate in the Cairns Coastal Region was 4.2%, compared with 4.8% for Queensland (Table 2.4). Moreover, some 63.6% of the Cairns coastal region was employed in full-time positions, slightly higher than the Queensland average of 61.6%; whilst 25.8% worked part-time, which was slightly less than the Queensland average of 27.7%.

Table 2.4: Labour force status in the Cairns coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Status	Cairns Coastal Region		Queensland	
	# population	% of labour force	# population	% of labour force
Employed, worked full-time	53,318	63.6	1,180,891	61.6
Employed, worked part-time	21,647	25.8	530,503	27.7
Employed, away from work	2,971	3.5	63,507	3.3
Hours worked not stated	2,320	2.8	50,095	2.6
Unemployed, looking for full-time work	2,214	2.6	55,141	2.9
Unemployed, looking for part-time work	1,307	1.6	35,808	1.9
Total labour force	83,777		1,915,945	
Not in the labour force	33,665	26.0	971,833	31.4
Not stated	12,013	9.3	210,219	6.8
Total	**129,455**		**3,097,997**	

2.3.6 Employment by industry and occupation

Cairns has a reasonably diverse economy, but one with is nonetheless largely focussed on reef-derived activities. In 2006, retail trade was the largest employment sector in the Cairns coastal region (12.5%) followed by accommodation and food services (11%) (Table 2.5). The high of persons engaged in the hospitality and accommodation sector is a likely reflection of the reef (and other) tourism dependency of the region. Other industries important to the Cairns region include the construction sector (9.8%) and the health care and social assistance sector (9.1%). The manufacturing sector within the Cairns region employs just 6.5% of all workers, considerably less than the statewide average, which stands at 9.9%.

Table 2.6 provides summary information of employment by occupation across the region, which is useful in identifying the key nature of workers in the region. In the Cairns Coastal region, technicians and trade workers represented the largest proportion of the region's labour force (at 16.5%), some 0.9% higher than the Queensland average. Other occupations with relatively large numbers of employed persons included professionals (14.5%), and clerical and administrative workers (13.5%), with the proportion of professionals in the region being 2.6% lower than the Queensland average.

Table 2.5: Employment by industry in the Cairns coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Industry sector	Cairns Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Agriculture, forestry and fishing	3,364	4.2	61,734	3.4
Mining	676	0.8	30,720	1.7
Manufacturing	5,204	6.5	180,212	9.9
Electricity, gas, water and waste services	821	1.0	18,541	1.0
Construction	7,841	9.8	164,936	9.0
Wholesale trade	2,408	3.0	72,075	3.9
Retail trade	10,034	12.5	212,423	11.6
Accommodation and food services	8,813	11.0	127,631	7.0
Transport, postal and warehousing	5,440	6.8	92,614	5.1
Information media and telecommunications	843	1.1	26,346	1.4
Financial and insurance services	1,497	1.9	52,036	2.9
Rental, hiring and real estate services	1,806	2.3	37,983	2.1
Professional, scientific and technical services	3,347	4.2	102,415	5.6
Administrative and support services	3,092	3.9	55,705	3.1
Public administration and safety	5,601	7.0	122,416	6.7
Education and training	5,501	6.9	139,089	7.6
Health care and social assistance	7,334	9.1	186,335	10.2
Arts and recreation services	1,312	1.6	24,625	1.3
Other services	3,003	3.7	68,361	3.7
Inadequately described/Not stated	2,315	2.9	48,801	2.7
Total	**80,252**	**100.0**	**1,824,998**	**100.0**

Table 2.6: Employment by occupation in the Cairns coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Occupation (ANZSCO)	Cairns Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Managers	10,313	12.9	225,695	12.4
Professionals	11,655	14.5	312,866	17.1
Technicians and trades workers	13,274	16.5	280,342	15.4
Community and personal service workers	8,657	10.8	166,400	9.1
Clerical and administrative workers	10,746	13.4	269,198	14.8
Sales workers	8,745	10.9	189,040	10.4
Machinery operators and drivers	5,201	6.5	132,113	7.2
Labourers	10,239	12.8	217,251	11.9
Inadequately described/Not stated	1,424	1.8	32,094	1.8
Total	**80,254**	**100**	**1,824,999**	**100**

2.3.7 Socio-economic disadvantage / advantage

The Census provides extensive information on a number of social and economic concepts, such as income, education and occupation. However, these attributes in isolation may not give a full indication of the social and economic conditions in a particular area. The Socio Economic Index for Areas (SEIFA) tool was developed by the ABS and is populated by data collected during national censuses. The SEIFA combines all these items into a series of four indexes, each summarising a different aspect of the level of socio-economic wellbeing in an area. The four indexes, as noted by the ABS (2003), are:

1. **Index of Disadvantage:** This index is derived from attributes such as income, educational attainment, unemployment, and dwellings without motor vehicles. In particular it focuses on low income earners, relatively lower educational attainment and high unemployment.
2. **Index of Advantage/Disadvantage:** This index is a continuum of advantage to disadvantage, and was first introduced in the 2001 Census. It takes into account variables relating to income, education, occupation, wealth and living conditions. This index replaces and builds on the previously reported urban relative advantage index.
3. **Index of Economic Resources:** Variables for this index include those relating to the income, expenditure and assets of families, such as family income, rent paid, mortgage repayments, and dwelling size.
4. **Index of Education and Occupation:** This index includes variables relating to the educational and occupational characteristics of communities, such as the proportion of people with a higher qualification or those employed in a skilled occupation.

The SEIFA index is useful in providing valuable insights into the socio-economic well-being of a community or region. It represents a composite index comprising several census variables, with an index of disadvantage being standardised at 1000 (and with a standard deviation of 100 points). Values exceeding this figure therefore indicate a higher level of socio-economic wellbeing than the Australian standard. Conversely, values below the Australian standard are indicative of a higher incidence of disadvantage. Typically, these describe populations with, for example, a higher prevalence of low income families, unemployed people, people without educational qualifications, households renting public housing and people in low skilled occupations. Thus, this information is extremely useful as a first level surrogate indicator for identifying the potential for impact and capacity for adjustment of a community to any major economic shifts or industry adjustments.

The values for the SEIFA Index of Disadvantage for each LGA in the Cairns Coastal Region are provided in Table 2.7. These indicate that that two of the LGAs within the target region (Douglas Shire and Cairns City) have a higher level of socio-economic wellbeing than the average for Australia. On the other hand, Cardwell and Johnstone, with index values of 967 and 959, respectively, sit well below the average Australian Index of 1,000, thereby indicating a relative disadvantage in their communities.

The Disadvantage Index produced by Vinson *et al.* (2007) is an alternative to the SEIFA tool. This index uses data provided by the ABS, the Australian Taxation Office, Centrelink, the Australian Health Insurance Commission and a broad range of government departments. Using 20-25 variables, the relative disadvantage index utilises principal component analysis to identify commonalities in indicators from different locations. The index scores (see Table 2.7) are produced by ranking the locations on each available indicator by the highest negative score (for example: the highest proportion of school leavers or the highest number of persons on sickness and/or disability benefits). The scores are then combined to produce an overall ranking. This produces a relative index range for Queensland of 1 to 466, with 1 (the ranking for Mount Morgan) considered to be relatively disadvantaged and 466 (the ranking for Brisbane City) considered relatively advantaged. Using this tool, Johnstone Shire is considered the most disadvantaged area in the Cairns region, with Cairns City being the most advantaged.

Table 2.7: Socio-economic index values for the Cairns coastal region (Source: SEIFA 2001 as modified from Hug and Larson (2006); Vinson *et al.* 2007).

LGA	Relative Disadvantage 1998	Disadvantage index (Vinson *et al.*)
Cairns	1,012	182
Cardwell	967	74
Douglas	1,012	92
Johnstone	959	30

2.4 Target Area 2: The Townsville coastal region

The second target area chosen for study was the Townsville area, which, despite being strongly linked with the reef, has one of the most diverse economies of the three target regions under study. The Townsville Coastal region includes the following Local Government Areas: Burdekin (S), Hinchinbrook (S), Thuringowa (C) and Townsville (C)5, and covers 11,671 km^2 or 0.7% of the State's area.

2.4.1 Population and population growth to 2026

The estimated resident population of the Townsville coastal region as of 30 June 2006 was 197,408 persons, representing 4.8% of the State's total population. Population projections from the OESR (2006) indicate that the region's population will increase from 178,024 in 2001 to 253,289 in 2026. It is further predicted that the average annual growth rate for the region between 2001 and 2026 will be 0.9%, compared with 1.7% for Queensland (OESR, 2006). Thuringowa is estimated to have the highest predicted growth rate in the region, with the city's population growing from 52,718 in 2001 to 93,228 in 2026: this represents an average annual rate of 2.3%, higher than the Queensland average (Figure 2.4). Townsville is also predicted to have relatively high growth (average of 1.3%), whilst in contract Hinchinbrook's growth is expected to only be 0.1% and Burdekin is expected to have negative growth of 0.1% (Figure 2.4).

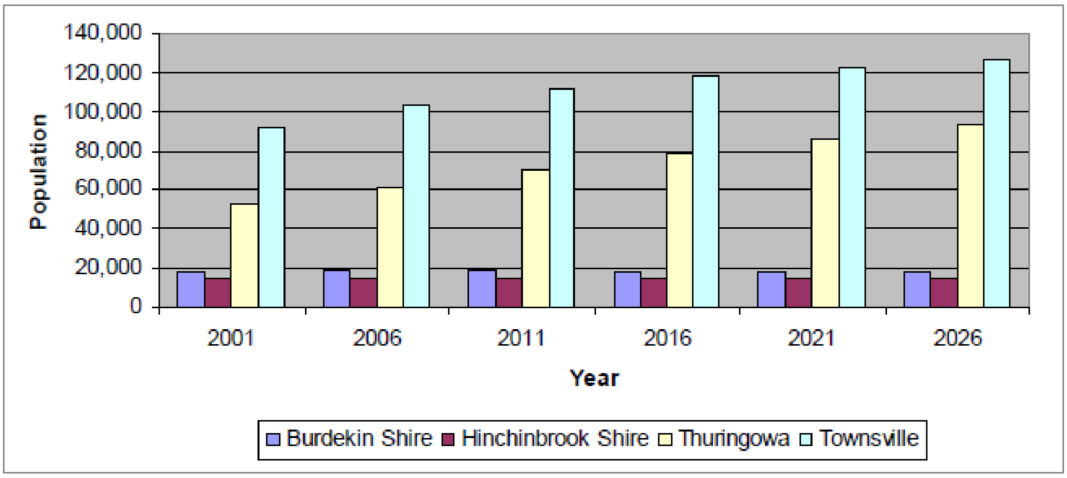

Figure 2.4: Projected resident population of the Townsville coastal region, 2001-2006 (Source: PIFU 2006).

[5] Following local government amalgamations in early 2008, Townsville City Council absorbed all of Thuringowa City Council; the Burdekin and Hinchinbrook Shires remain as separate entitites.

2.4.2 *Townsville region age structure*

The overall median age in the Townsville coastal region (37 years) is slightly higher than the Queensland median (35 years). During 2006, the largest age cohort in the region was the 25-54 year cohort (Table 2.8). The region as a whole has a strong base of population aged 0-24 years, which is indicative of growth in the region, together with a narrow band of residents aged 65 years or older. However, the 15-24 year age cohort appears to be lower than the expected level (Figure 2.5). Possible contributing factors to this are the attendance of students at boarding schools outside of the Townsville region, greater employment opportunities for young people outside the region (particularly in neighbouring Cairns City) and the increased travel and mobility of young people within the state generally.

With respect to specific areas, Thuringowa has a higher percentage persons aged 0-14 years and the lower percentage of over 65s (Figure 2.5). During 2006, there were also predominately higher population numbers in the working age group (25-54 years) as well as a high number of young children and early teens. This is indicative of a relatively younger community with a high number of young families, particularly in Thuringowa.

Table 2.8: Age structure of Townsville coastal region, 2006, according to Local Government Area (Source: ABS Census of Population and Housing 2006).

LGA	Population by Age				
	0-14	**15-24**	**25-54**	**55-64**	**65+**
Burdekin	3,684	1,745	6,656	2,153	2,783
Hinchinbrook	2,343	1,153	4,152	1,553	2,357
Thuringowa	15,265	8,628	25,851	5,442	3,979
Townsville	18,245	16,614	40,853	9,340	10,411
Townsville Coastal Region	39,537	28,140	77,512	18,488	19,530

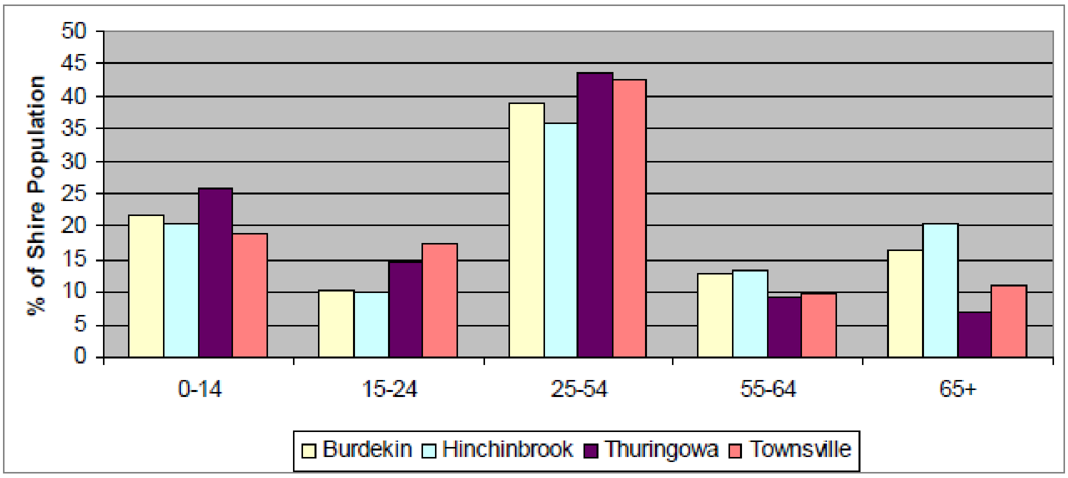

Figure 2.5: Age categories of the Townsville coastal region, described as a percentage of the Local Government Area total population (Source: ABS Census of Population and Housing 2006).

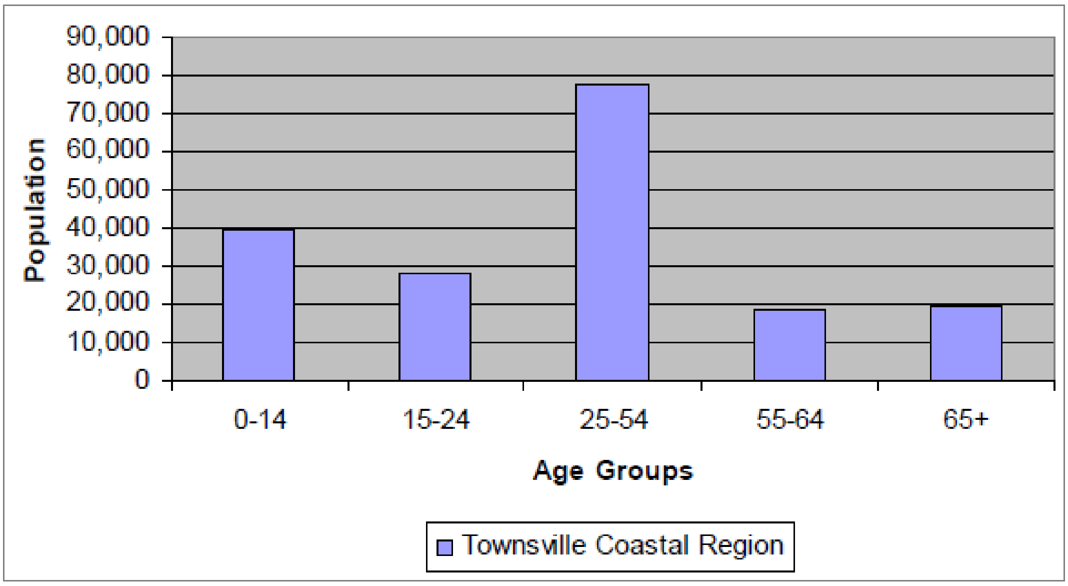

Figure 2.6: Age structure of the Townsville coastal region during the 2006 Census (Source: ABS Census of Population and Housing 2006).

2.4.3 *Selected socio-economic characteristics*

Data from the ABS 2006 Census of Population and Housing illustrate that there is considerable variability across the Townsville coastal region with respect to the median household income. For example, this statistic ranges from $1,159 in Thuringowa (higher than the Queensland average) to just $750 in Hinchinbrook. The average figure for the Townsville coastal area was $960, some $73 a week less than the equivalent Queensland figure of $1,033. A number of selected socio-economic indicators for the four local government areas within the target region including population, median age, mean household income, median rental and housing loan repayment and dwelling status are provided in Table 2.9.

Table 2.9: Socio-economic characteristics, Townsville coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Category	Local Government Area				Queensland
	Burdekin (S)	Hinchinbrook (S)	Thuringowa (c)	Townsville (C)	
Population (Place of usual residence)	17,020	11,558	59,164	95,464	3,904,532
Median age (years)	40	43	31	34	36
Indigenous persons (% of total)	5	6.4	6	5.2	3.3
One parent families (% of total)	13.9	12.4	15.5	17.3	15.9
Lone person households (% of total)	24	24.9	13.3	23.3	21
Median household income ($/weekly)	866	750	1,159	1,065	1,033
Median rent ($/weekly)	125	105	200	180	200
Median housing loan repayment ($/monthly)	867	830	1,224	1,200	1,300
Dwelling fully owned (% of total)	42.7	50.6	22.6	26	30.4

2.4.4 Post-school educational qualifications

The post-school qualifications held by the population of the Townsville Coastal region are summarised in Table 2.10. In 2006, some 23.5% of persons who indicated a post-school educational qualification in the region possessed a bachelor degree or higher, compared with 26% for the state as a whole (ABS, 2006). Of those that held formal qualifications, the region had a significantly higher proportion of its labour force holding certificates than the rest of the state. However, the proportion of the labour force holding graduate and postgraduate degrees remained similar to the Queensland average.

2.4.5 Labour force

The Townsville region is noted for military, agricultural and mining and industrial activity, and can be regarded as the least dependent on the reef, of the three target regions under study. The overall unemployment rate in the Townsville Coastal region at the time of the 2006 Census was 4.3%, slightly less than the state average of 4.8% (Table 2.10). Some 64.2% of the Townsville Coastal region's labour were employed and worked full-time, whilst 24.9% worked in part-time capacities – slightly less than the Queensland average of 27.7% (Table 2.11).

Table 2.10: Post-school educational qualifications, Townsville coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Qualification	Townsville coastal region		Queensland
	# population	% population	% population
Postgraduate Degree	2,249	3.2	3.9
Graduate Diploma and Graduate Certificate	1,281	1.8	2.3
Bachelor Degree	12,797	18.5	19.8
Advanced Diploma and Diploma	7,777	11.2	13.1
Certificate:			
Certificate nfd*	1,826	2.6	3
Certificate III and IV	24,287	35.0	30.2
Certificate I and II	1,755	2.5	2.3
Total	27,868	40.2	35.5
Level of education inadequately described	1,605	2.3	2.7
Level of education not stated	15,749	22.7	22.7
Total	**69,326**		

Table 2.11: Labour force status in the Townsville coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Status	Townsville Coastal Region		Queensland	
	# population	% of labour force	# population	% of labour force
Employed, worked full-time	59,791	64.2	1,180,891	61.6
Employed, worked part-time	23,207	24.9	530,503	27.7
Employed, away from work	3,573	3.8	63,507	3.3
Hours worked not stated	2,495	2.7	50,095	2.6
Unemployed, looking for full-time work	2,494	2.7	55,141	2.9
Unemployed, looking for part-time work	1,504	1.6	35,808	1.9
Total labour force	93,064		1,915,945	
Not in the labour force	41,471	28.9	971,833	31.4
Not stated	9,139	6.4	210,219	6.8
Total	**143,674**		**3,097,997**	

2.4.6 Employment by industry

Public administration and safety was the largest employer in the Townsville Coastal region at the time of the 2006 Census, accounting for 10,168 people or 11.4% of the region's employed labour force (Table 2.12). Other industries with relatively large numbers of employed persons included retail trade (10.9%), and health care and social assistance (10.6%). Both manufacturing and construction employed 9.2% (Table 2.12).

Table 2.12: Employment by industry in the Townsville coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Industry sector	Townsville Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Agriculture, forestry and fishing	3,292	3.7	61,734	3.4
Mining	2,184	2.5	30,720	1.7
Manufacturing	8,213	9.2	180,212	9.9
Electricity, gas, water and waste services	1,265	1.4	18,541	1.0
Construction	8,221	9.2	164,936	9.0
Wholesale trade	2,703	3.0	72,075	3.9
Retail trade	9,735	10.9	212,423	11.6
Accommodation and food services	5,860	6.6	127,631	7.0
Transport, postal and warehousing	4,270	4.8	92,614	5.1
Information media and telecommunications	1,298	1.5	26,346	1.4
Financial and insurance services	1,581	1.8	52,036	2.9
Rental, hiring and real estate services	1,456	1.6	37,983	2.1
Professional, scientific and technical services	3,593	4.0	102,415	5.6
Administrative and support services	2,368	2.7	55,705	3.1

Industry sector	Townsville Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Public administration and safety	10,168	11.4	122,416	6.7
Education and training	7,062	7.9	139,089	7.6
Health care and social assistance	9,455	10.6	186,335	10.2
Arts and recreation services	1,034	1.2	24,625	1.3
Other services	3,132	3.5	68,361	3.7
Inadequately described / Not stated	2,171	2.4	48,801	2.7
Total	**89,061**	**100**	**1,824,998**	**100**

2.4.7 Employment by occupation

The number of people employed within an industry provides an indication of the major industries within a region and their relative importance to the community. At the time of the 2006 Census, technicians and trade workers represented the largest number of employed persons in the Townsville Coastal Region, accounting for 16.7% of employed persons (Table 2.13). Other occupations with relatively large numbers of employed persons included professionals (15.2%) and clerical and administrative workers (14.2%).

