Marine and Tropical Sciences Research Facility

Synthesis Report

Managing for resilience of the Great Barrier Reef: Socio-economic influences

Compiled by J. Johnson and K. Martin

Australian Government
Department of the Environment, Water, Heritage and the Arts

Reef & Rainforest Research Centre

MTSRF Synthesis Report

Managing for resilience of the Great Barrier Reef:

Socio-economic influences

Compiled by Johanna Johnson and Katherine Martin

Reef & Rainforest
RESEARCH CENTRE

Australian Government

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Contents

Acknowledgements i
List of Figures iii
List of Tables iii
Acronyms and Abbreviations iv
About this Report v
Executive Summary vi
1. Introduction 1
2. Socio-economic resilience to climate change 3
3. Understanding how social systems change 6
3.1 The environmental economics of practice change 7
3.1.1 Cost of reducing pollutant loads 8
3.1.2 Influence of climate change and population growth 9
3.2 Understanding social attitudes 9
3.3 Measuring social resilience to change 13
4. Adaptive governance to enhance GBR resilience 20
4.1 Adaptive partnerships 20
4.2 Collaborative decision-making 22
4.3 Policy instruments to promote BMP uptake 23
4.4 Who pays? The burden of practice change 24
5. Management frameworks 26
6. Conclusions and management applications 28
6.1 Conclusions 28
6.2 Management applications 29
6.3 Future directions 31
7. References 33

List of Figures

Figure 1: The total economic value of the Great Barrier Reef: an estimate of the overall contribution to the social, economic and environmental functioning of society 1

Figure 2: Businesses by industry sector represented in the three regional centres (%): Cairns, Townsville and Mackay 4

Figure 3: Abatement cost curve for the Tully-Murray catchment 8

Figure 4: Conceptual diagram illustrating how a framework defining social resilience at three spatial scales can enhance the capacity to manage for social and ecological change across different levels of governance 14

Figure 5: Conceptual model of factors enhancing the likelihood that a social system in the GBR will successfully adapt to water quality change or interventions to improve water quality 18

Figure 6: Adaptive management strategies for the Great Barrier Reef Water Quality Improvement Plan 27

List of Tables

Table 1: Business operators' perceptions as to where the responsibility for managing climate change lies 5

Table 2: Cost-effectivness of best management practices for water quality improvement in sugarcane, horticulture and grazing production systems in the Tully-Murray catchment, from least effective to most effective 7

Table 3: The primary purpose of land ownership (%) for the five groups of surveyed landholders with similar behavioural attitudes 10

Table 4: Land use type (%) for the five groups of surveyed landholders with similar behavioural attitudes 10

Table 5: Percentage of surveyed landholders who have attended a short course on property management or have participated in a government NRM program in the last five years, by group 12

Table 6: Percentage of surveyed landholders with an existing property management or business plan, by group 12

Table 7: Percentage of surveyed landholders who are currently using a recognised farm or environmental management system 12

Table 8: A community-scale example of how indicator domains and indicator variables align with statements that characterise community resilience 15

Table 9: Resilience domains (broad themes) (column 1) for describing social resilience at the community and catchment/region scales 16

Table 10: Current set of selected indicators for assessing the adaptive capacity and resilience of social systems to change at the whole-of-GBR scale 19

Table 11: An overview of the SMART criteria used to assess partnership needs for delivery of the Tully-Murray Water Quality Improvement Plan 21

Table 12: An assessment framework incorporating knowledge attributes for collaborative water governance 22

Acronyms and Abbreviations

ANNEX .... Annual Nutrient Export

APSIM .... Agricultural Production Systems Simulator

BBN .... Bayesian Belief Network

BMP(s) .... Best Management Practice(s)

CSIRO .... Commonwealth Scientific and Industrial Research Organisation

DEWHA .... Commonwealth Department of the Environment, Water, Heritage and the Arts (now Sustainability, Environment, Water, Population and Communities)

DIN .... Dissolved Inorganic Nitrogen

DPC .... Queensland Department of the Premier and Cabinet

EESIP .... Environmental Economic Spatial Investment Prioritisation

EMS(s) .... Environmental Management System(s)