Table 2.13: Employment by occupation in the Townsville coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Occupation (ANZSCO)	Townsville Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Managers	9,963	11.2	225,695	12.4
Professionals	13,556	15.2	312,866	17.1
Technicians and trades workers	14,909	16.7	280,342	15.4
Community and personal service workers	9,964	11.2	166,400	9.1
Clerical and administrative workers	12,660	14.2	269,198	14.8
Sales workers	8,559	9.6	189,040	10.4
Machinery operators and drivers	7,750	8.7	132,113	7.2
Labourers	10,168	11.4	217,251	11.9
Inadequately described/Not stated	1,533	1.7	32,094	1.8
Total	**89,062**	**100**	**1,824,999**	**100**

2.4.8 Socio-economic disadvantage / advantage

The SEIFA and Vinson *et al.* Index of Disadvantage values for each LGA in the Townsville region are presented in Table 2.14. These data indicate that all LGAs within the target region have a lower level of socio-economic wellbeing than the average for Australia. In particular, the LGAs of Burdekin and Hinchinbrook returned index values of 982 and 933, respectively, and are therefore well below the average Australian Index of 1,000, indicating a relative disadvantage.

Table 2.14: Socio-economic index values for the Townsville coastal region (Source: SEIFA 2001 as modified from Hug and Larson (2006); Vinson *et al.* 2007).

LGA	Relative Disadvantage 1998	Disadvantage index (Vinson *et al.*)
Burdekin	982	102
Hinchinbrook	933	49
Thuringowa	996	129
Townsville	998	35

2.5 Target Area 3: The Mackay-Whitsunday area

The third and final target region chosen for the study was the Mackay-Whitsunday coastal region. This region has been based on the following five local government areas: Bowen (S), Whitsunday (S), Mackay (C), Sarina (S), Broadsound (S)[6]. Covering a total area of 46,744km^2, this region comprises approximately 2.7% of the total area of the state.

2.5.1 Population and projected population growth to 2026

The estimated resident population of the Mackay-Whitsundays region at 30 June 2006 was 140,293 persons, or 3.4% of the total Queensland population (OESR, 2007). Within the region, the largest increase in population occurred in Mackay City, up by 2,323 persons in the year to June 2006, representing 63.2% of all growth in Mackay Coastal region. The estimated average annual growth for the Mackay coastal region is 8.2% based on preliminary OESR data for 2005/06. The OESR (2007) projects that the population of the Mackay-Whitsunday coastal region will increase to 180,450 persons by 2026. However, the projected average annual growth rate in the region for 2001 to 2026 is 1.6%, which is slightly below the state average of 1.7%. This will see the Mackay-Whitsunday region's share of Queensland's population drop slightly from 3.3% to 3.2 % by the year 2026. Mackay City is projected to remain the most populous local government area in the region, with a projected population of 116,979 persons by 2026. In addition, Mackay City's share of the region's population is expected to rise from 63.2% in 2001 to 64.8% in 2026 (Figure 2.7). Whitsunday Shire is projected to be the second most populous area within the coastal region (27,367 persons by 2026), and is also the fastest growing, with an average growth rate of 2.3% from 2002-2026 (OESR, 2007).

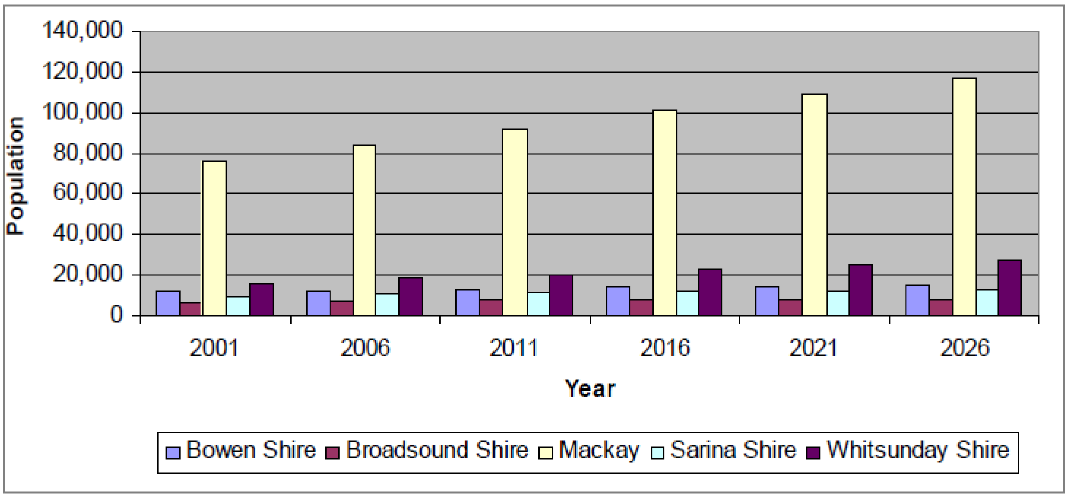

Figure 2.7: Projected population growth, 2001-2006, for the Mackay-Whitsunday coastal region (source: OESR 2007).

[6] Following local government amalgamations in early 2008, Bowen and Whitsunday Shire Councils formed Whitsunday Regional Council; Mackay and Sarina formed Mackay Regional Council, and Broadsound Shire was absorbed by the new Isaac Regional Council.

2.5.2 Mackay-Whitsunday region age structure

At 35.4 years, the overall median age in the Mackay-Whitsunday region is slightly younger than Queensland's median age (35 years). During 2006, the largest age cohort in the region was the 25-44 year cohort (Table 2.15). The region demonstrates an irregular age structure with the 15-19 year cohort being greatly underrepresented in comparison with the rest of the population as a whole. In addition, strong representation among the age cohorts upwards of 25 years indicates an aging population. Nevertheless, Figure 2.8 below indicates that there is some variation across the region; for example, a higher percentage of people aged 0-14 years and the lower percentage of over 65s in the Broadsound shire area. Otherwise, age groupings for the Mackay-Whitsunday coastal region are generally comparable to those of the Cairns region (Figure 2.9), whilst Townsville region has a notably larger contingent of 15-24 year olds. In addition, the Townsville region also has a lower ratio of persons in the 25 to 54 age group.

Table 2.15: Age structure of Mackay-Whitsunday coastal region, 2006, according to Local Government Area (Source: ABS Census of Population and Housing 2006).

LGA	Population by Age				
	0-14	**15-24**	**25-54**	**55-64**	**65+**
Bowen Shire	2,412	1,449	4,982	1,723	1,812
Broadsound Shire	1,787	811	3,354	643	250
Mackay City	18,652	11,483	37,108	8,492	9,154
Sarina Shire	2,408	1,284	4,602	1,371	1,056
Whitsunday Shire	2,960	2,417	8,228	1,884	1,457
Mackay Coastal Region	28,219	17,444	58,274	14,113	13,729

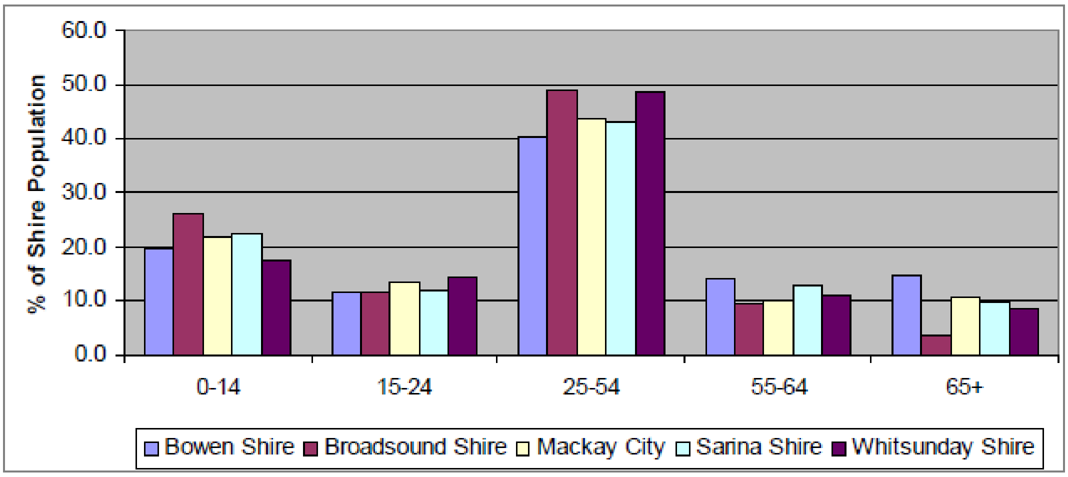

Figure 2.8: Age categories of the Mackay-Whitsunday coastal region, described as a percentage of the Local Government Area total population (Source: ABS Census of Population and Housing 2006).

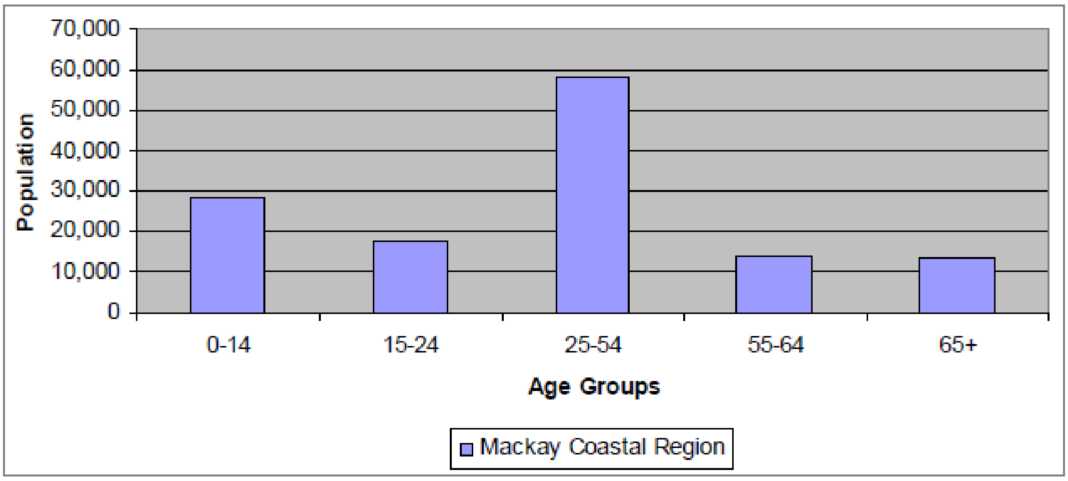

Figure 2.9: Age structure of the Mackay-Whitsunday coastal region during the 2006 Census (Source: ABS Census of Population and Housing 2006).

2.5.3 Selected socio-economic characteristics

Table 2.16 summarises key socio-economic characteristics for the Mackay-Whitsunday coastal region. These data indicate that rental costs in the Bowen area ($826/week) are substantially lower than for other centres in the region, whilst Broadsound has exceptionally high costs at $1,828/week – nearly twice the Queensland average. Broadsound also has a disproportionately lower number of lone parent families (Table 2.16).

Table 2.9: Socio-economic characteristics, Mackay-Whitsunday coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Cateogry	Local Government Area					Queensland
	Bowen (S)	Broadsound (S)	Mackay (C)	Sarina (S)	Whitsunday (S)	
Population (Place of usual residence)	12,377	6,843	84,890	10,720	16,955	3,904,532
Median age (years)	41	32	35	37	36	36
Indigenous persons %	6.5	2.4	3.9	4.4	1.9	3.3
One parent families %	13.7	7.9	13.6	12.4	11.7	15.9
Lone person households %	22.2	15.7	18.7	16.4	16	21
Median household income ($/weekly)	826	1,828	1,137	1,090	1,065	1,033
Median rent ($/weekly)	135	42	200	165	200	200
Median housing loan repayment ($/monthly)	953	867	1,300	1,200	1,300	1,300
Dwelling fully owned %	37.9	32.1	31	33.8	26.8	30.4

2.5.4 Post-school educational qualifications

Table 2.16 outlines the post-school qualifications of the Mackay-Whitsunday coastal region relative to Queensland. In 2006, nearly sixteen percent of persons who indicated a post-school educational qualification in the region possessed a bachelor degree or higher (ABS, 2006). Of those that held formal qualifications, the region had a higher proportion of its labour force holding certificates than the rest of the state. However, the proportion of the labour force holding graduate and postgraduate degrees was significantly below the Queensland average by approximately ten percent (Table 2.16).

Table 2.17: Post-school educational qualifications, Mackay-Whitsunday coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Qualification	Townsville coastal region		Queensland
	# population	% population	% population
Postgraduate Degree	696	1.4	3.9
Graduate Diploma and Graduate Certificate	752	1.5	2.3
Bachelor Degree	6,578	13.0	19.8
Advanced Diploma and Diploma	4,890	9.7	13.1
Certificate:			
Certificate nfd*	1,305	2.6	3
Certificate III and IV	19,322	38.3	30.2
Certificate I and II	1,333	2.6	2.3
Total	21,960	43.5	35.5
Level of education inadequately described	1,228	2.4	2.7
Level of education not stated	14,382	28.5	22.7
Total	**50,486**	**100.0**	

2.5.5 Labour force

The Mackay-Whitsunday coastal region is rapidly diversifying from an agricultural service hub to one of mining and tourism. The region's economy is increasingly focused on tourism and fishing, particularly in the Whitsunday area. The overall unemployment rate in the Mackay-Whitsunday region at the time of the 2006 Census was 3.7%, compared with 4.8% for Queensland (Table 2.18). Of the region's total labour force, some two-thirds were employed and worked full-time, while 23.8 % worked part-time, which was slightly less than the Queensland average of 27.7%.

Table 2.18: Labour force status in the Mackay-Whitsunday coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Status	Mackay-Whitsunday Coastal Region		Queensland	
	# population	% of labour force	# population	% of labour force
Employed, worked full-time	43,671	66.2	1,180,891	61.6
Employed, worked part-time	15,718	23.8	530,503	27.7
Employed, away from work	2,198	3.3	63,507	3.3
Hours worked not stated	1,935	2.9	50,095	2.6
Unemployed, looking for full-time work	1,579	2.4	55,141	2.9
Unemployed, looking for part-time work	830	1.3	35,808	1.9
Total labour force	65,931		1,915,945	
Not in the labour force	27,656	26.7	971,833	31.4
Not stated	9,974	9.6	210,219	6.8
Total	**103,561**		**3,097,997**	

2.5.6 *Employment by industry*

At the 2006 Census, retail trade was the largest employer in the Mackay-Whitsunday coastal region, with 7,221 (11.4%) of the region's employed labour force (Table 2.19). Of the people employed in the Mackay-Whitsunday coastal region, 9.1% were employed in the mining industry, a far higher figure than the Queensland average of just 1.2%. Other industries with relatively large numbers of employed persons included construction (6329 persons or 10% of the total), accommodation and food services (5,425 persons or 8.5%). The proportion of persons employed in the agriculture, forestry and fishing industry was 5.9% (Table 2.19).

Table 2.19: Employment by industry in the Mackay-Whitsunday coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Industry sector	Mackay-Whitsunday Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Agriculture, forestry and fishing	3,738	5.9	61,734	3.4
Mining	5,758	9.1	30,720	1.7
Manufacturing	5,420	8.5	180,212	9.9
Electricity, gas, water and waste services	531	0.8	18,541	1.0
Construction	6,329	10.0	164,936	9.0
Wholesale trade	2,583	4.1	72,075	3.9
Retail trade	7,221	11.4	212,423	11.6
Accommodation and food services	5,425	8.5	127,631	7.0
Transport, postal and warehousing	3,939	6.2	92,614	5.1
Information media and telecommunications	452	0.7	26,346	1.4
Financial and insurance services	1,060	1.7	52,036	2.9
Rental, hiring and real estate services	1,202	1.9	37,983	2.1

Industry sector	Mackay-Whitsunday Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Professional, scientific and technical services	2,541	4.0	102,415	5.6
Administrative and support services	1,604	2.5	55,705	3.1
Public administration and safety	2,416	3.8	122,416	6.7
Education and training	3,770	5.9	139,089	7.6
Health care and social assistance	4,683	7.4	186,335	10.2
Arts and recreation services	401	0.6	24,625	1.3
Other services	2,691	4.2	68,361	3.7
Inadequately described/Not stated	1,762	2.8	48,801	2.7
Total	**63,526**	**100.0**	**1,824,998**	**100.0**

2.5.7 Employment by occupation

The number of people employed within an industry provides an indication of the major industries within a region and their relative importance to the community. The data in Table 2.20 presents an overview of employment by occupation across the region. At the time of the 2006 Census, the 'technicians and trade workers' occupation had the largest number of employed persons in the Mackay coastal region (12,383 persons or 19.5% of employed persons). This was significantly higher than the Queensland average of 15.4% for the same occupation. Other occupations with relatively large numbers of employed persons included labourers (8,587 persons or 13.5%) and machinery operators and drivers (7,966 persons or 12.5%), both of which were higher than the Queensland average. The number of persons employed in professional occupations (7,452 persons or 11.7%) was below the Queensland average of 17.1% (Table 2.20).

Table 2.20: Employment by occupation in the Mackay-Whitsunday coastal region 2006 (Source: ABS Census of Population and Housing 2006).

Occupation (ANZSCO)	Mackay-Whitsunday Coastal Region		Queensland	
	# population	% labour force	# population	% of labour force
Managers	7,556	11.9	225,695	12.4
Professionals	7,452	11.7	312,866	17.1
Technicians and trades workers(b)	12,383	19.5	280,342	15.4
Community and personal service workers	4,688	7.4	166,400	9.1
Clerical and administrative workers	7,870	12.4	269,198	14.8
Sales workers	5,924	9.3	189,040	10.4
Machinery operators and drivers	7,966	12.5	132,113	7.2
Labourers	8,587	13.5	217,251	11.9
Inadequately described/Not stated	1,089	1.7	32,094	1.8
Total	**63,515**	**100.0**	**1,824,999**	**100.0**

2.5.8 Socio-economic disadvantage / advantage

The data in Table 2.21 indicate that all but two of the LGAs within the Mackay-Whitsunday Coastal region have a lower level of socio-economic wellbeing than the average for Australia. With a Relative Disadvantage Index ranking of 1,014, the Whitsunday Shire ranks well above that considered the ‘norm’ of the Australian average of 1,000. The shire of Broadsound achieved a SEIFA Index of Disadvantage close to that of the Australian average of 1,000. In contrast, the LGAs of Mackay, Sarina and Bowen with index values falling between 980 and 905 respectively are all well below the average Australian Index of 1,000, indicating a relative disadvantage.

Table 2.21: Socio-economic index values for the Mackay-Whitsunday coastal region (Source: SEIFA 2001 as modified from Hug and Larson (2006); Vinson *et al.* 2007).

LGA	Relative Disadvantage 1998	Disadvantage index (Vinson *et al.*)
Bowen	905	18
Broadsound	999	341
Mackay	980	39
Sarina	942	88
Whitsunday	1,014	242

2.6 Regional variations

The spatial price index is one measure of a community’s vulnerability to different climate change scenarios, because of its implications for adaptive capacity. The spatial price index for the Mackay-Whitsunday coastal region is higher than those for the other two target regions. The most substantial variation is the cost of housing, for which Mackay records much higher values than compared with the other locations (Table 2.22). The housing cost pressures for the Mackay-Whitsunday region are driven largely by ‘seachange’ population pressures and tourism investment. There are also extreme housing pressures coming from the inland mining areas of the Bowen Basin, where locations such as Moranbah are over 95% more expensive than Brisbane.

The mix of industries present in the three target areas may also be an indication of the capacity of a region to adapt to various climate change scenarios. According to the ABS Business Register[7] (June, 2006), the Cairns coastal region had 14,751 businesses registered with an ABN, whilst the Townsville coastal region had just 11,904 and the Mackay coastal region was 30% lower with 9,999 (Figure 2.10). However, there is some industry variation across the three regions; in particular, a higher percentage of businesses are apparent in the agriculture, forestry and fishing sector in the Mackay-Whitsunday coastal region (Figure 2.11). There are also a higher percentage of businesses in the property and business sector and the construction sector for both Townsville and Cairns compared with the Mackay-Whitsunday region. Finally, the percentage of businesses in the accommodation, cafes and restaurants sector in the Cairns coastal region are higher than Townsville and Mackay coastal regions (Figure 2.11).

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[7] Counts of businesses produced from the ABS Business Register comprise actively trading businesses in the Australian economy. Each Business has been classified (by the ATO and the ABS respectively – ANZSIC divisions) to a single industry class, irrespective of any diversity of activities undertaken. The industry class allocated is the one which provides the main source of income, which is generally based on a description provided by the business. Turnover is based on data reported to the ATO on Business Activity Statements (BAS) and includes imputation for missing periods.

Table 2.22: Spatial Price Index for regions of Queensland (retail prices, May 2006) (OESR 2006).

	Cairns	Innisfail	Townsville	Whitsunday	Mackay
Housing					
Index numbers	106.6	74.8	102.7	124.3	109.9
% difference from Brisbane	*6.6*	*-25.2*	*2.7*	*24.3*	*9.9*
Food, alcohol and tobacco					
Index numbers	100.6	102.2	103.5	103.2	108.1
% difference from Brisbane	*0.6*	*2.2*	*3.5*	*3.2*	*8.1*
Transportation					
Index numbers	97.2	94.8	101.8	98.2	95.7
% difference from Brisbane	*-2.8*	*-5.2*	*1.8*	*-1.8*	*-4.3*
Health, education and communication					
Index numbers	100.5	101.3	100.8	100.5	100.3
% difference from Brisbane	*0.5*	*1.3*	*0.8*	*0.5*	*0.3*
Financial and insurance services					
Index numbers	97.9	98.1	98.2	97.2	98
% difference from Brisbane	*-2.1*	*-1.9*	*-1.8*	*-2.8*	*-2*
All items less housing					
Index numbers	99.4	98.8	101.7	99.6	99.7
% difference from Brisbane	*-0.6*	*-1.2*	*1.7*	*-0.4*	*-0.3*
All items					
Index numbers	100.9	93.7	101.9	104.8	101.8
% difference from Brisbane	*0.9*	*-6.3*	*1.9*	*4.8*	*1.8*

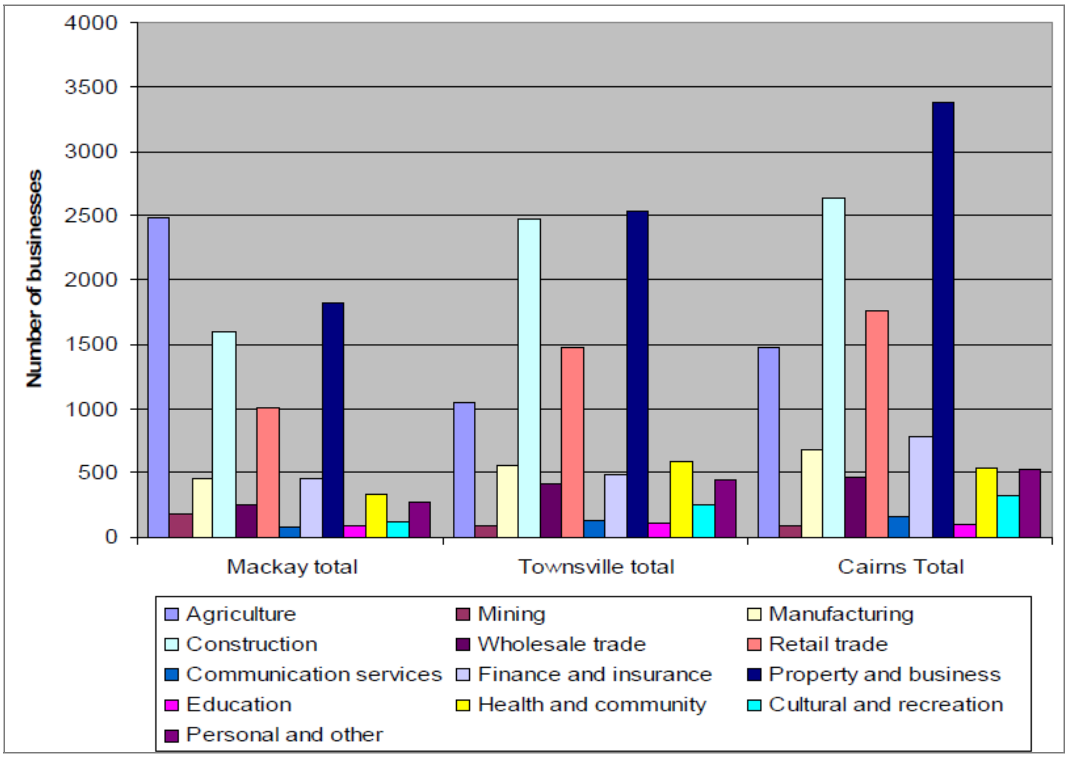


Figure 2.10: Number of businesses in different industry sectors for the three target regions in this study (Source: ABS, 8165.0 June 2003 to June 2006, Counts of Australian Businesses, including Entries and Exits).

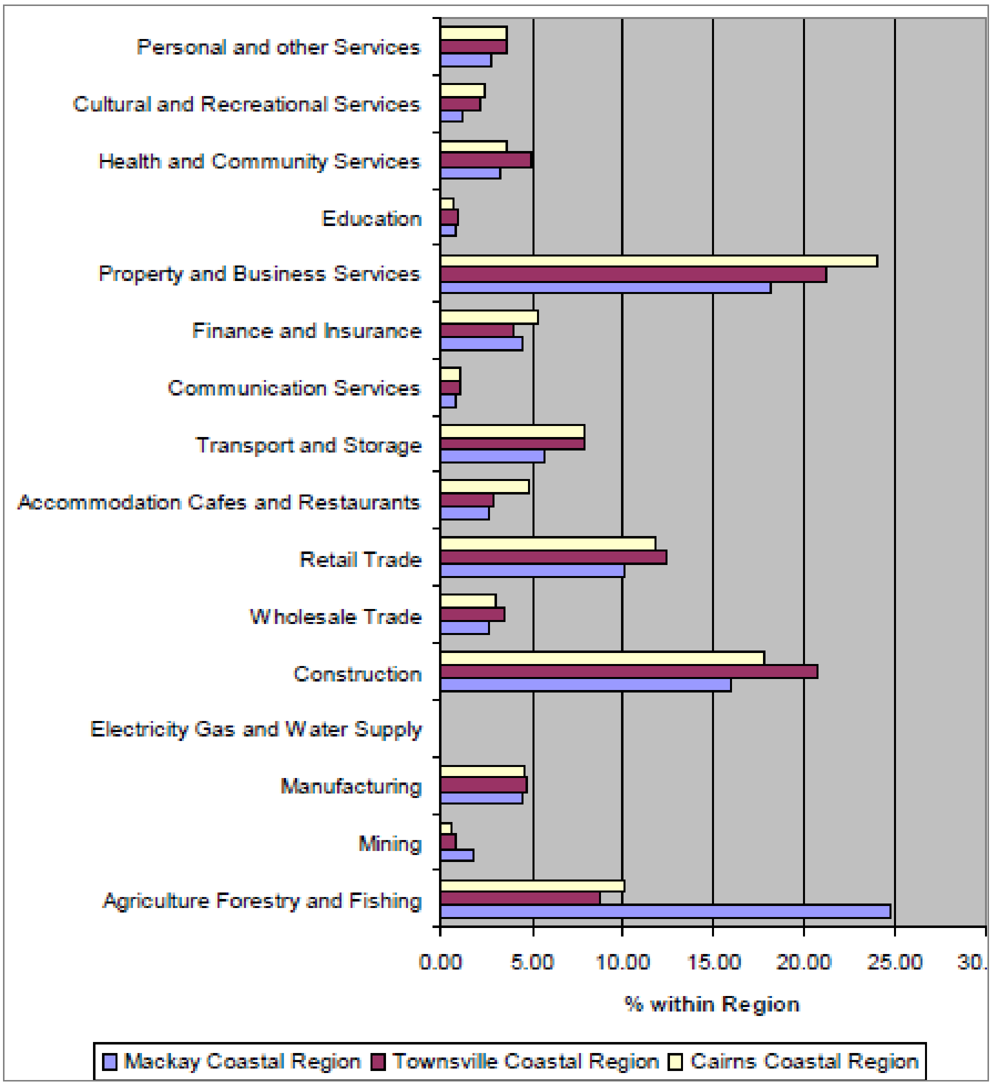
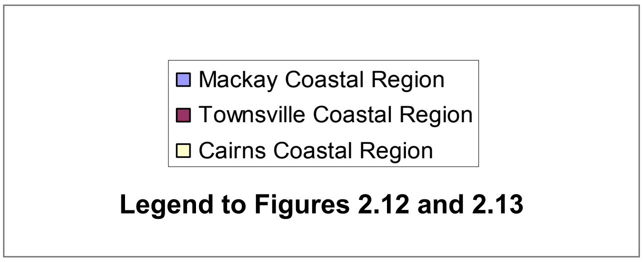


Figure 2.11: Percentage of businesses located in each industry sector, arranged by target regions for June 2006 (Source: ABS, 8165.0 June 2003 to June 2006, Counts of Australian Businesses, including Entries and Exits).

The Cairns coastal region has the highest number of businesses in the majority of categories, due to the higher total number of businesses in the region overall; but the proportion of businesses by employment size across the three regions is generally uniform (Figures 2.12 and 2.13).

The ABS Business Register also compiles a list of businesses categorised by the annual turnover ranges as recorded on the ATO Business Activity Statements. For each of the three target regions, the largest numbers of businesses fall into the $200,000 to $500,000 range and the number drops off sharply for businesses above that range (Figures 2.14 and 2.15). Across the annual business turnover ranges, there is little variation with the highest difference in percentage points being the $200,000 to $500,000 range with the Mackay-Whitsunday coastal region being 2.6% higher than Townsville.



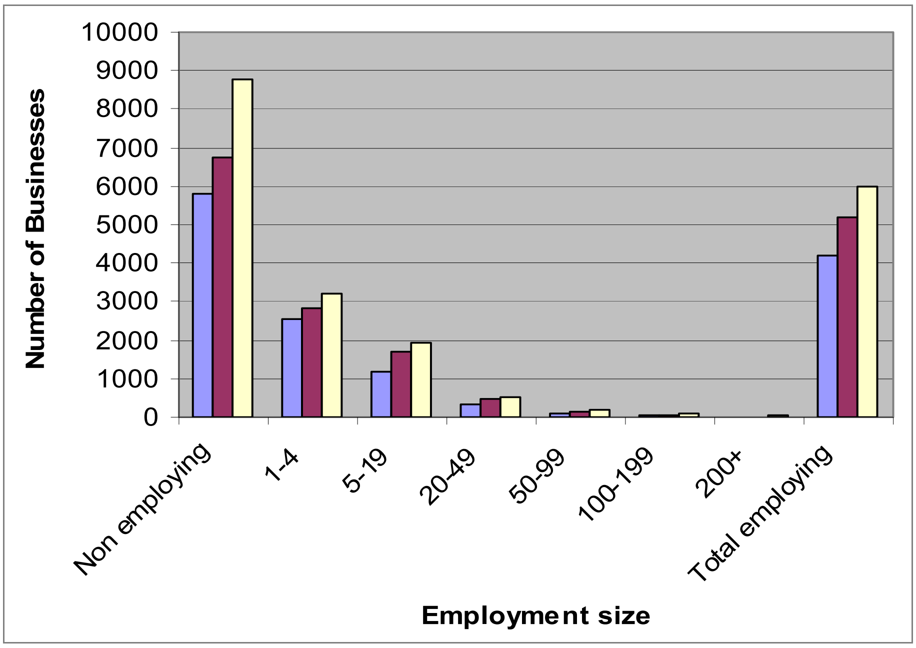


Figure 2.12: Number of businesses in different employment size categories for the three target regions in this study (Source: ABS, 8165.0 June 2003 to June 2006, Counts of Australian Businesses, including Entries and Exits).

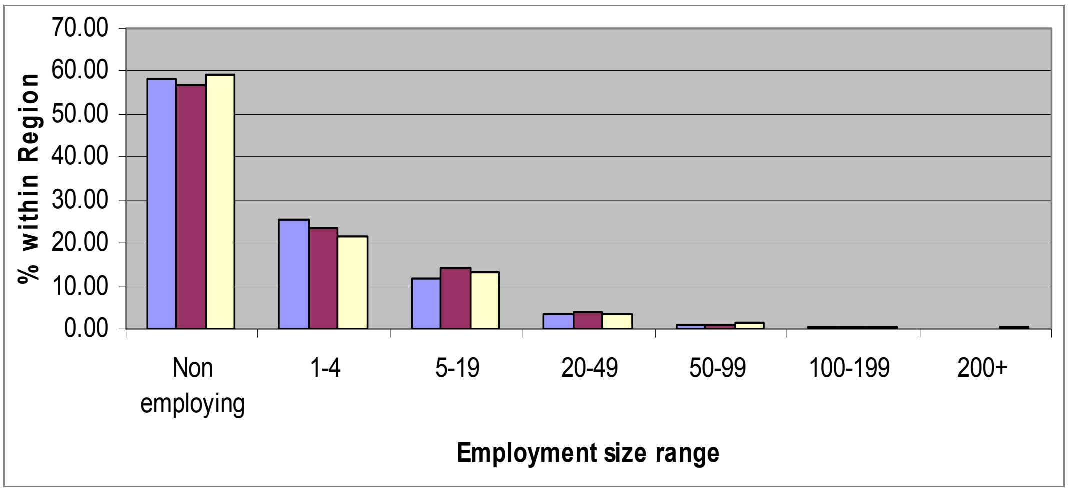
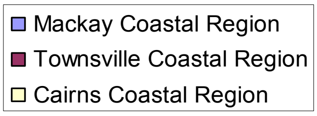


Figure 2.13: Proportion (percentage) of businesses in different employment size categories in the three target regions in this study during 2006 (Source: ABS, 8165.0 June 2003 to June 2006, Counts of Australian Businesses, including Entries and Exits).



Legend to Figures 2.14 and 2.15

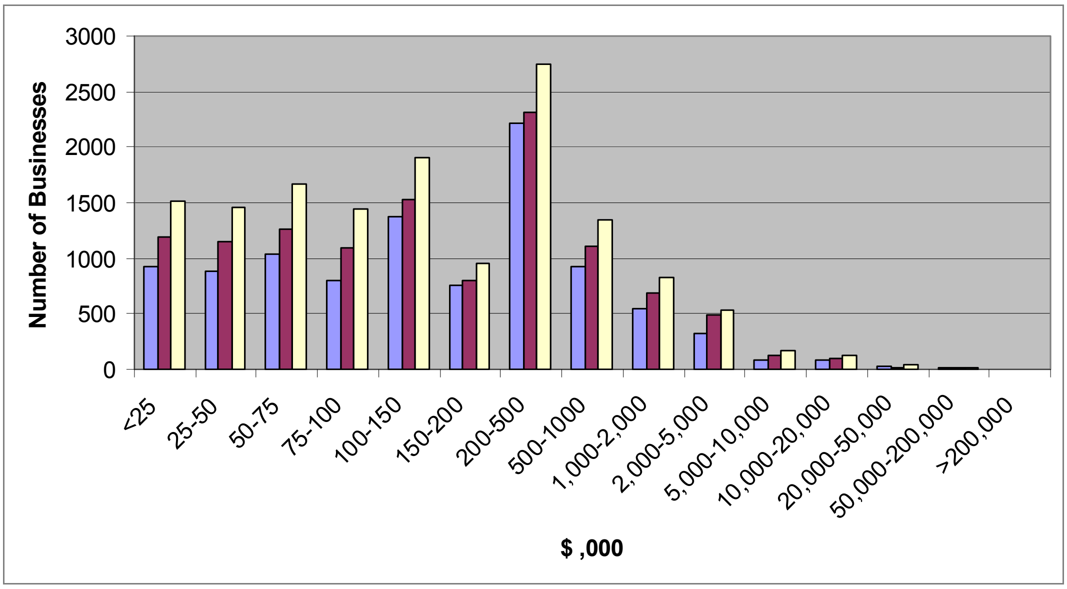


Figure 2.14: Businesses categorised by annual turnover ranges for the three target regions during 2006 (Source: ABS, 8165.0 June 2003 to June 2006, Counts of Australian Businesses, including Entries and Exits).

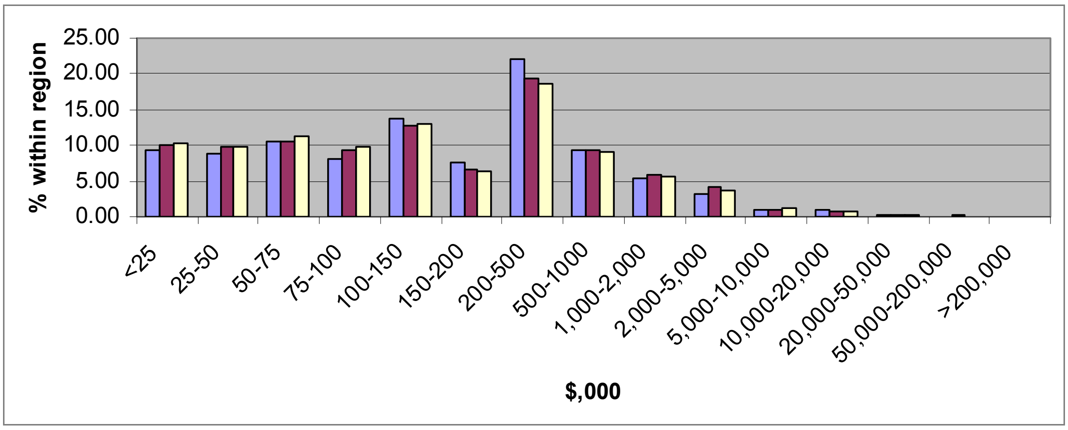


Figure 2.15: Proportion of businesses categorised by annual turnover ranges for the three target regions in this study during 2006 (Source: ABS, 8165.0 June 2003 to June 2006, Counts of Australian Businesses, including Entries and Exits).

2.6.1 Regional variations specifically for climate change

One example of targeted research into the impacts of climate change is the 2004 report 'Queensland Climate Change and community Vulnerability to Tropical Cyclones: Development of a Cyclone Wind Damage Model for use in Cairns, Townsville and Mackay'. In this document, the resilience of the housing stocks to excessive winds was modelled and assessed. The modelling relied on a general estimation of potential damage based upon the housing stock geometry and construction technique, covering houses from the 1860s to the present day. A detailed examination of the housing stocks and the topographical features of the three locations showed variation between the areas. The study concluded that the modelled region of Cairns had a lower overall vulnerability of its housing stocks to cyclonic wind strength than Townsville and Mackay. The variation was attributed in the main to the higher number of houses that were built in the Cairns area after the introduction of engineered house building requirements in the early 1980s.

2.7 Economic characteritisation of the industry sectors of the GBR

2.7.1 Identifying key industries of the GBR catchment

Major industries in the GBR catchment region include mining, agriculture and tourism (Productivity Commission 2003). The mining and the mineral processing industries include coal, oil and natural gas, metal ore and other minerals. The combined gross value of production (GVP) for mining and minerals processing industries in the GBR region was $8.45 billion during the year 2000, which represented about 47% of the GBR region's total GVP (Figure 2.16). The second largest industry in the GBR catchment region was agriculture and agricultural processing (including beef, sugarcane and horticulture), which contributed $4.1 to the region – approximately 28% of the total GVP. According to Access Economics (2005), the GVP generated by agriculture rose to $5.4 billion in 2004-05. Tourism is the third most important industry in the GBR catchment region, generating about 23% of the region's GVP. About 1.8 million visitors visited the GBR in 2001 (PDP Australia 2003)[8], when tourism generated about $4.2 billion annually. However, updated estimates of GVP reported the total value added from tourism activities in the GBR catchment area at $5.2 billion for 2004-05 (Access Economics 2005). Recreational and commercial fishing, including aquaculture and captive fishing both generate about one percent of the GVP for the GBR region.

The tourism, commercial fishing and recreational fishing sectors directly derive their income from the Great Barrier Reef. Given their direct reef-dependency, a firm understanding is required of the scale and contribution that these three make to the economy of coastal Queensland and its regions. Tourism, commercial fishing and recreation fishing are each intimately linked to the wider business and service sector of the GBR region, and isolating these three from other key business in the catchment does create a somewhat artificial barrier to a comprehensive assessment of the socio-economic impacts of climate change. It was for this reason that the high-level, but integrated, socio-economic characterisation of the three target regions was provided above. The following section completes these characterisations by profiling the tourism, commercial fishing and recreational fishing sectors as they operate in the target regions on the reef.

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[8] Also known as the 'Hand Report'.

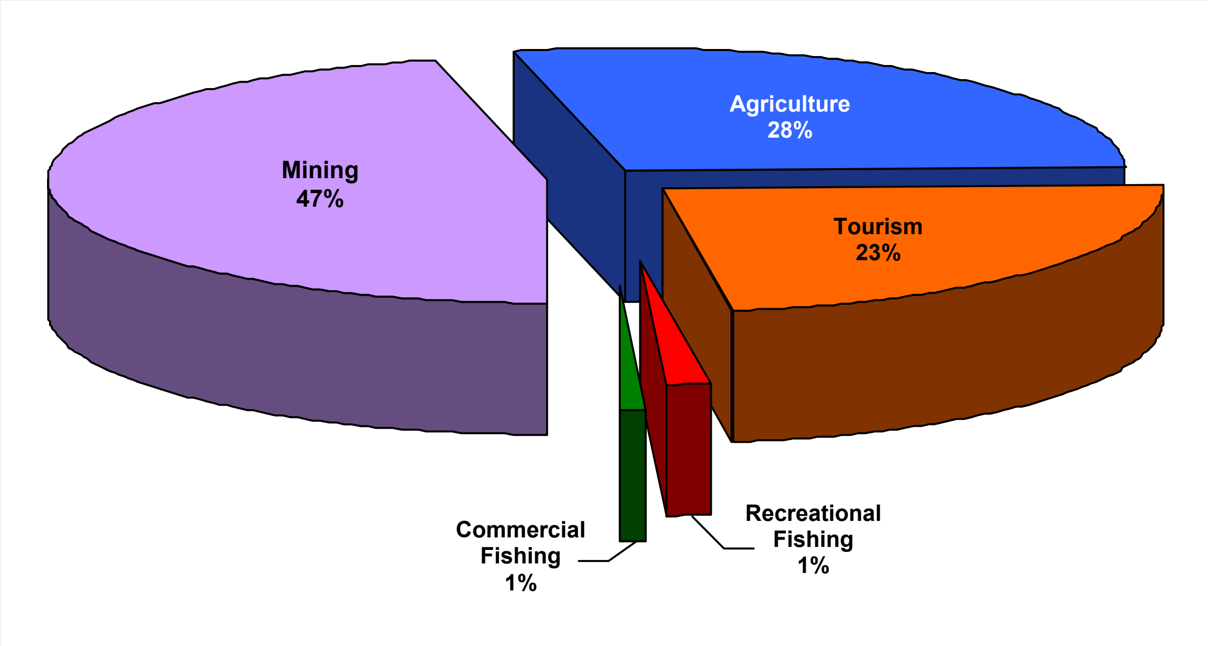

Figure 2.16: Key industry sectors in the GBR catchment based on contribution to gross value of production (GVP), 2003 (Source: Productivity Commission 2003).

2.7.2 The tourism sector and the GBR

During the year ended June 2003, there were an estimated 16.6 million domestic overnight visitors to Queensland, and these stayed a combined total of 79.6 million nights. Of these, some 24% visited the GBRMP tourism region, with 24% of their visitor nights being spent within the GBRMP tourism region (Bailey *et al.* 2003). The main tourism regions frequented by overnight visitors were the Tropical North Queensland, Fitzroy and Northern regions. However, as Bailey *et al.* (2003) note, it is important to acknowledge that not all domestic travellers to the GBRMP tourism regions experience the attractions of the GBRMP: only some 43% actually travel to the area for the purpose of a holiday.

In the 1998/99 year, total tourism expenditure in the Tropical North Queensland region totalled $2,064 million. This was linked with an estimated 1.846 million day trips in the region, 7.659 million domestic visitor nights and 5.788 million international visitor nights in the region. The gross regional product (GRP) for that year was estimated at $870 million and accounted for about 14% of total Queensland tourism (OESR 2002). In addition, tourism employment in the Tropical North Queensland region was 17,118 full time equivalent (FTE) positions, or 16.3% of all FTEs for the region (OESR 2002). Bailey *et al.* (2003) forecasted that tourism expenditure in the GBRMP will be in the vicinity of $62.2 billion over the period 2003/04 to 2022/23, based predominantly on a four to five percent average annual increase in international visitation, a 0.7-0.9 % increase in domestic overnight visitors and 0.5% growth in day trips. Bailey *et al.* (2003) also add that the overall health of the GBRMP is integral to this future growth. This is clear evidence that tourism is a significant employer in the Tropical North Queensland region.

During 2002, tourism-based employment in the GBRMP area was responsible for the employment of some 33,100 persons or 9.1% of total employed persons[9] (Bailey *et al.* 2003). The breakdown of this employment sector for each of the regions used in this research is shown in Table 2.23: approximately $131,000 of tourist expenditure resulted in one tourism-based job in 2002.

Table 2.23: Tourism employment in the Great Barrier Reef Marine Park tourism area, and Australia, during 2002 (Source: Modified from Bailey *et al.* 2003).