FSS .... Fine suspended sediments

GBR .... Great Barrier Reef

GBRMPA .... Great Barrier Reef Marine Park

GBRMPA .... Great Barrier Reef Marine Park Authority

HER .... Herbicides

MTSRF .... Marine and Tropical Sciences Research Facility

N .... Nitrogen

NRM .... Natural Resource Management

PASTOR .... Grazing production model

PPRR .... Preventative, preparatory, response and recovery

RRRC .... Reef and Rainforest Research Centre

RWQP .... Reef Water Quality Partnership

SedNet .... Sediment River Network

SMART .... Specific, measurable, achievable, realistic and timely

WQIP(s) .... Water Quality Improvement Plan(s)

WWF .... World Wide Fund for Nature

About this Report

This report provides a synthesis of the key findings of research conducted under the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) relevant to understanding the social and economic influences on managing for resilience of the Great Barrier Reef (GBR). The report summarises the findings of related projects supported by the MTSRF. Some of the information in this report is extracted from MTSRF project reports with the permission of the authors.

A key achievement of the MTSRF has been strong cooperation and collaboration between research institutions in project development and implementation. The findings presented in this report were derived from collaborative projects funded from several sources including the MTSRF, and the research institutions have also contributed significant in-kind resources. It should be noted that supporting information external to the MTSRF is included in this report to provide context or to complete the discussion. Publications generated specifically by the MTSRF are identified in the References section.

This synthesis report is one product in a series of informative reports that summarise MTSRF research findings relevant to the GBR. Other products include:

- 'Managing Great Barrier Reef water quality: MTSRF research overview', compiled by J. Waterhouse and M. Devlin (Waterhouse and Devlin 2011);
- 'Improved understanding of biophysical and socio-economic connections between catchment and reef ecosystems: Wet and Dry Tropics case studies', compiled by M. Devlin and J. Waterhouse (Devlin and Waterhouse 2011);
- 'Optimising water quality and impact monitoring, evaluation and reporting programs', compiled by J. Waterhouse (Waterhouse 2010a);
- 'Thresholds of major pollutants with regard to impacts on instream and marine ecosystems', compiled by J. Waterhouse (Waterhouse 2010b);
- 'Identification of priority pollutants and priority areas in the Great Barrier Reef catchments', compiled by J. Waterhouse and J. Brodie (Waterhouse and Brodie 2011);
- 'Water quality and climate change: Managing for resilience', compiled by J. Johnson and K. Martin (Johnson and Martin 2011); and
- 'Review of MTSRF research advancing our understanding of the source, transport and impacts of pesticides on the Great Barrier Reef and associated ecological systems', compiled by M. Devlin and S. Lewis (Devlin and Lewis 2011).

Executive Summary

Effective management and strategic investment in water quality improvement in the Great Barrier Reef (GBR) has been identified as critical to enhancing reef resilience in the face of climate change. Climate change has been recognised as one of the greatest threats to the GBR, and managing for resilience may mitigate some of the short-term risks, giving natural communities time to adapt to a changing environment. Understanding how to increase the uptake of land management practices, which aim to improve water quality, is the key to achieving this goal. In addition, changes to the GBR ecosystem will have implications for reef-dependent communities and industries, and understanding social resilience to future change will be important to support these communities.

MTSRF-funded research has provided insight into how strategies to improve water quality and enhance ecosystem resilience can be most effectively implemented, and increased understanding of how GBR communities are likely to be affected by changes to the GBR ecosystem. In addition, the complex interactions between different social scales and how they respond to change have been examined. Collectively, this new information has been used by MTSRF researchers to develop models that can deal with the complex nature of these relationships to predict how communities might respond to incentives and disincentives to change land management practices, and where effort should be placed to achieve the best resilience outcomes for the GBR.

MTSRF-funded research also identified social resilience indicators at the community and catchment scale that are specific to the GBR region, and can inform management actions and monitoring of social responses. At the whole of GBR catchment scale, a greater understanding of social adaptive capacity and the way different factors affect the likelihood of social adaptation also provides information for determining the most appropriate management actions.

While many questions still remain unanswered, findings to date can provide significant direction and tools for managers and policy-makers to prioritise and target effort, in particular to change land-holder perceptions and practices, and provide strategies to adopt new practices that facilitate progress towards meeting water quality targets. This knowledge supports effective implementation of land management practices aimed at improving GBR water quality, an important strategy for enhancing resilience of the GBR to future change (see the companion report ‘Water quality and climate change: Managing for resilience’ by Johnson and Martin 2011).