Target Regions	Tourism employed persons ('000)	Share of regional employment due to tourism (%)	Expenditure required to create one tourism job ('000)
Mackay-Whitsunday	5.2	8.2	121
Northern Queensland (incl. Townsville)	4.5	5.2	141
Tropical North Queensland (incl. Cairns/Far North Qld)	17.3	16.9	131
Australia	549.0	5.9	125

In the year ended December 2003, 35% of the overnight holiday/leisure visitors to Tropical North Queensland went on a daytrip to Port Douglas, Mossman, the Daintree or Cape Tribulation (Tourism Queensland 2004b). In 2004, there were approximately 21 tour operators running tours from Port Douglas to the Great Barrier Reef. According to the GBRMPA records of persons paying the Environmental Management Charge (EMC), approximately 280,000 tourists per annum use the offshore Port Douglas area for day trips and half-day trips (GBRMPA 2004). Assuming that the average cost for a both day and half-day trips is $100, then expenditure by tourists enjoying the Great Barrier Reef (with some benefits going to Cairns reef operators) is approximately $28 million per annum.

The Daintree National Park receives approximately 430,000 visitors every year (Klienhart 2002). The Queensland Parks and Wildlife Service (QPWS) indicate that there are currently 47 commercial permits specifically issued for tour operators to access attractions within the Daintree National Park. Key attractions include Mossman Gorge in the south-west of the Park, and Cape Tribulation in the northeast. Visitors must cross the Daintree River by ferry to reach the Cape Tribulation area. Griener and Rolfe (2004) reported that there were 110,000 ferry crossings in 1998/1999 at a charge of $7 per vehicle. Total direct use expenditure in the Park is estimated to be $93 million per annum, not excluding commercial accommodation costs or "local tours" (Klienhardt 2002).

As the bulk of visitor attractions in the Far North Queensland region are the coastal and reef areas, the tourism industry is heavily dependent on maintaining water quality levels. For example, Huybers and Bennett (2000, 2003) have reported that visitor numbers from the United Kingdom to Far North Queensland are likely to fall by 27% if environmental conditions degraded. Visitor expenditure will also fall by 30% under the same conditions. For example, if conditions fell from 'unspoilt' to 'very spoilt', the respective falls in visitor numbers and expenditure was predicted to be 58% and 61%, respectively. This implies that if environmental conditions in the Douglas Shire alone fell from 'unspoilt' to 'very spoilt', the annual shire income from tourism might fall by up to $120 million (more than six times the

[9] Based on BTR's methodology for calculating regional tourism employment.

total value of agricultural production in the shire).However, whilst environmental condition is an important consideration of tourists visiting the Daintree region, the impacts of poorer water quality on tourism activity may not be as pronounced as that reported by Huybers and Bennett (2000). This is because visitors from other countries and interstate may not be as discerning about environmental conditions as those from the United Kingdom, and because water quality is only one facet of environmental issues. Nevertheless, if water quality deteriorated to the point where recreation and/or tourism activities such as swimming and fishing were affected, major economic impacts might be expected. For example, even a one-percent reduction in expenditure is equivalent to $24 million annually, whilst a one-percent change in GRP equates to $10 million, and a one-percent loss in tourism-based FTEs reflects approximately 171 jobs.

2.7.3 Commercial fishing sector

The commercial fishing sector is of both social and economic importance to the Great Barrier Reef catchment. The gross value of fisheries production in Queensland fell from $297 million in 2003/2004, to $252 million in 2004/2005 (ABARE, 2005). This decline was attributed to a reduction in the value of wild-caught production from $229 million to $190 million during 2004/2005. For example, wild-caught prawn production fell by $18.9 million and wild-caught (fin) fish production fell by $20.6 million (ABARE, 2005). However, rising production costs and increasing prices in the wild-caught scallop sector drove a 58% increase in the value of scallop production to $15.7 million, which partly compensated for the fall in prawn and finfish production. ABARE (2005) also reported the gross value of aquaculture production fell by $6.0 million to $61.7 million in 2004/2005.

Data on the fishing industry of each of the three target regions are presented in Tables 2.24 to 2.26. These show that the total catch price paid on wharf to commercial operators across the three regions is expected to be in excess of some $30 million annually. The Queensland Seafood Industry Association (J. Beumer, pers. comm., 8 March 2005) has acknowledged the importance of good water quality to the Queensland commercial (and recreational) fishing industry. For example, around 75% of species valuable to fisheries production are directly dependant on estuarine environments for at least one stage of their life cycle, and, should that stage be interrupted, population impacts can be significant. However, it remains unclear how a decline in water quality standards in the Cairns region will affect commercial fishing, since fish stocks may or may not drop sharply once some threshold levels in water quality are breached. In addition, those fishing areas targeted by operators from Port Douglas may in fact be some distance from the water inflows from the Douglas Shire catchments.

Table 2.24: Summary of commercial fishing catch and total gross value of production (GVP) resulting from the commercial fishing sector in the **Cairns** coastal region (Source: The Coastal Habitat Resources Information System (CHRIS), QDPI&F 2007).

Fishery Activity	Tonnes	Boats Active	Days Fishing	GVP (AUD)
Line	84.8	78	1,368	$672,400
Net	241.9	24	396	$1,230,000
Trawl	327.8	145	1095	$4,460,000
Total	**654.5**	**247**	**2,859**	**$6,362,400**

Table 2.25: Summary of commercial fishing catch and total gross value of production (GVP) resulting from the commercial fishing sector in the **Townsville** coastal region (Source: The Coastal Habitat Resources Information System (CHRIS), QDPI&F 2007).

Fishery Activity	Tonnes	Boats Active	Days Fishing	GVP (AUD)
Line	679	363	4,708	$5,426,800
Pot	71.2	33	2,600	$641,100
Net	358.4	76	1,761	$2,042,100
Trawl	528.0	410	4,141	$5,861,800
Total	**1,636.6**	**882**	**11,928**	**$14,472,400**

Table 2.26: Summary of commercial fishing catch and total gross value of production (GVP) resulting from the commercial fishing sector in the **Mackay-Whitsunday** coastal region (Source: The Coastal Habitat Resources Information System (CHRIS), QDPI&F 2007).

Fishery Activity	Tonnes	Boats Active	Days Fishing	GVP (AUD)
Line	666.9	300	3,916	$5,308,500
Pot	25.6	38	1,167	$268,800
Net	188.9	76	1,425	$911,200
Trawl	415.1	390	3,058	$4,965,800
Total	**1,296.5**	**804**	**9,566**	**$11,454,300**

2.7.4 Recreational fishing sector

Recreational fishing is a significant social and economic activity within the GBR coastal area. The current annual commercial catch of reef fish from the GBR is about 4,000 tonnes, whilst the recreational catch is estimated to be about 2,000 tonnes (Williams, 2002). Allowing for some 346,000 km² for the reef and lagoon area of the GBR, this total annual catch equates to approximately 17kg/km². When compared with average annual catches of some 7,700 kg/km² as reported for a range of Pacific reefs (Adams *et al.,* 1996), it can be concluded that the GBR has a large unrealised capacity. However, obtaining reliable estimates of the economic impact of recreational fishing in the GBR is somewhat problematic.

The main distinction between commercial and recreational fishing is that people who fish for recreation may or may retain their catch for their own use, whereas the catch from commercial fishing is always kept and sold. Although commercial fishers are required to document catch sizes (from which values can be generated), this is not done for recreational fishers. Consequently, attempting to assess the tangible value of recreational fishing creates a difficulty when there are no official records of the numbers of fish caught (particularly for catch-and-release activities). Furthermore, the 'value' of a recreational catch may depend to a large degree on the estimations of the recreational fisher, and represents only a part of the overall value of the recreational fishing sector. Both Henry and Lyle (2003) and ABARE (2005) clearly state that recreational fishing expenditure is not a good proxy to assess the economic value of recreational fishing. ABARE (2005) also point out that translating the GVP from commercial fishing to estimates of recreational fishing expenditure is not appropriate. However, given the limited amount of data available regarding recreational fishing, reliance upon expenditure data provides a limited, but still useful, indication of recreational fishing activities within Queensland.

In a survey conducted of Queensland households during 2001, approximately one in every three households (or approximately 417,435 households in the state) had at least one member (aged 15 years or older), that had been recreational fishing during the twelve months prior. However, participation rates in recreational fishing appear to have been declining since 1996 (Figure 2.17). Despite the fact that recreational fishing need not be an expensive recreation, the reported decline in the number of recreational fishers may be partly attributed to the increased choice of less costly recreational activities available (Productivity Commission, 2003). In contrast, there has been an increase in the ownership of boats, with just under forty percent of the population fifteen years or older living in a household that owns a boat used for recreational fishing (representing 157,373 or some 37.7% of Queensland households) (Figure 2.17).

In 2000/2001, Australia's recreational fishers spent an estimated $1.8 billion on fishing related items – an average of $552 per person. Fishers reported more than 45 different expenditure items with expenditure on boats and trailers being the biggest individual expense ($940 million). Travel associated with fishing ($395 million) and purchase of fishing gear ($182 million) was also eminently important. In 2000/2001, more than 511,000 boats with a capital value of $3.3 billion were used for recreational fishing.

At the state level, Queensland's recreational fishers estimated their expenditure on fishing related items at $320 million, or the equivalent of $407 per fisher, during 2000/01. These are aggregated estimates and it is valid to recall the Tasmanian study conducted in 1994 *'Participation in Sporting and Physical Recreational Activities'* (ABS Tas. – Cat. No. 4175.6) estimated that some 47% of fishers spent less than $100 a year on their interest, thus indicating that a sizeable proportion of fishers do not add significantly to the economic value of recreational fishing.

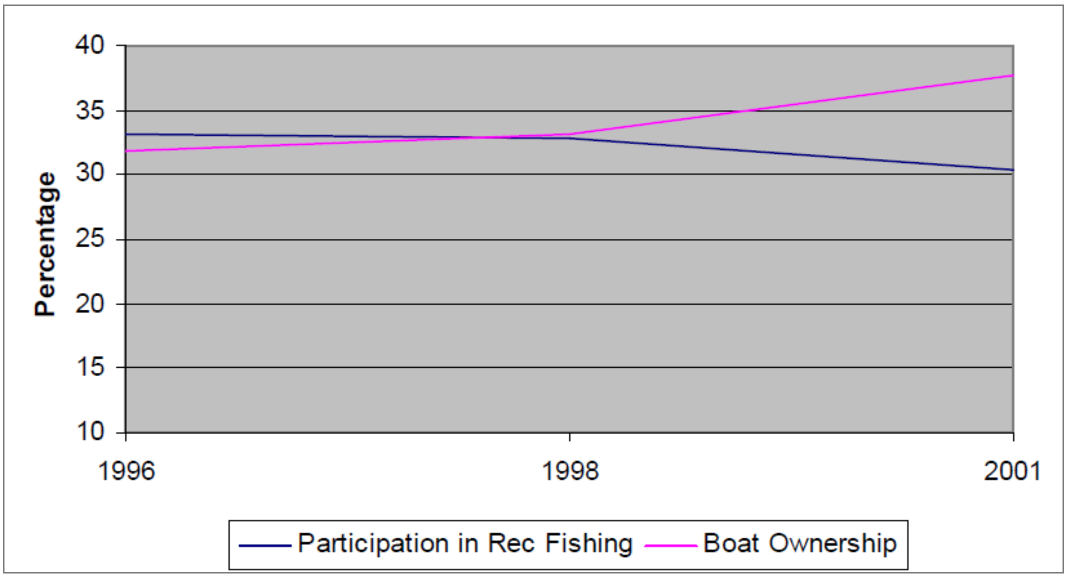

Figure 2.17: Participation in recreational fishing and boat ownership in Queensland during the period 1996-2001 (Source: National Recreational and Indigenous Fishing Survey, 2000/2001).

2.8 Conclusions

The three targets regions chosen for study each have different characteristics. The Cairns coastal region appears to have the most reef-dependent economy, primarily because of its strong linkages with the tourism sector. The economy of the Townsville coastal region is the most diverse, and consequently the most likely to exhibit the greatest capacity to buffer against the economic impacts created by coral bleaching. Finally, the Mackay-Whitsunday coastal region trails Townsville but is likely to be better placed than Cairns.

In chapter three, the outcomes of the business analysis are to be targeted toward obtaining a better understanding of how changes on the reef will affect businesses and other individuals that are dependent on the GBR ecosystem. This will be done particularly in terms of the level of understanding and perceptions of climate change amongst different reef users. Insight will also be able to be derived as to the management needs and in addressing community impacts resulting from reef degradation under climate change. A critical component of this analysis will be to what extent coral bleaching will impact on the tourist industry (given that the reef is only one component of the overall package offered to tourists), and the recreational and commercial fishing industries. This must be considered together with what behavioural changes are expected (or needed) and how these might translate economically.

3. A Survey of Socio-economic Impacts on Business and Local Government

3.1 Introduction

In order to effectively manage the resources of the Great Barrier Reef under climate change, information from many sources must be integrated in such a way that the risks are identified, mitigated against and managed for. These risks are linked to uncertainty, and will differ with local circumstances and planning. However, the risks can be made explicit by quantifying the degree of exposure and vulnerability, using scenarios and probability. A critical step in meeting this challenge is the development of spatially explicit, sub-regional scale information about the risks posed by climate change and variability in regional resilience. Once these risks are understood, management tools can be built to facilitate the optimum use of management and resources under conditions of ongoing uncertainty.

This chapter presents the results of a staged research process that was targeted at qualitatively determining the level of impact that climate change will have on the business economy of the GBR catchment. The study incorporated the following key elements:

1. A broad-sweep survey of business owners/managers in the three reef-based communities (Cairns, Townsville and Mackay), generate an understanding of business reaction to and preparedness for climate change in the GBR catchment;
2. Detailed follow-up telephone interviews with those survey respondents (as above) who indicated they were willing to participate in further research; and
3. A series of in-depth focus group meetings with councils and other government and planning instrumentalities (Cairns, Townsville and Mackay) in to scope the breadth of risk posed by climate change to the socio-economic fabric and infrastructure of the area. These focus groups were aimed at obtaining a detailed insight into the higher level exposure and vulnerability of the businesses, as well as the level of preparedness to adapt to or mitigate against these risks.

3.2 Mail-out survey of businesses

3.2.1 Design and sample size

In the first stage of data collection, a mail-out survey was sent to 7,780 businesses from reef-based communities. The sample was stratified to match business concentrations in each of the three locations (Table 3.1). Participation in the research was restricted to business owners or managers, who were contactable by postal address within the target locations, and who were over 18 years of age. Business contact details were sourced from the MarketPro database, a licensed electronic white page directory. A random selection approach was used to ensure that all businesses had an equal chance to be contacted. All duplicate and out-of-scope business addresses were purged from the computer-generated list before selection took place (for example, this included removing nursing homes, government organisations and non-profit businesses from the sample).

Table 3.1: Sample size for the mail-out survey in each of the three target regions in this study.

Sample statistic	Cairns coastal area	Townsville coastal area	Mackay-Whitsunday coastal area	Total
Total businesses	20,571	16,003	9,489	**46,063**
Percent representation across target areas	41%	36%	23%	
First sample extracted	4,000	3,500	3,000	**10,500**
Sent	3,246	2,549	1,985	**7780**
Not delivered - returned	797	402	570	
Second sample extracted	1,500	1,500	1,500	**4,500**
Sent	797	402	570	
Total sent	**4,043**	**2,951**	**2,555**	**9,549**
Total completed	**106 (3.9%)**	**79 (2.6%)**	**64 (2.5%)**	**249 (2.6%)**

The survey instrument was comprised of four parts, with questions drafted under the following themes:

- Business identification,
- Perception and attitudes towards impacts of climate change on the Great Barrier Reef,
- Managing climate change and responding to risk, and
- Demographics and reef dependency.

A complete version of the survey is provided in Appendix 1. Before administration to the target group, a draft research survey was submitted for approval by the Human Ethic Research Review Panel at Central Queensland University (certification # H07/10-095). Once this had been granted, the mail-out took place: participants were invited to take part in the research by completing the survey instrument, designed to take approximately five minutes to complete. The survey was accompanied by an introductory letter outlining the research objectives and a statement regarding the participant's rights, data management and ethics requirements and researcher contact details (see Appendix 2). A reply-paid envelope was also provided for return of the survey.

3.2.2 Data collection

During the week 29 October to 2 November 2007, a pre-test of the survey was undertaken. Fifteen paper-based questionnaires were delivered to fifteen businesses with a request to respond to the questions based on business operators' experience and circumstances. Of these, ten surveys were completed and returned, and, based on the feedback from the respondents; a number of minor changes to the format of the introductory letter and survey were made.

The first mail out to the three target locations commenced shortly afterwards on 20 November 2007. A total of 7,780 letters (with surveys) were posted using the Australia Post bulk mail facility. A significant proportion of these letters were returned marked 'address unknown' or 'not deliverable'. Consequently, a second random sample was drawn for each target area and the returned mail re-addressed and posted (see Table 3.1).

3.2.3 Response rate

The reporting of response rates as indicators of quality and representativeness for population based surveys is an important tool that allows for comparisons between surveys. In order to assist this aim, the recommended standard final outcomes categories and standard definitions of response rates based on the American Association for Public Opinion Research, Standard Definitions[10] was used. The response rate is a calculated percentage representing the number of businesses participating in the survey, either with completed or partially completed surveys, divided by the businesses selected in the sample. The numerator is the number of completed or partially completed surveys and the denominator includes the completed and partially completed surveys, the refusals, the sample not contacted, and other non eligible businesses from within the sample frame. The RR6 (maximum response rate) for the mail out survey was 3.32%.

A number of factors that restricted the overall effectiveness of the mail-out survey. Unfortunately, the MarketPro database appeared somewhat dated, and thus resulted in a high mail failure rate. The database also does not include the name of the business owner, which meant that the generic addressee 'To the Business Owner' was used on envelopes: this which could have been responsible for the low return rate. Alternatives were suggested by the postal service however these were outside the scope of the research budget. In addition, a delay in the initial mailing of the survey resulted in the second round of surveys being sent just prior to the end-of-year closure for many businesses: as this is a busy time of year for many operators, many may have decline to participate simply through time constraints.

3.2.4 Data manipulation

Data were entered into a spreadsheet and selected variables transferred to the SPSS[11] statistical analysis tool, where the data were tabulated and cleaned (including wildcode, discrepant value and consistency checks). The resultant dataset contained 249 cases, each with 27 variables. Open ended data was thematically analysed.

3.2.5 Results and analysis

3.2.5.1 Business identification

The businesses that responded to the survey were closely proportional to the percentage of businesses existing in each of the targeted area, as referenced by the ABS business exit survey. Over forty percent (or 106 respondents) of businesses were from Cairns whilst Townsville and Mackay had just over thirty percent (or 79 respondents) and 25% (or 64 respondents), respectively Businesses in the construction, retail trade, and professional, scientific and technical services comprised some 38% of all survey participants (Table 3.2).

3.2.5.2 Business statistics and reef dependency

Nearly sixty percent of the businesses participating in the survey had annual turnovers of $500,000 or less, with just under ten percent of respondents turning over in excess of $10million annually (Table 3.3). Almost three-quarters of businesses were either family owned and/or operated ventures, or franchises (Table 3.4). This is an important finding given the inherent capacity and capability that will be required of those operators in order to

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[10] The American Association for Public Opinion Research. 2004. *Standard Definition: Final Dispositions of Case Codes and Outcome Rates for Surveys. 3rd edition.* Lenexa, Kansas: AAPOR.

[11] SPSS (Statistical Product and Service Solutions – formerly Statistical Package for the Social Sciences), a product of SPSS Inc., Chicago, Illinois.

implement the changes required to maintain business viability. Only thirteen percent of businesses were newcomers (aged five years or less), with over half having been operating for between 6-20 years (Table 3.5). Over half of the businesses employed five or less full time staff (Figure 3.1), with nearly 90% employing five or less part time staff (Figure 3.2).

Table 3.2: Participating businesses grouped by ANZSIC category.

ANZSIC Category	Frequency	Valid Percent	Cumulative Percent
Agriculture, forestry and fishing	11	4.5	4.5
Mining	4	1.7	6.2
Manufacturing	10	4.1	10.3
Electricity, gas, water and waste services	9	3.7	14.0
Construction	30	12.4	26.4
Wholesale trade	7	2.9	29.3
Retail trade	34	14.0	43.3
Accommodation and food services	20	8.3	51.6
Transport, postal and warehousing	7	2.9	54.5
Information media and telecommunications	1	0.4	54.9
Finance and insurance services	6	2.5	57.4
Rental, hiring and real estate services	8	3.3	60.7
Professional, scientific and technical services	28	11.6	72.3
Administrative and support services	9	3.7	76.0
Public administration and safety	3	1.2	77.2
Education and training	7	2.9	80.1
Health care and social assistance	19	7.9	88.0
Arts and recreational services	7	2.9	90.9
Other services	22	9.1	100.0
Total	**242**	**100.0**	

Table 3.3: Average annual turnover characteristics of participating businesses.

Amount	Frequency	Valid Percent	Cumulative Percent
< $100,000	64	29.0	29.0
$100,001 – $250,000	31	14.0	43.0
$250,001 – $500,000	31	14.0	57.0
$500,001 – $1,000,000	21	9.5	66.5
$1,000,001 – $10 million	54	24.4	90.9
> $10 million	20	9.1	100.0
Total	**221**	**100.0**	

Table 3.4: Summary showing structures of the businesses surveyed across the three target areas.

Business structure	Frequency	Valid Percent	Cumulative Percent
Family owned and operated	172	70.2	70.2
Franchise	6	2.5	72.7
National chain – Head office	2	0.8	73.5
National chain – Regional office	16	6.5	80.0
Other	49	20.0	100.0
Total	**245**	**100.0**	

Table 3.5: Summary of the age of businesses sampled in the three target areas.

Age of business	Frequency	Valid Percent	Cumulative Percent
1-5 years	32	13.4	13.4
6-20 years	133	55.9	69.3
21-40 years	54	22.7	92.0
41-60 years	8	3.4	95.4
More than 60 years	11	4.6	100.0
Total	**238**	**100.0**	

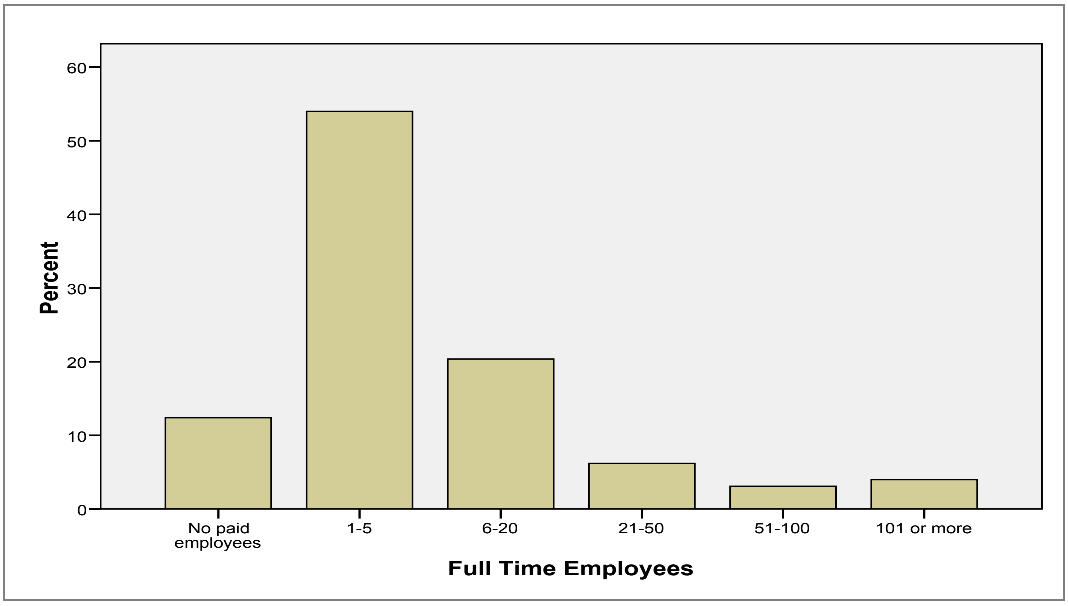

Figure 3.1: Number of full-time paid employees working for business who participated in the survey.

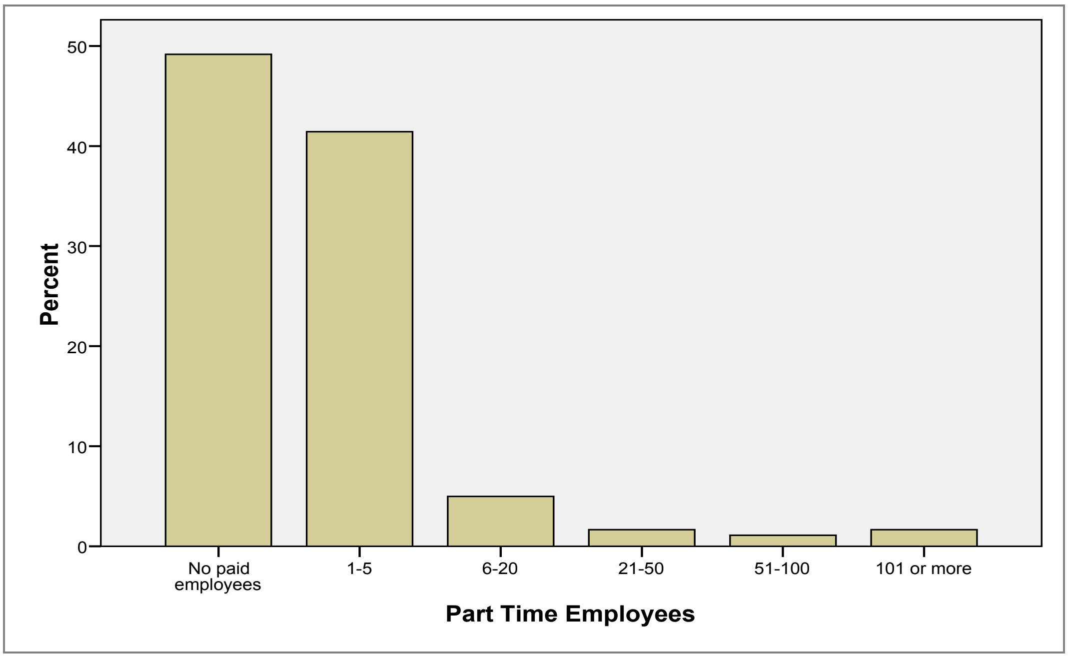

Figure 3.2: Number of part-time paid employees working for businesses who participated in the survey.

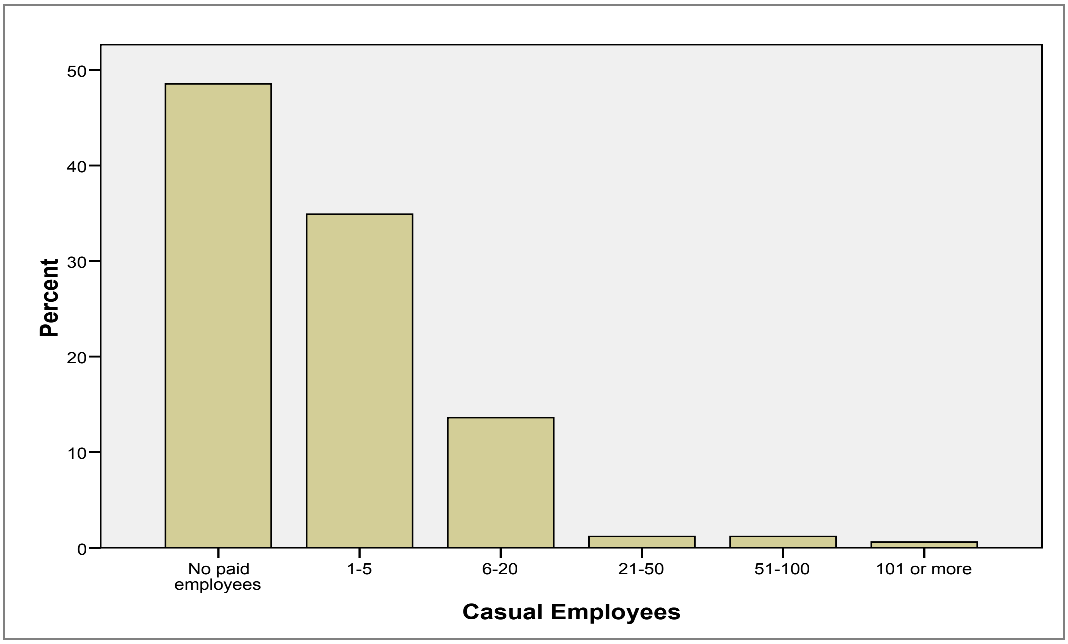

Figure 3.3: Number of casual paid employees working for businesses who participated in the survey. More than fifty percent of business operators surveyed indicated that they intended to grow and develop their business (Table 3.6), pointing to a positive economic climate and outlook. It is inferred that this positive outlook towards growth and development indicates the business communities that are receptive to change to achieve improved business viability and productivity.

Table 3.6: Summary of current phase or stage of business operations of those surveyed in that three target regions.

Current phase / stage of business	Frequency	Valid Percent	Cumulative Percent
Intending to expand in the future	124	50.8	50.8
Intending to decline in the future	16	6.6	57.4
Intending to stay the same	85	34.8	92.2
Other	19	7.8	100.0
Total	**244**	**100.0**	

The nature of the businesses as being reef-dependent was examined by determining the total proportion of trade (business throughput) that resulted from transactions derived from the reef. This indicated that overall, most businesses (some 76%) had only a mild dependency on the reef-based transactions, with only 0-20% of their transactions being reef-related (Table 3.7). On a regional basis, however, it was evident that the Cairns target area contained some businesses that were highly reef-transaction dependent (Figure 3.4). However, it is important to acknowledge that a low reef-related throughput may not necessarily translate to a low overall reef-dependency (or vice versa). It is also interesting to note that only a quarter of participating businesses thought their business mix in relation to the reef would change in the future (Table 3.8).

Table 3.7: Summary showing the proportion of trade derived from the Great Barrier Reef for businesses participating in the survey.

Proportion of trade derived from the GBR	Frequency	Valid Percent	Cumulative Percent
0-20 per cent	184	76.3	76.3
21-40	14	5.8	82.1
41-60	18	7.5	89.6
61-80	9	3.7	93.3
81-100	16	6.7	100.0
Total	**241**	**100.0**	

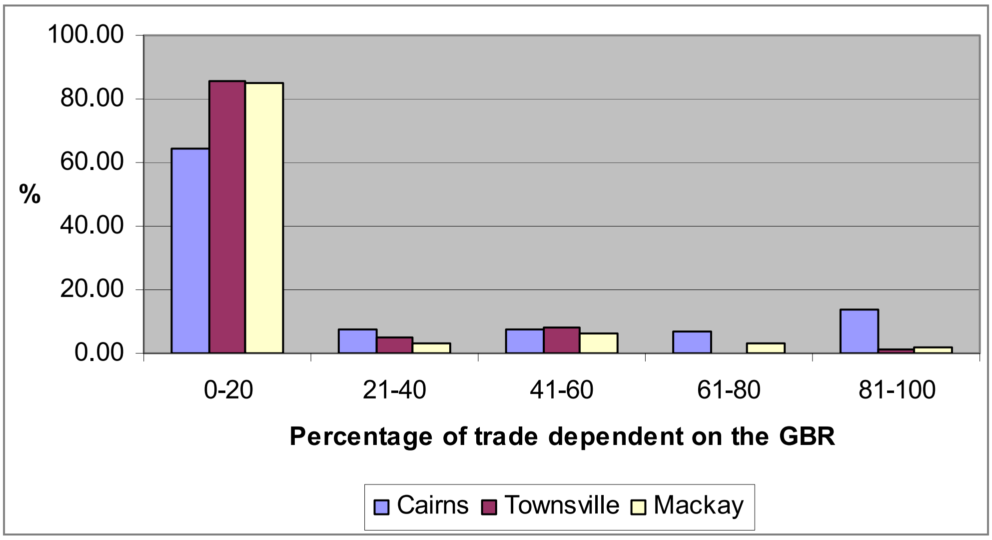

Figure 3.4: Summary showing the proportion of trade derived from the Great Barrier Reef for businesses participating in the survey, grouped by target region.

Table 3.8: Summary of responses for 'change in the relationship between business and the Great Barrier Reef in the future'.

Response	Frequency	Valid Percent	Cumulative Percent
Yes	63	26.0	26.0
No	179	74.0	100.0
Total	**242**	**100.0**	

3.2.5.3 Perceptions of and attitudes towards impacts of climate change on the Great Barrier Reef

Across the three GBR coastal regions, the majority of respondents (70%) attached some importance to the health of the Great Barrier Reef for their current and future business: close to 40% indicated that this was 'very important' (Table 3.9). Less than one-fifth of participants believed it was 'not very important' and just 11% thought it was unimportant. When data were arranged by target region, a considerable difference between the three coastal regions was noted with respect to the importance of climate change impacts on the GBR to business. For example, whilst nearly half of participants in Cairns rated climate change as 'very important', only one-third and one-quarter of respondents gave the same answer, for Mackay and Townsville, respectively (Figure 3.5). This is consistent with the reef-dependency of the economy of the Cairns coastal region that was identified in chapter two, compared with the more broad economic bases evident in Mackay and Townsville, where business may be based around the agricultural and mining sectors.

Table 3.9: Summary of responses regarding the importance of health of the Great Barrier Reef for businesses in the three target regions (* Valid cases for variable).

Response	Frequency	Valid Percent	Cumulative Percent
Very important	96	38.9	38.9
Somewhat important	37	15.0	53.9
Important	37	15.0	68.9
Not very important	49	19.8	88.7
Unimportant	28	11.3	100.0
Total	**247***	**100.0**	

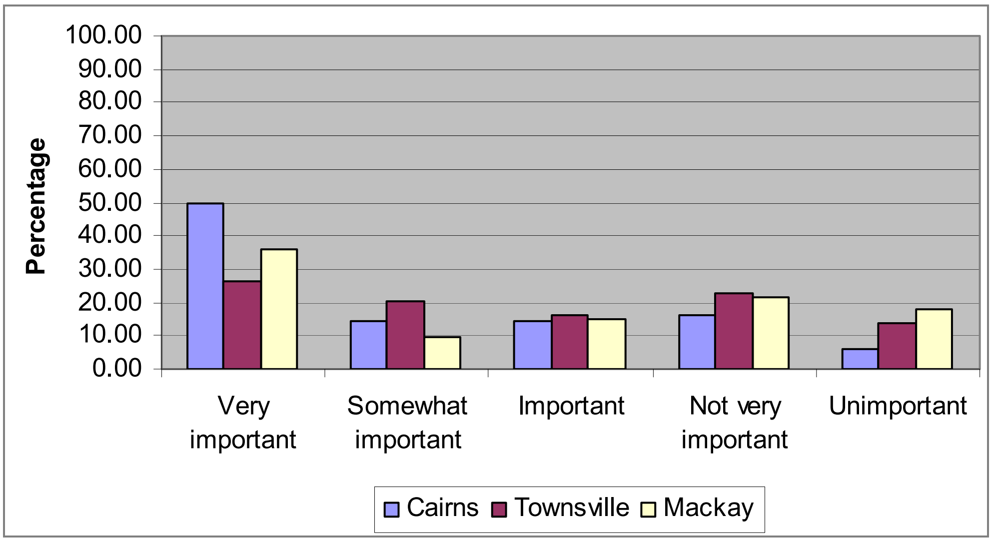

Figure 3.5: Summary of responses regarding the importance of health of the Great Barrier Reef for businesses, arranged by target region.

Business operators were asked to rate the expected level of impact that climate change would have on the health of the GBR on a scale of one to ten (where one indicated no impact and ten a major impact). They were also asked to assess the consequences of this impact on their businesses over a five year timeframe, using the same scale. These questions were designed to determine business operator's perceptions of how climate change will impact on the health of the GBR and their business. More than half of the surveyed business operators believed that climate change will have a considerable, or major, impact on the reef (Table 3.10); with the median score being 7 (considerable) whilst the modal score was 8 (considerable). Just twelve percent of participants thought that climate change would have no impact on the GBR at all.

Interestingly, business operator's perception of the likely impact(s) of climate change on their business differed from the impacts nominated on the GBR. For example, the modal score was in the 'no impact' range, whilst the median score was five (moderate impact) (Table 3.11). Nearly one-third of participants rated climate change as having no real impact on their business, with less than one in eight businesses indicating that a major impact was likely.

Table 3.10: Summary of responses regarding the importance of health of the Great Barrier Reef for businesses in the three target regions (* Valid cases for variable).

Rating	Scale	Frequency	Valid Percent	Cumulative Percent
1 or 2	No impact	30	12.1	12.1
3 or 4	Very little impact	31	12.6	24.7
5 or 6	Moderate impact	39	15.8	40.5
7 or 8	Considerable impact	77	31.2	71.7
9 or 10	Major impact	70	28.3	100.0
	Total	**247***	**100.0**	

Table 3.11: Summary of responses given for 'rank the level of impact that climate change might have on your business'.

Rating	Scale	Frequency	Valid Percent	Cumulative Percent
1 or 2	No impact	67	27.1	27.1
3 or 4	Very little impact	40	16.2	43.3
5 or 6	Moderate impact	56	22.7	66.0
7 or 8	Considerable impact	54	21.9	87.9
9 or 10	Major impact	30	12.1	100.0
	Total	**247**	**100.0**	

The data from these two questions were then used to determine the difference in business operators' perceptions of climate change risk for the reef, compared with the risk to their business. This analysis showed that business operators were generally in agreement across all three of the target regions (Cairns, Mackay and Townsville), with the expectation being that the impacts on the reef would be approximately 1 to 1.5 units higher (=worse) compared with the perceived risks of climate change on business (Figure 3.6).

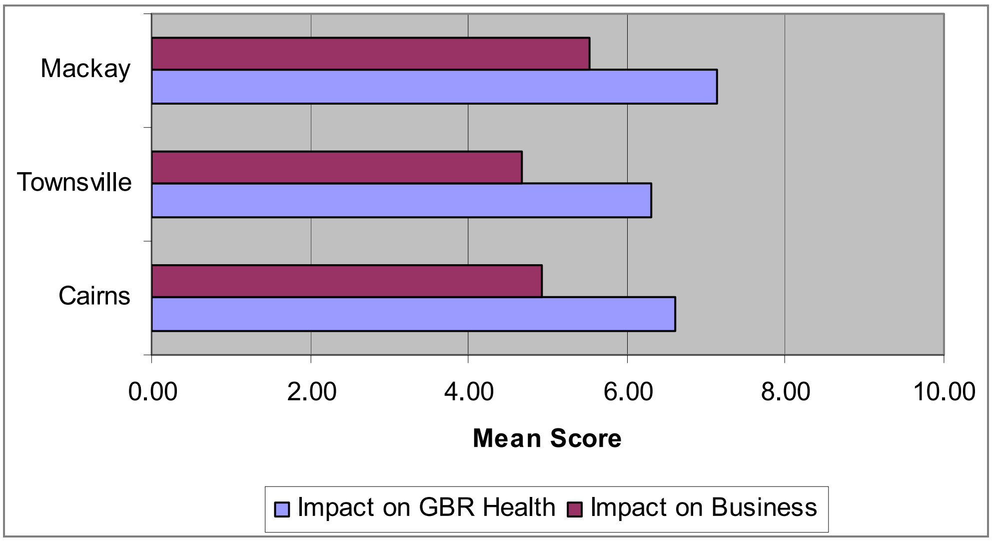

Figure 3.6: Mean scores recorded for the likely impact(s) of climate change on the health of the Great Barrier Reef, compared with impact(s) recorded for business.

As a follow-up to these questions, respondents were asked to identify what they thought would be the likely impacts of climate change on their business. The impacts most often mentioned by participants revolved around a reduction in business through-put due to declining tourist numbers, increased energy costs and a general economic downturn affecting all businesses (Table 3.12). Some parties also reported that they felt that there would be considerable flow-on effects, as well as productivity and health problems. Very few parties thought that there would be no impact (<5%). At a more general level, businesses in tourism and recreation indicated the decrease in interest in the reef will result in a reduction of tourism and visitors to the regions and saw the reef as a keystone industry for the economic wellbeing of the region. It is of particular note that some respondents (albeit few) actually saw potential for positive impacts or opportunities for their businesses, including increased demand for cooling products, shade and shelter and new forms of recreational products and services (Table 3.12). Other positive impacts included potential for change in consumer preferences, with accompanying demand for new products and services requiring new and innovative ways of doing business.

Table 3.12: Summary of the key impact(s) that climate change will have on businesses in the three target regions (as nominated by operators).

Impact / Response	Percentage
Decline in tourist numbers due to lack of appeal of area due to reef degradation, therefore less people visiting	25
Increased energy costs	15
Economic downturn, effecting all businesses	15
Changed rainfall patterns affecting farm income	10
Increased temperatures therefore lack of water	10
Impact on unsustainable resources e.g. coal mining industry/ construction	5
Decrease in population	5
People productivity, health problems, stress and work conditions	5
Loss of business due to loss of allied industries	5
No impact / Nil	4
Change in client base / more business opportunities, therefore increase in business	1

3.2.5.4 Managing climate change and responding to risk

The general topic area ‘managing for climate change’ and ‘responding to climate change risks' was also explored. This was done to investigate the level of perceived ownership of the issue and the degree of responsibility that business operators believe they have in managing for climate change. One of the questions asked revolved around who business operators believed was responsible for managing the possible impacts of climate change on the GBR. Some ten percent of respondents identified that business had a role to play, but an equal number of respondents also listed the Great Barrier Reef Marine Park Authority, the Government, all Australians and ‘no-one’ (Table 3.13). The Federal and State tiers of government, specifically, were also listed by a further fifteen percent of people, indicating that many participants had an expectation that climate change risks would be managed by their government agencies.

Table 3.13: Summary of responses to the survey question ‘Who is responsible for managing the possible impacts of climate change on the Great Barrier Reef?’

Responsible Entity	Percentage
Federal and State Governments	15
Every person	15
Great Barrier Reef Marine Park Authority	10
All Australians / the whole country	10
No-one	10
All levels of Government / Local, State and Federal Governments	10
Local business / consumers	10
Not sure	5
The community	5
Society	5
The next generation	1
The whole world	1
United nations	1
Environment Ministers / Environmental Protection Agency	1

The open-ended question ‘What do businesses think are the key issues for business operators as they face the possible impacts of climate change on the Great Barrier Reef?’ was used to provide an insight into what the business community feels are the more pressing issues. Many respondents reported that there will be a need for considerable business change, diversification and the engagement of more effective risk management (Table 3.14). However, what was not adequately explored was the capacity and capability of business operators to manage and meet the costs of these changes to ways of doing business, and the structure and function that would be necessary for those businesses to maintain long term viability.

Table 3.14: Summary of responses to 'key issues for business operators as they face the possible impacts of climate change on the Great Barrier Reef'.

Key issue(s) for business operators	Percentage
Business change / diversify operations / risk management practices – which includes more energy efficient practices, design and work methods and redefining costs as well as environmentally friendly work practices and staff education	40
Business costs increase	15
Decrease in tourism	15
Affect on secondary resources and economic impacts e.g. flow-on effects on tourism, fisheries as well as social issues	10
Loss of habitat, diversity and fish stocks	5
Business downturn	5
Other	10

The key issues facing business operators in the region appear to be immediate effects of climate change on their business and the subsequent requirement to diversify. For example, the recreational and fishing industries seem primarily concerned about reef productivity and how this will affect their costs structures and the impact on tourism. However, businesses are also concerned with the awareness of their staff, the environmental responsibilities shouldered by businesses and the education needed for businesses to survive. A cross section of some of the more salient statements provided by business operators are as follows:

- D"ownturn in tourism due to ill health of reef, remedial measures to protect reef from further damage. Reduced fishing, boating, diving, adherence to a new code of behaviour relating to the reef";
- "Business operators who are directly linked with the reef (i.e. tourist operators) will need to assess their operations in a smaller area of the reef – fewer available areas – longer to travel";
- "Definitely tourist operators would notice the change with the operation of their business – due to more maintenance issues and also maybe lower passenger numbers";
- "I don't think most of them will care in mining support industries. Tourism support businesses will obviously be copying government for max protection";
- "Every business owner large or small should accept the responsibility for the waste they generate";
- "Insurance; climate change affecting the bottom line; creation of an uncertain future.";
- "Loss of appeal to tourists and residents alike. Resources boom driving local economies but how long will we be able to do so, with such disregard for the natural environment - the biggest issue facing governments is trying to deal with climate change";
- "Unpredictability in business climate, e.g. outlays, income, customer decline";
- "No tourism means loss of jobs across entire region and in every sector (has flow on effect)";
- "No barrier reef means no Cairns, no Cairns means no development or migration and no building"; and
- "Major impact on fishing industry with a domino affect on others, i.e. less fish, less fishermen, less spending hotels, supermarkets, clothing, etc."