1. Introduction

Managing the Great Barrier Reef (GBR) in the face of climate change poses many challenges, particularly as many knowledge gaps exist. Recent MTSRF-funded research has delivered valuable information on ecological responses to and interactions with water quality stressors (see the companion report 'Water quality and climate change: managing for resilience' by Johnson and Martin 2011), and this report outlines the socio-economic implications of managing for resilience to climate change. A healthy GBR delivers goods and services of vast benefit to regional communities (Figure 1), and major changes to ecosystem condition will have broad-scale social and economic implications. Continued input of land runoff containing elevated concentrations of suspended sediment, nutrients and pesticides and the associated decline in inshore habitat will have implications for reef resilience as well as the industries that depend on the GBR, such as tourism and fishing, and for coastal communities (Miles *et al*. 2009). Social pressures can also exacerbate these impacts, for example, an increasing coastal population is likely to place greater pressure on recreational uses of the GBR, leading to trade-offs between the associated economic benefits and reduced attractiveness of the region as a holiday destination (Coghlan and Prideaux 2009).

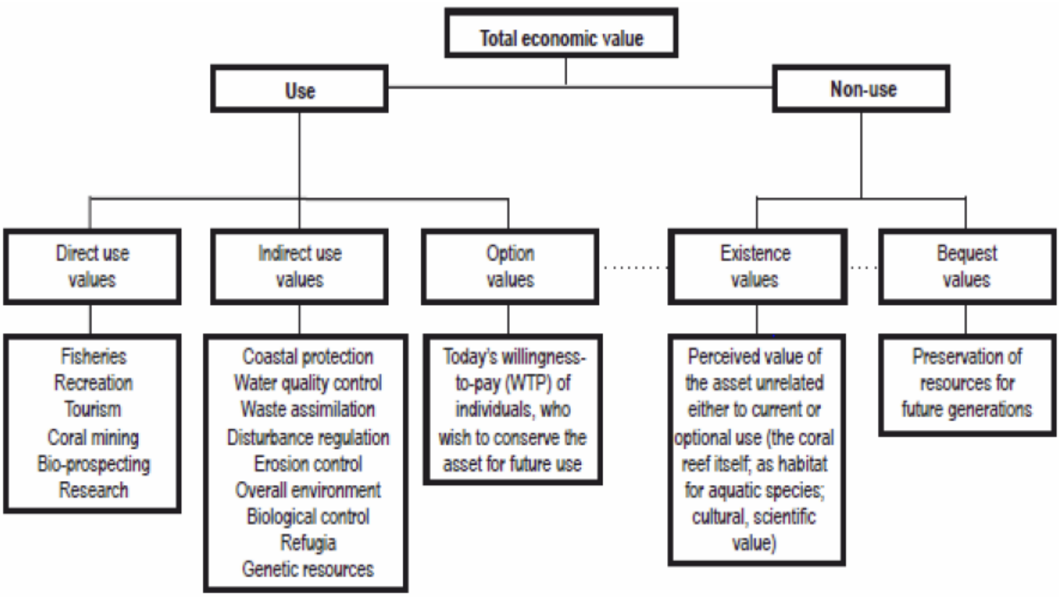

Figure 1: The total economic value of the Great Barrier Reef: an estimate of the overall contribution to the social, economic and environmental functioning of society (Miles *et al.* 2009).

The health of the GBR depends on the integrity of its ecological processes, and may be characterised by high diversity and species richness and its resilience to (or ability to cope with) anthropogenic and natural disturbance. Ecological resilience is the "capacity of an ecosystem to resist, recover or regenerate from disturbances or damage without a change in state, so as to maintain key functions and processes" (Nyström *et al.* 2000). Over time, chronic sub-lethal stress may decrease the resilience of reef organisms to other forms of environmental stress (Hughes *et al.* 2003) and declining water quality is one of the chronic pressures that have been shown to undermine ecosystem resilience to future climate change. Therefore, working in the GBR catchment to improve uptake of land management practices that improve water quality is an important management priority.

In anticipation of some of the challenges of managing the highly heterogeneous environment, multiple pressures and often-competing interests of GBR stakeholders, MTSRF-funded researchers have been looking into changes in land management and land-use that would be economically viable, socially acceptable, and effective in building GBR resilience (e.g. van Grieken *et al.* 2010a, 2010b). While simplified modelling scenarios are used to test linkages between biophysical and socio-economic relationships, there are very encouraging indications that 'win:win' situations are possible – adoption and/or refinement of agricultural best management practices (BMP) could lead to increases in profitability, as well as improvements in water quality. Specific studies include the socio-economic constraints of managing for resilience in the context of adaptive governance arrangements and collaborative decision-making for coordinated water quality improvement (see Robinson *et al*. 2011).

2. Socio-economic resilience to climate change

Climate change impacts on coral reefs may have flow-on effects for communities who depend on reefs for a range of ecosystem goods and services. Communities, like ecosystems, also have an inherent resilience to change, and for socio-economic systems this is characterised as “the capacity of social systems to absorb recurrent disturbances to retain essential structures, processes and feedbacks” (Adger *et al*. 2005). The effective management of potential socio-economic impacts of climate change on regional communities requires the integration of spatially-explicit information to quantify exposure and identify high-risk areas. Communities that feature a diverse economy with healthy age-sex structures, a diversity of skills and employment, a high level of education and above-average socio-economic indices might be expected to adapt rapidly to climate change; that is, have a high degree of resilience (Lynam *et al.* 2010, Miles *et al.* 2009). However, communities which are less diverse and highly economically dependent on direct-uses of the GBR, such as commercial fishing, recreational fishing and tourism, may have a lower degree of resilience (Miles *et al.* 2009).

In a MTSRF study assessing the socio-economic implications of climate change in the GBR catchment (Miles *et al.* 2009), the coastal regions of Cairns, Townsville and Mackay were characterised to assess their socio-economic resilience to climate change (Miles *et al.* 2009). Each is a key regional centre and contains a balanced cross-section of the communities within the GBR catchment. Cairns has the most reef-reliant economy of the three regions, primarily because of a high dependency of many businesses on the tourism sector. In contrast, the economy of Townsville is the most diverse and therefore the least vulnerable to impacts of climate change on the GBR (Figure 2).

As part of this MTSRF project, the survey revealed that while many businesses across the three regions will be affected by climate change, managers have a low level of awareness of the likely impacts of climate change on their business (Miles *et al*. 2009). Interestingly, the likely impacts of climate change on the GBR were perceived to be more severe than any impact on business. The key issues for businesses with a high risk of being affected by climate change were identified as ‘business diversification’ and the ‘engagement of an effective risk management strategy’. However, the capacity of managers to meet the cost of any adaptive measure and the long-term viability of these businesses were not explored. Furthermore, there were regional differences in the likelihood of businesses to engage in risk management that was not related to the level of dependency on the GBR, with managers in Mackay more likely to implement strategies to reduce risk. The variability in incorporating risk assessments into business operations may be related to the accessibility of information, the difficulty in determining individual vulnerability given the uncertainty of climate change predictions, or to the perceived level of ownership and degree of responsibility that business operators believe they have in managing for climate change. For example, there was a high degree of variability in the assignation of responsibility for managing climate change on the GBR, with 15% of operators expecting that the risks would be managed by government agencies, which is the same percentage of operators that believed ‘every person’ is responsible for management the impact of climate change (Table 1).

Several major policy or institutional changes were identified by Miles and others (2009) as necessary to assist business and local governments adequately manage climate change:

- Stronger leadership at local, state and national level;
- Planning certainty in policy and regulatory development;
- Incorporation of 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;
- Educational programs to drive behavioural change and adaptability; and
- Assessment of the costs and resources required at the regional level.

This research has provided a solid foundation for understanding the resilience of communities to climate change that can be built on to develop effective strategies for measuring and enhancing social resilience. Further modelling of socio-economic resilience that includes indirect and direct interactions and dependencies is required to determine the flow-on benefits generated from direct uses of the GBR to other businesses in the region, and therefore provide a complete picture of community resilience. Additionally, analysis of the social aspects of socio-economic resilience is required to estimate many of the indirect costs of climate change, as focussing solely on economic outcomes provides only part of the assessment.