One indicator of the extent to which business operators in the GBR are prepared for climate change is the percentage of businesses who indicate that they have strategies in place to reduce business risks posed by climate change. This figure is also suggested of the level of seriousness with which climate change risk is viewed. Consequently, the question was asked of business operators, 'Do you plan to implement any strategies to reduce business risks that may be posed by climate change over the next five years?' Overall, less than half of respondents indicated that they intend to implement some kind of strategy (Table 3.15); however, at the regional level, it was apparent that operators in Mackay are the advanced in terms of planning for risk reduction with regards to climate change (Figure 3.7). Thus, Mackay-based businesses appear more likely to implement strategies than either Cairns or Townsville-based businesses. However, the issue of the 'appropriateness' of the climate change adaptation strategies which are being intended by those businesses was not examined. Further research should consider pursuing this issue further.

Table 3.15: Summary of responses to the survey question 'Do you plan to implement any strategies to reduce business risks that may be posed by climate change over the next five years?'

Response	Frequency	Valid Percent	Cumulative Percent
Yes	103	42.4	42.4
No	140	57.6	100.0
Total	**243**	**100.0**	

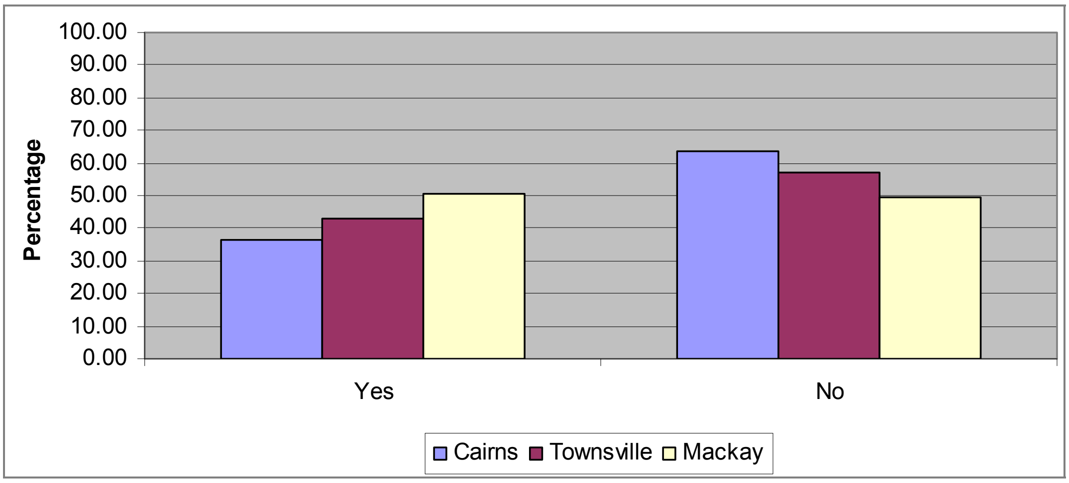

Figure 3.7: Percentages of business operators planning to implement climate change risk reduction strategies in the next half-decade.

The same dataset can be viewed from another angle by examining the relationship between those businesses that do plan to implement strategies in response to climate change impacts together with the proportion of trade generated from the GBR, for those same businesses. For example, Figure 3.8 (below) illustrates that most of the business with risk planning in place in actuality have a very low level of dependency on the GBR. A similar finding was found for those operators who did not have planning processes in place (Figure 3.9). As this is a somewhat surprising finding, it should be stressed that only a basic analysis has been done on the available data. Nevertheless, it does appear from this examination that the level of dependency on the GBR for trade is not a factor with regard to the propensity of business operators to consider the planning of climate change adaptation strategies.

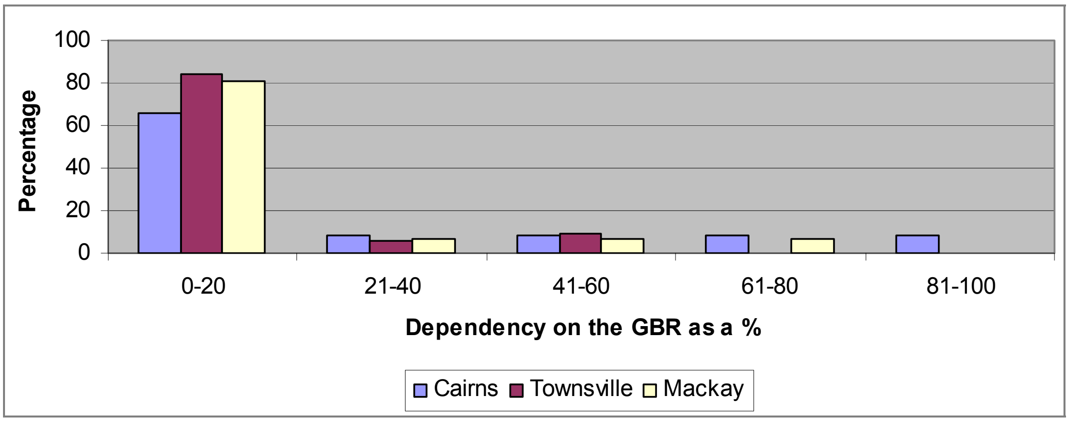

Figure 3.8: Businesses who plan to implement climate change risk reduction strategies, grouped by business dependency on the Great Barrier Reef.

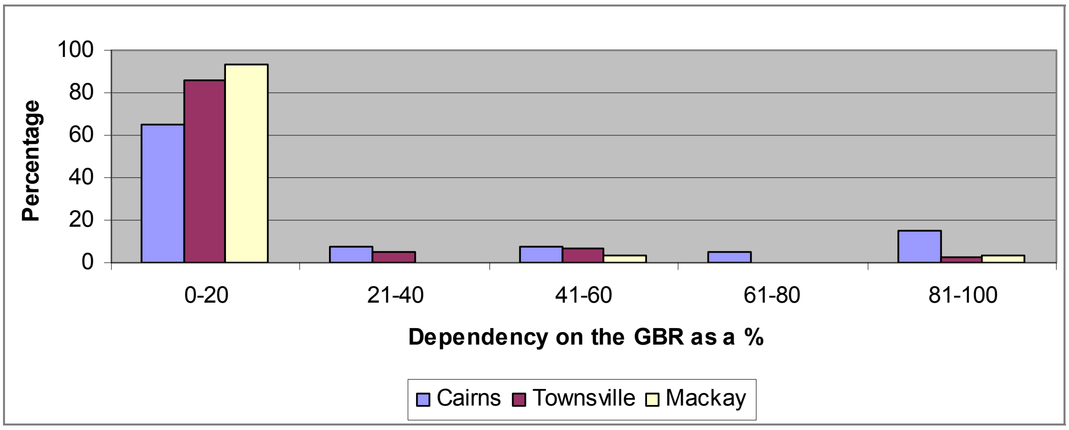

Figure 3.9: Businesses who do not plan to implement climate change risk reduction strategies, grouped by business dependency on the Great Barrier Reef.

3.3 Phone surveys of businesses reliant on the Great Barrier Reef

3.4.1 Methods

The surveys reported above yielded insights as to business operators' perceptions and attitudes. However, the responses also revealed that, without regionally-specific climate change projections, and regional models of land use and socio-economic change being developed and communicated to business operators (to a point where an understanding of the implications was reached), assessing the merits of adaptation options would not be possible.

At the end of the business survey instrument, participants were offered an opportunity to further participate in the research by either contacting ISRD (CQUniversity) directly, or by including a contact telephone number in the returned survey. Thus, to further investigate business operators' perceptions, attitudes and adaptive capacity, a stratified sample of the initial survey respondents were interviewed by telephone. The sample was drawn according to:

- Respondents' consent to participate beyond the initial survey response; and
- Respondents' indicating that they perceived climate change as a potential threat to their business activity.

Initially, 63 business operators were approached to participate in the personal interview stage. This was scaled back to fifty, since thirteen operators had either closed down or changed contact details. Semi-structured telephone interviews were conducted with a total of fourteen business operators from this cohort. A copy of the questions used to guide the interviews is provided in Appendix 3.

3.4.2 Response rate

A significant proportion of business operators declined to participate because they did not have time (Table 3.16). A total of 38% of potential respondents were unable to be contacted within the time allocated to complete the interviews. The Cairns cohort (forty percent of the response) appeared more willing to participate than those in Townsville (31%) and Mackay/ Whitsunday (12%). This may be due to the Cairns region's closer proximity to the GBR and its greater reliance on the tourism sector. However, the general lack of willingness to participate in the survey was directly attributed to the low level of awareness, understanding and interest by the business owners of the implications of climate change or the level of risk, exposure and vulnerability. This point needs to be considered in future survey work as well as the development of education and awareness programs.

Table 3.16: Distribution of participants of phone interviews.

	Cairns	Townsville	Mackay-Whitsunday	Total
Approached	20	13	17	50
Interviewed	8	4	2	14
No response received	9	4	6	19
Declined to participate	3	5	9	17

3.4.3 Results

The initial business survey was conducted to assess business operator's perceptions of vulnerability to, and readiness to adapt to, climate change. These surveys revealed a significant gap in understanding: it appears that 'adaptation' with regard to climate change is not a concept to which business owners have been exposed. In turn, this undermined the attempt to determine the adaptation options that would apply to the regions under study.

The follow-up telephone interviews confirmed this gap and revealed that, when considering climate change, business operators are generally unaware that they may have opportunities to adapt. Rather, the focus of their thinking in regard to climate change is mitigation – 'decreasing the carbon footprint', 'recycling', 'reusing water', 'energy saving'. Discussion within peer networks appears to focus on climate in terms of general sustainability issues (ride to work/ public transport, recycling), as opposed to direct reference to climate change, impacts, business risks or exposure at the regional level.

3.4.3.1 Discussions on climate change by business operators

Of the fourteen respondents interviewed, ten indicated that they participated in some level of discussion of climate change within their networks, while four indicated that it was not a topic that was discussed (Table 3.17). The topics of discussion reported among the business operators interviewed further illustrated the gap in knowledge that may exist regarding potential adaptation to climate change. For example, the discussion tended to centre on environmental issues rather than specific climate change issues, and around the levels of uncertainty in predictions of climate change. This bias towards non-specific discussion and levels of uncertainty may be the result of the source of information accessed by business operators.

Table 3.17: Topics discussed within business operators' networks (as nominated during telephone interviews).

Topic	Respondents
General discussion (environment, sustainability) without specific reference to climate change (recycle, ride to work, energy saving)	5
Uncertainty of predictions/ what are the realities (level of sea level rise, areas likely to be impacted, reduced rainfall/ water issues)	5
Risk management/ adaptation; disaster planning	2
How we do our business	1
Possible business opportunities	1

3.4.3.2 Sources of information regarding climate change

According to the business operators interviewed, the most popular source of information about climate change is the media (Table 3.18). As highlighted in the background to this report, a business sector informed by media with regard to this issue is not necessarily well-informed. Hence, there is a clear need to address the issue of communication of knowledge with potential to inform business planning. This includes ensuring business operators are informed of adaptation potential, rather than purely mitigation strategies.

Table 3.18: Sources of information about climate change as reported in survey responses.

Source	Number of times reported
Media	11
Local council	3
Industry associations	2
Internet	3
Government via news	1
Bureau of Meteorology	1
Research bodies (e.g. GBRMPA)	2
Local electricity company	1
'[The] Al Gore movie'	1
General scientific publications (New Scientist, National Geographic)	1

Business operators were also asked whether they believed they had enough information to include climate change impacts in their planning and risk assessment/ risk management processes. Of the fourteen respondents, only four indicated that they had enough information to inform their planning processes. Of these, three had integrated potential climate change impacts into their business planning, while the fourth respondent reported he had downsized the family car to reduce fuel consumption.

When asked what further information would enable them to build climate change impacts into their planning and risk management processes, the business operators' responses were somewhat fragmented and pointed to the limitations on information they had accessed to date (Table 3.19).

Table 3.19: Summary of responses regarding further information required to inform planning and risk management.

Response	Number of times reported
Specific regional information (e.g. predicted patterns of coastal change for local area)	4
Costs of adaptation, strategies	2
Energy saving strategies	1
Water saving strategies	1
Recycling	1
Dollar value for carbon trading	1

The majority of respondents reported that they did not have enough information to undertake risk management planning. When asked what information the business operator believed would assist, there was no common thread, indicating a lack of clarity about what is needed. This is perhaps consistent with the general discussion that the levels of uncertainty around potential impacts made it difficult for business operators to assess the potential impacts for their individual operations.

3.4.3.3 Using climate change scenarios to guage likely responses

The uncertainty around impacts of climate change at the regional level has provided little scope to gather definitive answers to the question, 'How will climate impact businesses?' In an attempt to get some sense of the type of responses business operators may employ, the following 'what-if' scenarios were presented to the business operators, with the request that they indicate their likely responses:

> *If your business suffered a downturn in demand of 10%, 25% or 50% as a result of climate change impacts, what would this mean to your business?*

Respondents were asked to indicate at each level whether they could absorb the downturn, would need to reduce staff, look for alternative markets, look for alternative products or close their business. They were also given the opportunity to offer other responses that they may consider. Of the fourteen businesses surveyed, five reported that they expected demand for their services to increase rather than decrease, including a refrigeration service provider, aged care provider, medical centre, seafood wholesaler and an engineering consultant (Figure 3.10).

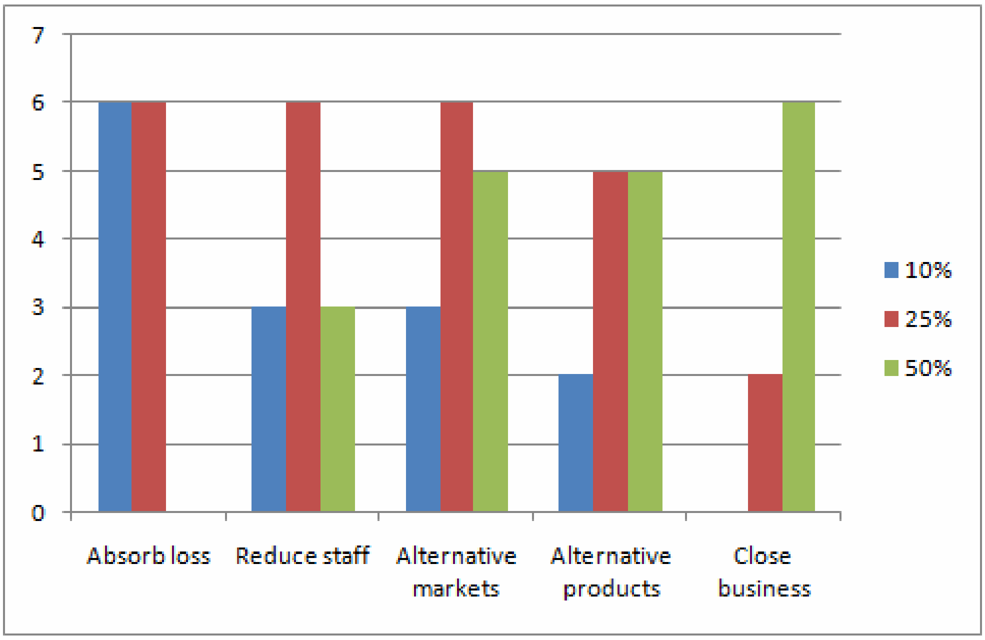

Figure 3.10: Business operators' beliefs about their capacity to respond to a downturn of demand induced by climate change impacts.

When provided with this series of 'what-if' scenarios, the business operators could generally provide some indication of their potential responses. Of the fourteen business operators interviewed, five indicated that they expected to see an upturn in business. Of the remaining nine, no business operators indicated that they would need to close as a result of a ten percent downturn, while six indicated that they would be likely to close in response to a fifty percent downturn. The most likely alternatives to closing in response to the 25-50% downturns in demand were (a) reducing staff, (b) diversifying by seeking alternative markets and (c) alternative products. This set of responses indicates that business owners have the capacity to respond to changed conditions, if they have some sense of what the changed conditions are likely to be. Caution however should be exercised with the use of these results as this sample was very small and may not be indicative due to the limited sample size.

3.4.3.5 Attitudes towards business futures

The phone interviews also attempted to draw out business operators' in regard to their attitude to the future of business in climate change conditions. To this end, participants were asked whether they had identified any opportunities that may arise for their business, as a result of climate change impacts. The responses were evenly split, with seven respondents indicating that they saw opportunities and seven indicating that they did not. When asked whether they had implemented or were developing plans to take advantage of the opportunities they believed would present, six of the seven participants were able to briefly describe their progress:

- (Refrigeration specialists) "Energy auditing – attended training workshops; employed new person to focus on energy audits and to research other potential opportunities; as large organisation, can allocate resources to research and training";
- (Seafood distributor) "No plans in place, waiting for hysteria to die down; staying level headed about opportunities that are being talked about";
- (Service to construction industry) "Staying aware of what's happening";
- (Accommodation provider) "Actively marketing in corporate conference market, less in leisure market";
- (IT service provider) "No plans in place but aware that more people will want environmentally friendly (service provision), e.g. programming air-conditioners to save energy, software development for power saving"; and
- (Distributor of farming inputs) "Changes to fertilisers; investigation potential for genetically modified crops; general business practice to build into planning".

Business operators who had identified potential opportunities were then asked whether there were any barriers that would prevent them from taking up these opportunities. Two operators identified potential barriers:

- (Accommodation provider) "Water restrictions – helps in long run but decreases attractiveness"; and
- (Distributor of farming inputs) "Legislation – GM crops; precision farming techniques such as yield mapping, more specific use of inputs in agriculture are purely market driven, so reliant on sellers to get right price; day to day distractions can get in the way of doing adequate forward planning.

Business operators were then asked whether there was anything currently not available to them that would support them in adapting to climate change, whether that be planning or taking advantage of opportunities that may present. The responses are listed below.

- (Refrigeration specialists) "Dollar value for carbon trading; benchmarking to enable quantification of potential savings for business if they take up options to reduce carbon footprint";
- (Medical centre) "Another four doctors";
- (Seafood distributor) "Good laymen's-type information from both sides of the argument";
- (Service to construction industry) "Not yet, but probably will be when time comes";
- (IT service provider) "Education / training, e.g. business planning workshops; tax incentives towards businesses becoming more eco-friendly";
- (Accommodation provider) "Information about energy saving and water saving; information on how to stop chemicals used for cleaning getting into runoff; information about reusing water and recycling generally; recycling bin";

- (Engineering consultancy) "Qualified engineers; skilled workers";
- (Service to boating industry) "Relocation costs – if Cairns were inundated so would many other places be. The government couldn't afford to prop up businesses";
- (Online training provider) "Could be opportunities to educate people about climate change, but people would probably want free education, so funding to provide education"; and
- (Child care provider) "Knowledge of current effects on region".

Looking forward, half of the business operators interviewed could see opportunities as a result of climate change. While plans to take up these opportunities were generally not highly developed, this response indicates optimism on the part of operators with regard to their capacity to respond to the challenges of climate change.

Finally, the participants were asked to rate their level of knowledge of climate change, on a scale of 1 to 10 where 1 is minimal knowledge and 10 is high level knowledge. Most respondents chose a 'middle of the road' figure between 4 and 8 (Figure 3.11).

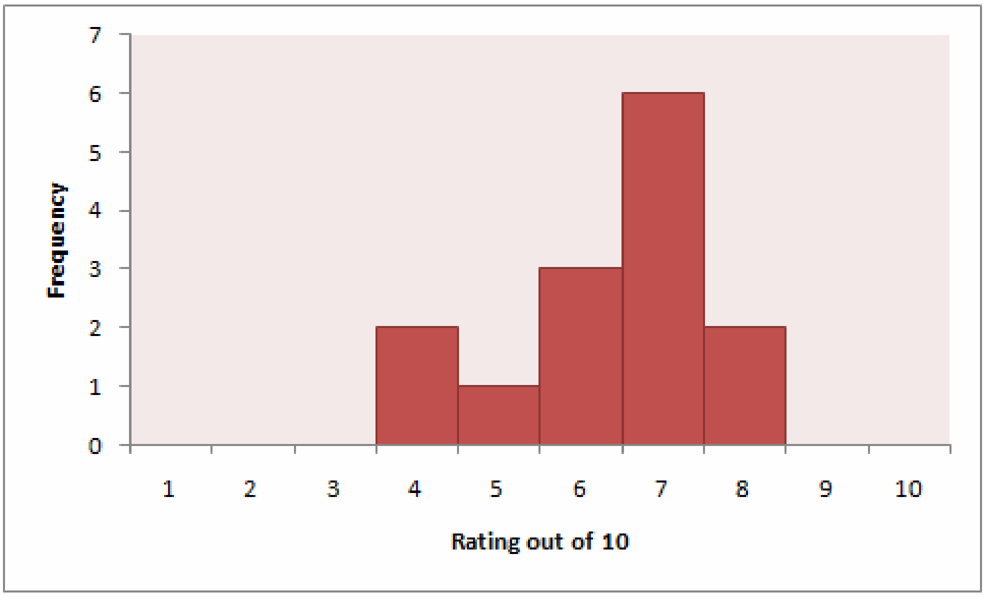

Figure 3.11: Business operators' self-ratings of level of climate change knowledge.

3.4 Local government and regional planners focus groups

A series of climate change impact assessment focus group workshops were conducted in partnership with the Queensland Local Government Association in the three target areas[12]. Participants included the Local Government (the target group) and some State Government departments (e.g. Queensland Department of Primary Industries and Fisheries and Department of Natural Resources and Water, as well as local representatives from Federal Government departments such as the Department of the Environment, Water, Heritage and the Arts and the Great Barrier Reef Marine Park Authority). The focus group workshops had the agenda of assessing risk and exposure of local government and planning instrumentalities to climate change at the social, economic and environmental level.

The key objective of the focus groups was the identification of the risks, vulnerability and exposures of local Government in Queensland to climate change and the strategies required to mitigate or manage the expected impacts of these issues. This included the broad objectives of:

- Developing a shared understanding and knowledge by Councils of the key challenges presented by climate change;
- Identifying, through focus group work-shopped exercises, the areas of risk and exposure of local Councils to climate change; and
- Identifying practical processes and strategies to address or mitigate these exposures.

3.5.1 Focus group methods

The approach followed the risk assessment methodology as presented in the Local Government Association of Queensland publication, *Adapting to Climate Change – A Queensland Local Government Guide (2007)*. The workshop methodology comprised of:

- Prior to the workshops, an introductory overview of current research on regionally relevant as well as global climate change projections and potential impacts as published by the IPCC, CSIRO and BOM;
- Workshop based focus group meetings, with a duration of approximately four hours, utilising the AS/NZS 4360 risk assessment framework; and
- High level assessment undertaken by focus group of possible risks to climate change from a social, economic and environmental perspective, with a focus on three scenario states of low, medium and high for (a) reduced rainfall, (b) increased intensity/frequency of storms, cyclones and tidal surges and (c) increased temperature.