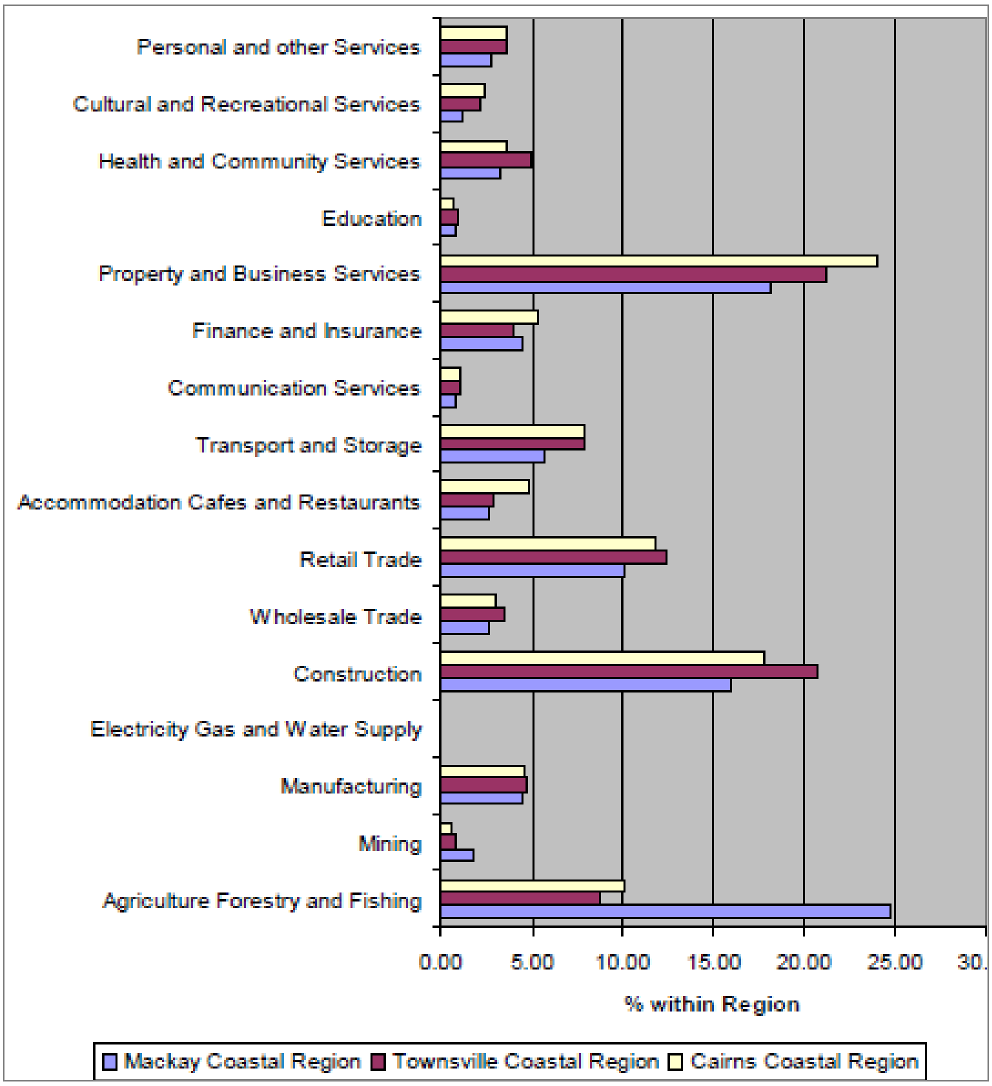

Figure 2: Businesses by industry sector represented in the three regional centres (%): Cairns, Townsville and Mackay (ABS, June 2003 to June 2006 Counts of Australian Businesses; Miles *et al*. 2009).

Table 1: Business operators' perceptions as to where the responsibility for managing climate change lies (Miles *et al*. 2009).

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

3. Understanding how social systems change

As a multiple-use marine resource, the Great Barrier Reef Marine Park (GBRMP) has many sectors that receive direct economic benefit and are the focus of estimates of economic value, including commercial fishing, recreational fishing and tourism (Driml 1987, 1994, Hoegh-Guldberg 1999, Access Economics 2008). However, there are many other functions of ecological, social, cultural and economic value that are not easily included in these assessments, either because benefits from these functions are indirect or very difficult to quantify. Estimating the economic value of the GBR, and therefore the cost of any loss of ecosystem function and diversity, is therefore complicated by the difficulty in assigning economic value to the wide variety of goods, services, functions and values provided. For example, the value of inshore coral reefs and seagrass meadows as nursery habitats for commercially important pelagic and demersal fish is difficult to quantify but essential for the sustainability and profitability of some commercial fisheries.

The total economic value of the GBR therefore is derived from both its use (direct and indirect) and non-use (intrinsic) values (Figure 1). For example, the latter includes value to people who never visit the GBR, but gain benefit from knowing it exists (Driml 1994). Suitable methods need to be developed as a priority to assess intrinsic values of the GBR (Bateman *et al.* 2002); the links between key functions provided by the GBR; and the flow-on effects (externalities) on other sectors. Many uses are mutually exclusive or only partly compatible, for example, the economic benefits derived from the commercial fishing industry (direct use) cannot necessarily be added to the economic benefits derived from conserving the GBR as a biological resource (non use) (see Miles *et al.* (2009) for further discussion of natural resource valuation techniques). The uncertainty in estimating the intrinsic value of the GBR is an impediment to evaluating the socio-economic implications of managing for climate change and other impacts.