The focus group workshops were interactive and participative and based on practical climate change research findings and exercises drawing from and building on local area input and knowledge. Risks were assessed in terms of the likelihood and consequences, prioritised and considered against the impacts on (a) planning and development; (b) infrastructure to support communities, business and essential services; (c) community health and wellbeing; and (d) the environment. Adaptation measures and action planning, networks partnerships and alliances were then considered using the AS/NZS 4360 risk assessment framework action template (Table 3.20).Human ethics approval was obtained from the Human Ethics

[12] This research was carried out for the Local Government Association of Queensland (see Miles 2008); but the key results pertinent to the communities of the Great Barrier Reef target have been identified for this project.

Research Committee of Central Queensland University (certificate H07/11-108) and all data and material managed in accordance with the strict confidentiality requirements of the ethics committee.

Table 3.20: Focus group data analysis method.

Three stage process		
Identified Risks	**Climate change**	**Risk category**
	Storms	Economic Environment
IDENTIFIED RISK	Temperatures	Litigation Community and lifestyle
	Declining rainfall	Infrastructure Public safety

3.5.2 Focus group results

At the outset of the forums, each participant was asked what their respective organisations/departments were doing on a scale of one to ten on climate change, where 'one' equals very little activity and concern and 'ten' represents significant activity and concern. With very few exceptions, participants scored this question between one and three indicating very little proactive action or activity being undertaken. While all participants were aware of climate change issues, there was not a great deal of action or perceived understanding of the potential impacts. As a general observation, climate change issues were regarded by the participants as being on the lower end of activity and understanding of their organizations, which is reflected in the business community survey.

The main concerns for Councils included the impact of the expected increases in climate variability and extreme weather such as flooding, droughts and storms/cyclones as well as expected water shortages. Evidence and modelling from the Australian Insurance Group has demonstrated that even small shifts in climate averages such as extended dry periods, storm intensity and wind speeds have large implications for existing infrastructure. This potentially will affect Business, Councils, and the community at large – both urban and rural, and will have positive and negative implications for land use planning, various Local Government infrastructure, community services, and natural assets.

Local Governments make investments in infrastructure that underpin the business environment in most communities and the infrastructure is designed to last for many decades. However, infrastructure design has traditionally been based on past climatic conditions, and the design has not considered or factored in the risks and exposures generated through a changing climate. Given the climate changes expected into the future, these historic conditions are no longer accurate indicators for planning, maintenance and upgrades. Land use planning and infrastructure location are key climate change risk mitigation considerations that now need to be proactively imbedded into future planning strategies. While these issues are not directly linked to the ecology of the climate change impacts on the GBR they do underpin the lifestyle and liveability of communities and the business environment. This is particularly relevant where industries such as tourism are concerned. The liveability and lifestyle of the community and functionality of the infrastructure underpins the tourism sector.

The land use practices however are critically linked. For example the impacts of sediment yields from single extreme episodic events on the reef (Tropical Cyclone *Larry* and now the Central Queensland Floods (Fitzroy and tributaries)) can cause significant losses of and/or damage to inshore reefs. Hence it is important to consider these wider issues.

3.4.3 Risk and vulnerability analysis

The focus group participants identified and generated lists of key risks based on three main climate change scenarios, including increased storms, increased temperatures and declining rainfall. The identified risks were grouped by six risk categories: economic, environment, litigation, community and lifestyle, infrastructure, and public safety.

Risks were then prioritised and their likelihood of occurrence and consequence determined. Some of the factors used by the participants to classify the risk included the level of risk to the individual, whether the risk was manageable, whether it was a threat to essential services, the breadth of the impact, whether it was life threatening, whether it constituted a threat to property, the scale and quantum of cost, whether a behavioral change was required, the environmental impact, the impact on human health or safety, the cumulative effect, wide spread public health issues, disease, level of education on the topic by business, industry or government, level of impact on demand for services.

Major issues identified during focus groups

The focus groups brainstormed a wide range of issues and were then asked to identify the most significant implications of climate change to Councils, Business and the Community in the target areas. As the list of issues was similar for the three regions, results are summarily presented here.

- Economic cost to the region of a decrease in tourism due to coral bleaching, and the loss of rainforest species;
- Negative effect Climate Change will have on the productive capacity of the reef based on current commercial uses;
- A loss of ecosystem diversity and habitat (coral reef, marine and terrestrial);
- Removal of natural barriers to major storm events e.g. mangroves;
- Increase in beach erosion and sediment levels causing loss of visual amenity and ecosystem impacts ;
- Pollutant discharges from different land uses compounding climate change impacts on the reef;
- Reduced water supply affecting regional economics, business continuity, social amenity and regions' aesthetics;
- Increased cost of living and general decline in liveability of the region;
- Impact of extreme events on infrastructure and assets and the increased burden of the recurrent cost of repair/replacement;
- Increased cost of community services, litigation and public safety;
- Cost of implementing changes to building codes and development standards;
- Loss of wetlands and unique regional ecosystem treasures;
- Sea level rises, storm and cyclone damage and associated impacts on coast line and zoning;
- Health risks (increase in tropical diseases – Ross River fever, Malaria etc.); and
- Isolation and job losses after events as well as interruptions to the supply of goods and services.

The group was also asked to identify the major policy or institutional changes that are required to assist local government and business to cope with climate change:

- Stronger leadership is required at local, state and national level;
- Policy and regulatory development is required to provided planning certainty;
- Need to incorporate climate change into all levels of planning, regional development strategies and infrastructure development by all levels of government and industry;
- Greater decision making capability at the local level;
- Education and programs to drive behavioural change to reduce impact and cope with change; and
- Assessment of the cost and resource requirements at the regional level.

Of note is that a number of the participants recognised that there is a need to reinforce the message that climate change can bring new and emerging business opportunities and to encourage businesses to operate differently to create win-win outcomes in the face of managing risk and uncertainty – it is not always a win-lose situation.

The question was also asked, 'What support is required by councils and business to commence/undertake actions in response to climate change and from where should this support should come?' The responses included:

- There is a need to secure support from senior level managers in all organisations and in particular the three levels of government to accept climate change as an issue and provide appropriate financial commitments and long term planning;
- Greater regional networking between all stakeholders and the community to look at interrelationships and down stream consequences;
- Federal and state government to implement effective policies, procedures and information for catalysing change projects;
- Governments at all levels to work in partnership with business and the community to be proactive and not reactive and to think about positive and mature actions to achieve positive long term outcomes;
- Technical support to identify risk assessment, adaptation and action planning;
- Community and internal support to raise the awareness to progress this issue; and
- Government to think about international investment and required changes.

3.5 Conclusion

The data from this research indicate that there is an obvious need to consider the impacts of climate change holistically. The implications of using a single variable (such as coral bleaching) has many ancillary issues that need to be considered, and the socio-economic implications cannot be dealt with in isolation. From the results of the survey and focus groups, the interdependency of the issues and the implications and impacts of climate change on the GBR cannot be understated. It is also clear from the work with the Councils and planning instrumentalities that they (Councils) are key stakeholders in ensuring a holistic approach is taken.

The comparison between the results of two very different survey approaches (mail-out and telephone interviewing) together with the target focus groups to assess climate change impacts as identified by local government and business shows considerable consistency of interests. Local government is more focused toward the underpinning prerequisites that support business and the community such as infrastructure and services. In addition, local government clearly identifies the need to have the necessary policy and institutional setting and educational frame to achieve desired change at the institutional or business level.

From the survey and focus group meetings the interlinked issues of rising temperatures, reduced rainfall and the increased incidence in extreme events such as cyclone and storm surges all have significant implications for coral bleaching through the multiplier effect of land use impacts. The survey work indicates that the business sector will be somewhat affected by climate change and that there are many issues and implications. However, the level of awareness and interest among business operators was not seen to be high. Of particular note is that business operators and local government both recognized the potential for both negative and positive impacts, and a range of alternative ways of doing business.

The specific blockers to conducting a cost-benefit analysis of climate change impacts on the regions highlighted by the business surveys and follow up interviews are:

- Without projections specific to their regions, business operators are confounded by the level of uncertainty around just what the impacts of climate change will be, and are therefore unsure about their level of vulnerability;
- Business operators are not clear on adaptation approaches – the most salient examples being the raising of recycling, reusing water and reducing power use as adaptation responses; and
- Of the business operators that reported having enough information to start including climate change impacts into their risk management planning, few had included climate change factors in their medium and long term planning.

It is clear from the evidence collected to date that the implications of coral bleaching on the tourism and fishing sectors will be large and inseparable from the wider climate change impacts. This information would strongly indicate that the next step in the research process is that the socio-economic implications of the climate change scenarios will need a full input output scenario based modelling exercise.

4. Risk to and Resilience of the Business Communities: Strategic Issues

4.1 Project synthesis

The overarching purpose of this study was to provide an integrated and holistic insight and understanding of the socio-economic impacts of climate change on businesses in the GBR catchment area, and particularly in the target regions of Cairns, Townsville and Mackay-Whitsunday. The following are summaries of the key components of the research.

4.1.1 Review of the literature

This project began with a review of the literature focusing on past research on the biophysical and socio-economic implications of climate change and coral bleaching in the GBR. The literature review also included an evaluation of the analytical methods and limitations on measuring socio-economic impacts. The review has found that climate change (specifically increasing ocean temperatures) has the potential for significant affect the health of biological communities of coral reefs. The GBR, in particular is likely to see numerous changes, including decreased biodiversity, changes to reef ecology and appearance.

The direct and indirect impacts of climate change, and particularly coral bleaching, on the study region have not yet been analysed to the point where definitive statements about impact can be made. In order to adequately assess the socio-economic impacts of climate change, such information is needed. While research on the effects of temperature and land based pollutants on coral reefs is being undertaken as part of the wider MTSRF research program, that this project is part of, this work will not specifically provide information on the changes in the commercial productivity of the reef. In lieu of specific information on reef productivity, a panel of technical experts was formed and provided a range of likely scenarios to map potential impacts. These scenarios drew on published work relating to this area of study, and the scenarios were assembled in such a way that as knowledge increases and matures, incremental changes to the scenarios can be made, providing a dynamic framework that changes as new information is derived.

The scenarios were developed based on current estimations of likely sea surface temperature rises. The scenarios ranged from a minor change (less than one degree temperature rise – with intermittent coral bleaching event occurring less than once a decade), to a moderate change (one to two degree temperature rise – with coral bleaching event occurring more than once every five years), and finally a major change (more than three degree temperature rise – with coral bleaching event occurring art least annually). Likely biophysical responses to these changes and their impact on the tourism, recreational fishing and commercial fishing sectors were outlined. In addition, a scenario presenting an alternative state, which may occur should the GBR see a total decline in its structure, was also developed. This final scenario considered the impact of the GBR being replaced by a significantly changed ecosystem.

These scenarios were developed to aid understanding of the range of impacts of change to the reef on users and communities that are dependent on the reef, as well as reef productivity. These changes were used as key inputs in informing the development of the survey tools and focus group discussions used in the project.

Socio-economic flow-on effects are expected in the recreation and commercial fishing and tourism sectors but also any business or economic activities that rely on the health, productivity and current biological diversity of the reef. The GBR region's reliance on the tourism and fisheries business sectors, which are likely to be significantly affected by climate change, means that the region has a high degree of exposure and vulnerability to climate change. With continued uncertainty around the exact nature and extent of climate change impacts at the local level, the extent of the exposure and vulnerability will depend on the GBR's biological and social communities' capacity to adapt and respond.

While the social and economic costs of degradation of coral reefs are expected to be extensive (Dunstan 1998), to date there has been little in the way of socio-economic impact studies that allow definitive statements to be made about what the impacts and associated costs will be. This project looked at the techniques that may be employed to determine and measure the changes in value of direct and indirect uses of coral reefs. Through the literature review and the surveys conducted, some of the key blockages to measuring the socio-economic impacts of climate change on GBR communities have been identified.

The review revealed that the natural spatial and temporal variability of the climate is complex. This makes modelling potential impacts with any certainty difficult (Houghton 1997). Recent work by the Intergovernmental Panel on Climate Change (IPCC) (2007) showed that:

- There is now regional-level evidence that natural systems are being effected by changing temperatures due to climate change;
- Other effects on natural and human systems are also emerging; and
- Vulnerability of sectors particularly susceptible to climate change is exacerbated by other stressors (i.e. there is a cumulative effect to which climate change is one contributor).

Drawing from this assessment it is of note that Australia is particularly vulnerable to the effects of climate change due to its low altitude, scarce water resources and population concentrated in vulnerable regions (that is, coastal regions) (IPCC 2001).

Icon ecosystems such as the GBR are considered to be extremely vulnerable. For example, an increase in seawater temperature of 1°C is likely to induce some bleaching of coral, and an increase of 2.5°C will potentially lead to a major decline in the viability of corals (IPCC 2007). The uncertainty that exists around just what the temperature changes will mean suggests that reef-reliant communities will need to be prepared for little change, major change or anything in between – a situation that makes it difficult to define the 'risk'. Other impacts such as increased cyclonic activity and levels of seawater acidity have similar uncertainty, and the prevailing levels of uncertainty limit the abilities of local researchers to predict definitively regional impacts.

Uncertainty around predictions of changes to the reef leads to major uncertainty around impacts of these changes on reef-dependent businesses and communities. It is also impossible to predict whether changes to the reef will be permanent, or the capacity of the GBR to recover, given that both of these factors rely heavily on the magnitudes of change. It can however be stated that effects will be significant with regard to reef-dependent production if: bleach events are sustained; recovery periods are long; changes to species assemblages result in loss of key species and dominant populations; and lost species have particular value to reef-dependent industries (e.g. commercial or recreational fishing, tourism).

The literature points to the influence of cumulative impacts (impacts of human systems on the reef that cannot be attributed to climate change) on the level of impact of climate change on the GBR. However, it does not reveal whether cessation of all activity that induces impacts other than those induced by climate change will result in an environment that is robust enough to withstand the potential impacts of climate change. That is, will significant changes to land use management increase the GBR's capacity to respond to climate change to a level that will see it 'saved'? If all other impacting activity ceased today, would the GBR be able to survive the high end predictions of a 2.5°C change in seawater temperature, over which action at the local level has no control? Is the economic and social cost as well as the opportunity cost of taking this option the best option in the long term?

In order to assess the socio-economic value of environmental factors such as reefs, the literature reveals that a range of methods have been used. However, the literature does not reveal a fit-for-purpose model that can be applied to determine the social and economic value of the reef, nor the impact on its socio-economic value of changes induced by climate change. Direct changes to economic value could be estimated using an 'Effects of Production' (EoP) approach, using production revenue (Ahmed et al 2005). However, in the case of the GBR, this approach requires definitive knowledge of the impact of climate change on reef fish populations, which as outlined earlier is limited by uncertainty.

The 'Travel Cost' method has been used to estimate the value of a reef to tourism; however, this approach requires a great deal of detailed data and complex analysis. Indirect valuation methods may be used, such as the 'Willingness to Pay' approach, which utilises a combination of direct and indirect valuation methods. Other indirect valuation tools examined include hedonic pricing and stated preference via choice modelling or contingent valuation. The final option considered is cost-benefit analysis, which evaluates the advantages and disadvantages of alternative options in terms of their economic benefit and is best suited to exploring scenarios reflecting the degree of uncertainty associated with climate change.

Undertaking an economic analysis of the impacts of changes to the reef due to climate change is likely to prove difficult due to the uncertainty as to how the changes will manifest themselves. It is likely that a range of tools will need to be applied to assess both the social and economic impacts of climate change on GBR communities. Any such models used should reflect the need to be adaptable and robust enough to accommodate new information, knowledge and data, as they come to hand. Application of particular tools and approaches in particular areas will be dependent on the data already available and the resources required.

In order to move forward with the initial assessment and to determine the most suitable pathway for the analysis a socio-economic characterisations of the region was undertaken. This was followed by a survey of businesses in the reef dependent communities. The socio-economic characterisation allowed for a high level the evaluation of the likely degree of resilience of the target communities in the face of change and their ability to adapt of mitigate/offset the risks. The business survey was undertaken on a broad cross section of businesses to determine the level of knowledge of climate change, the degree of proactive engagement, the perceived risk and exposure, the actions planned and the overall vulnerability of the businesses to impacts induced by climate change.

4.1.2 Socio-economic characterisation of target regions

Cairns

The Cairns region has a population growing at a rate similar to that of Queensland as a whole. Of the working population, the sectors that the Cairns region is most reliant on for employment are retail trade and accommodation and food services, both of which are higher than the respective Queensland proportions. This is reflective of a reliance on tourism in the Cairns economy. Similarly, the agriculture, forestry and fishing sector employs a higher proportion of the labour force than Queensland.

Townsville

Population growth predictions for the Townsville region are just below those for Queensland as a whole. Townsville's labour force is greatly influenced by the presence of the Australian

Defence Force – 11.4% of the region's labour force works in the public administration and safety sector, compared with 6.7% for Queensland. The retail trade, accommodation and food services, and arts and recreation services sectors all employ a lower proportion of the labour force relative to the Queensland proportions, indicating less reliance on tourists within the Townsville economy. The mining sector and agriculture, forestry and fishing sectors both employ higher proportions of the labour force than Queensland as a whole.

Mackay-Whitsunday

Population projections for the Mackay region, developed prior to the 2006 Census, indicate that growth of the region is just below that for Queensland. However, the influence of recent growth in the mining sector should see changes to this, once the aggregated information becomes available from the Office of Economic and Statistical Research. The Mackay-Whitsunday region has seen a decline in reliance on agriculture (particularly sugar cane) and an increase in influence of mining activity on its economy. This is reflected in labour force statistics for the region, which show 9.1% of the region's working population involved in mining, compared to 1.7% for Queensland. Retail trade, accommodation and food services, and arts and recreation services sectors all employ workers in the region at lower levels than Queensland as a whole, while agriculture, forestry and fishing employs significantly more than across Queensland.

Both the Townsville and Mackay regions are potentially insulated from changes to the GBR, due to their diverse economies. While the Whitsunday area of the Mackay region is reliant on the reef, the region as a whole is more likely to be impacted by changes in the resources industry. However, changes to agricultural production regimes, in response to efforts to reduce impact on the reef, have the potential to impact on the Mackay region's economy. Townsville's diverse economy indicates less impact from changes to the tourism and agriculture sectors than either Cairns or Mackay. Changes to Townsville's economy are more likely to emanate from the changes to the level of presence of the defence force than to direct impacts of climate change. The Cairns region has a less diverse economy which is more vulnerable to changes to tourism in particular, and to a lesser extent agriculture, as a result of climate change.

While changes to the economies of the regions can be deduced if the impacts of climate change can be clearly articulated, less clear are the potential social impacts. For example, the cumulative impact of the ageing demographic seen in each of these areas (and the rest of Australia) and changes to regional climate conditions are yet to be determined.

4.1.3 Surveys and focus groups

Whilst the potential impacts of climate change on recreational and commercial fishing and on tourism related activity were the obvious foci, further stages of this research considered the downstream or flow-on impacts of climate change, that is, the implications for other business sectors that will not necessarily suffer direct impacts of climate change. In doing so, this research aligns with the Australian Greenhouse's approach (AGO 2004), which included:

- Development of climate change projections specific to the region;
- Development of regional models of land use and socio-economic change;
- Development of spatial vulnerability and/or hazard maps;
- Integrated assessment models for the key sectors in the region;
- Cost-benefit analysis of different adaptation options; and
- Expansion of monitoring to reduce knowledge gaps.

The survey work and focus groups were carried out to try to determine the level of exposure and vulnerability as well as the preparedness of businesses within the GBR community to meet the challenges of climate change. The data gathered as part of this process indicated a need for a holistic approach, to ensure all potential impacts were taken into account. That is while the effects of climate change on issues such as business viability and resilience are of primary interest; there is a need to be considered the wider array of socio economic impacts. These may include but are not limited to: changes to purchasing patterns; consumer preferences; and even things such as the required changes to the structure and location of buildings; which in turn may be may be influenced by factors such as cost and supply of materials; land availability (zoning); local authorities capacity to respond to changes to land management and; population growth. A key learning from the survey of businesses therefore was that any focus on a single variable without acknowledging the complexity of the system as a whole is unlikely to provide a clear pathway forward to unravelling the true socio-economic impacts of climate change.

The mail-out survey of business operators and focus group meetings with local government authorities and planning instrumentalities were undertaken as two separate activities. The findings showed that while there exists an overarching consistency of interest between these two groups, local governments' focus is to ensure the infrastructure and services exist to support business and the community, and business operators' focus is more directed to achieving a specific commercial return on investment. In addition, by its nature, local governments are more concerned with policy and institutional frameworks and governance than the business operators. The difference of focus provided a useful insight as to the complexity of the issue under study and the degree of interdependence between different communities of interest and sectors.

The interdependency and interconnectedness of the issues and implications of climate change impacts was made clear through the results of the survey work and focus groups. For example, increased cost of energy was highlighted by the business sector survey as being one potential concern influenced by climate change. However, costs of provision of energy are not simply a result of climate change. The cost of supplying energy to the consumer is connected to supply of coal and oil, changes in technology and other demand-driven issues. It is possible that changes to technology, which is costly in the initial phases, may result in a reduction of the cost to consumers in the future. The implications of climate change impact on energy supply and cost are therefore not clear, with connections to other issues.

The focus groups with local government authorities and planning instrumentalities made clear that it is the groups 'on the ground' that will be key to ensuring a holistic approach to climate change impacts within the three target areas. Focus groups identified the need to incorporate climate change into all levels of planning, regional development strategies and infrastructure. While much of the planning takes place at the strategic level, implementation takes place at the ground level, meaning local authorities and the teams that they work with are key to successful integration and implementation of changes and new approaches that may be required.

The focus group meetings (local government authorities and planning instrumentalities) indicated awareness of and concern about issues of rising temperatures, reduced rainfall and increased extreme events but very little understanding of the impact, exposure or pathways forward to mitigate risk or adapt to climate change. The business surveys suggested business operators believe they will be affected to some degree by climate change but the level of awareness of potential impacts is not high and in many instances has not been considered or factored into planning or business decision making frameworks. This lack of awareness and engagement was a major impediment to taking a quantitative approach to the economic impact analysis and further analysis was therefore limited to being scenario based.

The wider industry survey conducted was exploratory research, scoping the attitudes and levels of awareness among business operators with regard to the potential impacts of climate change as well as the perceived vulnerability of their businesses to climate change. This work while qualitative and value based is seminal to understanding the complexity of, interdependency on and the limitations to building a more comprehensive quantitative analysis. The surveys revealed limited knowledge about what climate change means at the regional level, and in particular what it means quantitatively for individual businesses and their individual business model or planning horizons. Some of the issues that were raised during the survey and focus group process paralleled those raised in the literature review.

Summary findings from the survey and focus groups include:

- The need to focus on the interaction of the systems under climate change conditions – not in isolation from other factors. That is, climate change needs to be considered as one of a range of influences on regional ecosystems and socio-economic circumstances. Demographics and changes in land use (e.g. residential developments in response to population growth etc) are two sources of change that are likely to run concurrent with climate change, and their impacts are likely to be on the same or at a larger scale than impacts of climate change on the GBR. This was particularly apparent from the focus group discussions;
- The lack of region-specific projections of impacts of climate change make quantification very difficult for individual business operators. While this limitation is slowly being overcome, with region-relevant impact scenarios being developed and updated, the evolving nature of the process adds a layer of complication. Outside of related research fields, information about potential impacts of climate change for many of those surveyed is delivered by the media. This is a major concern as the media is often more interested in increasing the size of the reader audience as opposed to the provision of factual information. This means that only the most or least dire consequences are communicated to the general public. Until authorities on the ground in the regions (e.g. local government, relevant state and federal departments and agencies) are able to provide current and specific information directly to the populations concerned, the populations will only respond to the information that they can easily access. For many of those surveyed, 'climate change' was largely a global concern that was outside the boundary of their influence or responsibility and hence respondents were not actively engaged;
- The disconnected nature of climate change research to date. This issue is being addressed, with research focus shifting to integrated models and developing networks to increase sharing of knowledge. However, the fragmentation of research today has added to the perception perpetuated by the popular media that there are no hard and fast facts to be had; and
- The lack of consistent, up-to-date socio-economic data. While economic data is available, benchmarking changes in economic conditions is not carried out as a matter of course, and data that gives a clear picture of social circumstances is not readily available. The process of collecting and analysing current, accurate data for modelling impacts of change is expensive, and involves extensive surveying. While a model can be developed by piloting such a task in a region, the subtle differences that distinguish one region from another mean that direct application of a model that works in one region will not necessarily yield accurate or useful information in another. This is particularly the case with questions of social circumstances, as much of a region's culture and social climate is reflected in the values and aspirations of the resident population.

In order to gain more detailed understanding of the impacts of climate change on businesses follow up phone interviews were conducted. While the surveys yielded insights as to business operators' perceptions and attitudes, the responses revealed that, without climate change projections specific to the region and regional models of land use and socio-economic change being both developed and communicated to business operators in the regions (to a point where an understanding of the implications was reached), assessing the merits of adaptation options would not be possible. A stratified sample of the initial survey respondents (N = 14) were interviewed by phone to further investigate business operators' perceptions, attitudes and adaptive capacity.

The initial surveys, conducted to assess business perceptions of vulnerability to, and readiness to adapt to, climate change revealed a significant gap in understanding. It appears that 'adaptation' with regard to climate change is not a concept to which business owners have been exposed. This in turn undermined the attempt to determine the adaptation options that would apply to the regions under study. Confirming this gap, the follow up phone interviews revealed that, when considering climate change, business operators are generally unaware that they may have opportunities to adapt. Discussion within peer networks appears to focus on climate in terms of general sustainability issues (ride to work/ public transport, recycling), as opposed to direct reference to climate change, impacts, business risks or exposure at the regional level.

The interviews reaffirmed that most of the business operators drew their information about climate change from the media. As such there is a clear need to address the issue of communication of knowledge with potential to inform business planning. This includes ensuring business operators are informed of adaptation potential, rather than purely mitigation strategies.

Business operators where asked whether they believed they had enough information to include climate change impacts in their planning and risk assessment/ risk management processes. Less than seventy percent of the respondents indicated that they had enough information to inform their planning processes.

The majority of respondents reported that they did not have enough information to undertake risk management planning. When asked what information the business operator believed would assist, there was no common thread, indicating a lack of clarity about what is needed. This is perhaps consistent with the general discussion that the levels of uncertainty around potential impacts made it difficult for business operators to assess the potential impacts for their individual operations.

The uncertainty around impacts of climate change at the regional level has provided little scope to gather definitive answers to the question, how will climate impact business? In an attempt to get some sense of the type of responses business operators may employ, the following 'what-if' scenarios were presented to the business operators, with the request that they indicate their likely responses:

> *If your business suffered a downturn in demand of 10%, 25% or 50% as a result of climate change impacts, what would this mean to your business?*

Respondents were asked to indicate at each level whether they could absorb the downturn, would need to reduce staff, look for alternative markets, look for alternative products or close their business. Of the businesses surveyed no business operators indicated that they would need to close as a result of a ten percent downturn, while only forty percent indicated that they would be likely to close in response to a fifty percent downturn. The most likely alternatives to closing in response to the 25-50% downturns in demand were reducing staff, and diversifying by seeking alternative markets and alternative products. This set of responses indicates that business owners have the capacity to respond to changed conditions, if they have some sense of what the changed conditions are likely to be.

Looking forward, half of the business operators interviewed could see opportunities as a result of climate change. While plans to take up these opportunities were generally not highly developed, this response indicates optimism on the part of operators with regard to their capacity to respond to the challenges of climate change.

The specific blockers to conducting a cost-benefit analysis of climate change impacts on the regions highlighted by the business surveys and follow up interviews are:

- Without projections specific to their regions, business operators are confounded by the level of uncertainty around just what the impacts of climate change will be, and are therefore unsure about their level of vulnerability;
- Business operators are not clear on adaptation approaches – the most salient examples being the raising of recycling, reusing water and reducing power use as adaptation responses; and
- Of the business operators that reported having enough information to start including climate change impacts into their risk management planning, few had included climate change factors in their medium and long term planning.

4.2 Discussion

Research conducted in other countries with regard to socio-economic impacts of climate change at the regional level comes up against similar difficulties. In Norway, an attempt has been made to estimate the socio-economic implications for the primary sectors of fisheries, agriculture and forestry (Schjolden 2004). Schjolden concludes that the impacts can only be quantified to a point, and this quantification is based on an attempt to interpolate climate impacts at the regional level using scenarios assembled at the global level. The resulting quantifications have since been shown to be more than double the actual impact. In addition, Schjolden (2004) points out that one of the missing links in the socio-economic impacts of climate change in Norway is the less tangible social impact – assessing this and analysing it in terms of the economic impacts is difficult.

In 2007, the Malaysian Ministry of Science, Technology and Innovation hosted a seminar on the socio-economic impacts of extreme weather and climate change (Malaysian Ministry of Science, Technology and Innovation 2007). One of the issues rising from the seminar is the difficulty in assessing direct and indirect, tangible and intangible costs. As with this current project, assessing the 'social' side of socio-economic impacts is vital to determining many of the indirect and intangible costs, and yet little work has been done in this area. Focusing on economic outcomes only provides some of the necessary information, and filling the gap requires specific, focussed, wide ranging surveying, which has the unfortunate barrier of being expensive to accommodate. It may be that the definition of 'socio-economic' must be revisited and further resources devoted to ensuring the capture of social impact data in conjunction with economic impact data.

The literature review conducted in the initial stages of this project highlighted the range of potential options to assess the socio-economic impacts of climate change on the Cairns, Townsville and Mackay-Whitsunday regions. Approaches outlined in the literature review included:

- Direct (economic) values – net revenue, effects on production, travel cost, net factor income, replacement cost and input-output analysis;

- Non-market, non-use and indirect-use values – willingness to pay, hedonic pricing, stated preference, choice modelling and contingent valuation modelling; and
- Cost-benefit analysis.

In summary, the direct value approaches focus on economic values without consideration of social aspects, whereas the non-market, non-use and indirect use value approaches and cost-benefit analysis, which include attitudinal data, are complex, require large amounts of survey work, are time consuming and ultimately expensive. The approach used to determine socio-economic impact of climate change within the GBR region may differ between areas within the region and will depend on the data and resources available.

While conducting this type of research is an expensive undertaking, the information it can provide with regard to potential socio-economic changes due to degradation of the GBR will inform current and future management of resources. To this end, the use of input/output modelling or general equilibrium modelling, further informed by cost benefit analysis that accounts for attitudes to induced (direct or indirect impact of climate change) or implemented (e.g. land use management) change, will provide input to one element of the proposed model being developed by AIMS, based on the Bayesian Belief Network (BBN) model. While there is still much uncertainty around the level of impacts that may eventuate, a management process informed by current, place-based data would in the interim help to ensure minimisation of negative impacts for the community and allow optimisation of potential for the reef to recover (Wilkinson 1996).

This project initially aimed to work towards a cost-benefit analysis to look at the advantages and disadvantages of adaptation strategies with regard to climate change. However, defining the options for business sectors that do not yet have the information needed to determine what the threats and opportunities that climate change will bring, limits the available data to undertake such an analysis at this stage. The ensuing approach was that of a scoping study that has served to inform the approach that needs to be taken in going forward. In order to achieve a cost-benefit analysis, or other appropriate economic modelling of climate change impact, resources need to be applied at a level that will enable adequate, current data to be gathered and analysed. The needs will be different depending on the region under study, with factors such as defined potential impacts, stakeholder knowledge of these impacts and monitoring activities already underway influencing the approach to be taken within areas of the greater region. With regard to reef dependency, the characterisation has determined that the Cairns region is more dependent on the reef in economic terms, and it may be that a narrowing of the focus of the project to this region is the best way forward, in the face of scarce resources to achieve appropriate outcomes.

The review of the purely economic options, along with the results of the surveys and interviews conducted as part of this project, illustrate that integrating the social aspects of climate change is vital for both assessing options and supporting adaptation to climate change by business sectors and, by implication, communities. That is, where adaptation to climate change impacts is possible, it will only be possible if implementation is guided by the value the community (including the business community) places on the GBR and their attitudes to retaining it as a focus for activity in the region. These values and attitudes cannot be assessed using purely economic valuation, but need to be an element of the BBN-based model.

As an example of the need to include social attitudes in assessments of options for change, one of the options to try to reduce the potential for degradation of the GBR as a result of climate change is a change in land management practices. The issues around achieving this are similar to those seen in adopting best management practices for water quality in the Mackay-Whitsunday region, for example (Rolfe *et al.* 2007). This study found that the public benefits associated with best management practices vary. Cost of implementation can be a major factor – loss of productivity in the sector making changes, needs to be balanced by gains in the other sectors. Other issues included:

- Who pays for changes – are there incentives/penalties for compliance/non-compliance?
- Is there a blanket change or do the individual circumstances of the landholder mean implementation are complex? and
- Blockers to adoption – cost effective solutions not yet developed; changes are incompatible with existing operations; legislation is slow to change and may be a disincentive to implementation.

In the case of changes to land management practices to benefit the GBR, will potential losses to the agricultural sector be balanced by gains in the tourism and fisheries sector? The question of who will resource such changes is one that landholders will be asking prior to implementation. Will there be incentives, or penalties? Responses to these may be attitudinal and emotional rather than economic – who will pay rather than what is the cost; will they be penalised for non-compliance to this new order. In order to ensure changes to management practices are maintained, evidence of impact will be needed, which requires a large degree of monitoring. The question remains, given the predictions for temperature rise (IPCC 2007), will the changes make a difference in the long term? Is acting to try to save the reef the best way forward, or is the opportunity cost of doing so too high?

4.3 Conclusions

This project is part of a larger program seeking to develop tools to support resilience-based management in the face of climate change. The objectives of the program of work are to develop an atlas of climate change risk and resilience for the GBR social-ecological system, and to develop integrative knowledge for prioritising management responses to climate change. The series of reports, of which this is the fourth, contributes to the development of integrative knowledge on climate change impacts on the GRB. This research will be used to inform and guide further work on the development of a model to aid management at local authority level to prioritise its responses in the face of climate change.

The literature review revealed that while the knowledge of climate change impacts is growing at the broader level, information specific to individual regions and individual elements (for example, the Great Barrier Reef) is at best highly uncertain. The socio-economic characterisation of the region under study showed that the Cairns region is more exposed and vulnerable to the potential impacts of climate change, due to the dependency of its economy on reef-based production and activities. The Townsville and Mackay-Whitsunday regions while interacting and strongly linked to the GBR, have more diverse economies and as such are less exposed to climate change impacts that specifically affected the GBR. While degradation or loss of the reef would be of consequence to the Townsville and Mackay-Whitsunday regions, it would have much greater impact on the Cairns region.

The surveys, focus groups and phone interviews conducted as part of this project revealed a limited engagement and knowledge of climate change by the broader business community. This may be due to in part to the lack certainty or the knowledge of the specific impacts of climate change on the GBR, the lack of advice and support by Government and their own peak bodies through to the sources of the information used by business operators.

This lack of knowledge of the implications of climate change for their business is reflected in very little direct action to adapt to Climate change. Furthermore it is apparent from both the surveys and the phone interviews that business operators do not distinguish between mitigation of climate change (using less energy, recycling) and adapting to climate changes (changing the way they do business in response to climate change induced changes to the business environment). However if substantive change in the productivity of the reef is realised then the perceived vulnerability of the reef dependent businesses will be substantial with many expecting to go out of business if impacts exceed 25%.

In moving forward it is suggested that the following options be considered: in order to ensure that appropriate and current data and analysis will contribute to the Bayesian Belief Network based model that is under development

- Using a regional modelling tool (such as input/output or general equilibrium modelling), to conduct scenario analysis to inform likely flow-on impacts to all business not just those directly impacted by climate change on the GBR (beyond the scope of this studies resources);
- Regional projections of climate change impacts then need to be communicated to the sectors expected to be directly impacted on by climate change in the GBR. This will allow business operators to more effectively and proactively engage and to start to consider and asses the likely implications for their business operations and enable regional businesses to feed the potential outcomes of climate change into their planning and risk management; and
- Undertake a more comprehensive baseline study to assess the level of knowledge of climate change within the business community. Follow up to fill the knowledge gaps, and subsequent surveying benchmarked against the baseline to determine penetration of the new knowledge.

The development of the BBN-based model to integrate the knowledge required to make informed decisions around the management of climate change impacts is a resource intensive task. However, it is integral to providing an atlas of risk and resilience to climate change that can be applied by stakeholders charged with leading the broader GBR communities through the challenges posed by climate change. Access to current, appropriate levels of social and economic data and analysis to contribute to the model is one component among a range that will contribute to the success development of the model.

Progressing towards the delivery of the model and the atlas of risk and resilience, the next six to twelve months will see the disparate project teams bringing together their respective project elements, moving towards the devolution of a model and atlas that can be tested and applied with stakeholder involvement and place-based data.

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Appendix 1: Copy of Business Survey

Assessing the socio-economic impacts of climate change on business in the Great Barrier Reef (GBR) catchment area

A socio-economic impact questionnaire

Strictly confidential

Q1. Name of Business (optional): ____

Q2. Location (please circle):
1. Cairns metro
2. Cairns non-metro
3. Mackay metro
4. Mackay non-metro
5. Townsville metro
6. Townsville non-metro

Q3. Business postcode: _______________

Section 1: Perceptions and attitudes towards climate change on the GBR

Q4. How important do you consider the health of the Great Barrier Reef is to your business? (Please circle correct response)
- Very important
- Somewhat important
- Important
- Not very important
- Unimportant

Q5. On a scale of 1 to 10, what level of impact do you believe climate change will have on the health of the Great Barrier Reef over the next five years? (Please circle correct response)

No impact 1 2 3 4 5 6 7 8 9 10 ***Major impact***

Q6. On a scale of 1 to 10, what is the level of impact that climate change might have on your business over the next five years? (Please circle correct response)

No impact 1 2 3 4 5 6 7 8 9 10 ***Major impact***

Q7. What do you think the key impact/s of climate change on your business will be? (Open-ended response)

____
____
____
____

Section 2: Managing climate change and responding to risk

Q8. Who do you think is responsible for managing the possible impacts of climate change on the Great Barrier Reef?
(Open-ended response)

____

____

Q9. What do you think are the key issues for business operators as they face the possible impacts of climate change on the Great Barrier Reef?
(Open-ended response)

____

____

Q10. Do you plan to implement any strategies to reduce business risks that may be posed by climate change over the next five years? (Please circle correct response)

1. Yes
2. No

Q11. If yes, what would those strategies be?
(Open-ended response)

____

____

Q12. If no, what is the main reason?
(Open-ended response)

____

____

Section 3: Demographics and reef dependency

Q13. In which business sector is your business? (Please circle correct response)

1. Agriculture, forestry and fishing
2. Mining
3. Manufacturing
4. Electricity, gas, water and waste services
5. Construction
6. Wholesale trade
7. Retail trade
8. Accommodation and food services
9. Transport, postal and warehousing
10. Information media and telecommunications
11. Finance and insurance services
12. Rental, hiring and real estate services
13. Professional, scientific and technical services
14. Administrative and support services
15. Public administration and safety
16. Education and training
17. Health care and social assistance
18. Arts and recreational services
19. Other services (please describe)

Q14. What are the main goods produced or main services provided by your business? (Open-ended response)

____

____

Q15. What is the average annual turnover of the business? (Whole Aus. Dollars)

$_ _ _, _ _ _, _ _ _, _ _ _

Q16. How many paid employees are there in the business?

Full-time_______ Part-time________
Casual ________

Q17. What structure best describes your business? (Please circle correct response)

- Family owned and operated
- Franchise
- National chain – we are the head office
- National chain – we are a regional office
- Other (please describe)

Q18. How many years has your business been operating? (Please enter years)

Q19. What is the current phase or stage of your business operations? (Please circle correct response)

- Intending to expand in the future
- Intending to decline in the future
- Intending to stay the same
- Other (please describe)

Q20. What proportion of your trade would you estimate as being dependent upon the Great Barrier Reef?
(Enter percentage)
_______ %

Q21. Do you see the relationship between your business and the Great Barrier Reef changing in the future? (Please circle correct response)
1. Yes
2. No

Q22. If yes, please describe the change and why. (Open-ended response)

____

____

Thank you for participating in this study

Please return the survey questionnaire in the reply-paid envelope provided, thank you.

Appendix 2: Additional information provided for survey participants

Institute for Sustainable Regional Development

Central Queensland University

Building 32, Central Queensland University

Bruce Highway, Rockhampton QLD 4702

<DATE>

To the Business Owner/Manager,

***Scoping survey for businesses*:**
Assessing the socio-economic impacts of climate change on business in the Great Barrier Reef catchment area

Researchers from the Institute for Sustainable Regional Development (ISRD) at Central Queensland University have been provided with funding from the Reef and Rainforest Research Centre to examine the socio-economic effects of climate change in key communities on the Queensland seaboard. The aim of this research is to better understand:

- Business awareness of climate change;
- Business attitudes towards the possible risk(s) posed by climate change on the Great Barrier Reef;
- The likely impacts of climate change on key industry sectors; and
- The preparedness of local communities to meet and overcome the challenges associated with climate change.

A key part of this research involves conducting a socio-economic survey of business operators in three key reef-based communities (Cairns, Townsville, and Mackay-Whitsunday). This is designed to gather information on the abovementioned issues from approximately 3,000 participants (1,000 in each target region).

We invite you to participate in this research by completing the enclosed business survey, which should only take about 5-10 minutes of your time. A reply-paid envelope has been provided for you to return the surveys to us. Responses will be kept strictly confidential and anonymity will be ensured because names are not recorded. You are free to withdraw from participating at any time. Please note however that once we have received the data we will not be able to identify your unique entry. The data gained from this research project will be stored for 5 years in accordance with the Code of Conduct for Central Queensland University.

The data generated from this research will be used to produce a report for the Reef and Rainforest Research Centre and to inform academic publications.

If you would like more information about this research project, you can contact the principal researcher Professor Bob Miles, Institute for Sustainable Regional Development (Phone: (07) 4930 6408; Fax: (07) 4930 6756; Email: isrd@cqu.edu.au). Bob will be happy to discuss with you any concerns you may have on how this study has been conducted. Alternatively, you may also contact Central Queensland University's Human Research Ethics Committee on (07) 4923 2607.

Note: This study has been approved by the Central Queensland University Human Research Ethics Committee. The Approval Number is H07/10-095. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Office of Research (Phone: (07) 4923 2607). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome. If required, you may also contact the Rockhampton Mental Health Service (Phone: (07) 4920 6111) or the Lifeline (Phone: 13 11 14) 24-hour service.

If you would like to participate in stage two of the research – an in-depth examination of climate change impacts by industry sectors – then please contact Bob directly on (07) 4930 6408. Some businesses may be contacted again as part of stage two.

Yours sincerely,

Professor Bob Miles

Appendix 3: Questions that formed the basis of telephone interviews

Business name: ____________________________ **Phone number:** _______________
Contact name: ____
Date interviewed: ____
Permission to record? Yes/ No

Question 1: You previously responded to our survey on climate change, we are interested in how you derived your knowledge of climate change? e.g. Saw Al Gore's documentary, attended a course/workshop, general media articles, practical experience.

Question 2: Is climate change impact on business an issue that is being actively discussed among your business networks and contacts? If yes, try to scope extent of discussion (risk management, adaptation, mitigation etc)

Question 3.1: Do you believe you have enough information to start including climate change impacts in planning and risk assessment/management processes for your business?
Yes / No

If yes:
Question 3.1.1: What steps have you taken/ do you intend to take? (e.g. consulted with business advisor/ planner) Time frame: current; next 12 months; next 3-5 years.

If no:
Question 3.1.2: What further information would enable you to build climate change impacts into your planning and risk management processes?

I will give you a range of what-if conditions and would like you to provide information about your potential responses. In some cases, you may choose more than one response.

Question 4.1: If your business suffered a downturn in demand as a result of climate change impacts, what would this mean to your business?

	Threshold that triggers response		
Response	**10%**	**25%**	**50%**
Absorb the loss			
Reduce staff numbers (indicate numbers at each threshold)			
Look for alternative markets			
Look for alternative products			
Close business			
Other (specify)			

Question 5.1: Have you identified opportunities (new products, new markets, increased demand for current products & services) for your business as an outcome of climate change?
Yes / No

If yes
Question 5.1.1: Do you have plans in place to allow you to take advantage of these opportunities?
Yes/ No

Question 5.1.2: Have you identified anything that has the potential to prevent you from taking advantage of these opportunities?
Yes/ No
Elaborate:
____
____
____

Question 5.1.3: Is there anything not currently available to you that would help/ support you in taking up the opportunities?

Question 6: On a scale of 1 to 10 (where 1 = *minimal knowledge* and 10 = *high level knowledge*) how would you rate your level of knowledge of climate change issues?

1 2 3 4 5 6 7 8 9 10

Further Information

Marine and Tropical Sciences Research Facility
PO Box 1762
CAIRNS QLD 4870

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