Land management practices have a vital influence on spatial and temporal resilience to climate change (Hughes *et al.* 2003). However, whether the potential costs of practice change are balanced by direct gains in the tourism and fisheries sectors and/or indirect benefits associated with enhancement of intrinsic values is an important consideration. Integrating the socio-economic costs and benefits derived from changes in land management practices currently focuses on relatively simple assessments of direct-use values of the GBR (e.g. tourism and fishing). Whilst modelling outcomes for commercial sectors is attractive to stakeholders, the full benefit of practice change on social and economic systems is likely to be underestimated.

To provide more accurate evaluation of the socio-economic costs and benefits of changes in land management practices requires:

- Estimates of extended ecological services or non-use values provided by a healthy ecosystem;
- Estimates of the impact of climate change and water quality interactions on ecosystem health and therefore 'value'; and
- Knowledge of the capacity (social resilience) of local communities to adjust to changes in ecosystem productivity.

This section provides an overview of MTSRF-funded research results about the socio-economic influences associated with a changing climate, and the implications on communities and land managers of implementing practices to improve GBR water quality and therefore reef resilience.

3.1 The environmental economics of practice change

Several industries have developed voluntary BMP programs to secure the benefits from agricultural activities through assisting landholders to improve land management practices, whilst minimising potential adverse impacts on water quality and the GBR ecosystem (van Grieken *et al.* 2010a). Concern about the ecological and economic implications of ecosystem degradation has motivated several studies within the MTSRF about the cost-effectiveness of recommended BMPs and rates of uptake for the major industries that are significant sources of sediment and nutrients (e.g. sugarcane, horticulture and grazing) across the GBR catchments (Roebeling and Webster 2004a, 2004b, Roebeling *et al.* 2004, 2007a, 2007b, Bohnet *et al.* 2007, Roebeling and Webster 2007, van Grieken *et al.* 2009, 2010a, 2010b).

Limited resources and the social cost of implementing changes in land management practices highlight the importance of selecting practices likely to deliver improved outcomes for GBR water quality under the Reef Water Quality Protection Plan (herein referred to as the 'Reef Plan'; Department of the Premier and Cabinet, 2009) and Reef Rescue initiatives (Australian Government 2007). Depending on whether the implementation of BMPs has an associated cost or benefit, water quality targets and associated land management arrangements may need to be linked with incentives or extension for industry adoption, respectively (Pannell 2008).

Enviro-economic constraints to and incentives for the adoption of BMPs to improve water quality were investigated by MTSRF-funded researchers in priority catchments using environmental economic models, which assess the effects of different management scenarios on profitability, costs and environmental outcomes (van Grieken *et al.* 2010b, Roebeling *et al.* 2007a). For example, in the Tully-Murray catchment (Roebeling *et al.* 2007b), the cost-effectiveness of various land management practices were assessed using the approach developed by Roebeling and others (2004) that employs production system simulation models at the plot level (e.g. APSIM, PASTOR) and hydrological models (e.g. SedNet, ANNEX) at the sub-catchment level. The study explored the long-term cost effectiveness of BMPs for achieving water quality improvement at the regional level (Table 2; Sections 3.1.1 and 3.1.2) using the Environmental Economic Spatial Investment Prioritisation (EESIP) model, and the impact of population growth and climate change on attaining water quality targets (Roebeling *et al.* 2007a).

Table 2: Cost-effectiveness of best management practices for water quality improvement in sugarcane, horticulture and grazing production systems in the Tully-Murray catchment, from least effective (--) to most effective (++) (Roebeling *et al.* 2007a). Abbreviations: FSS = fine suspended sediments; DIN = dissolved inorganic nitrogen; HER = herbicides.

Production system	Management practice	Gross margin	FSS delivery	DIN delivery	HER delivery
Sugarcane	Tillage management	(+)	++	0	0
	Fallow management	+	0	-	0
	Nitrogen application rate ~ requirements	+	(0)	++	0
	Nitrogen application method	(0)	0	(+)	0
	Herbicide application rate	(-)	0	0	++
Horticulture	Inter-row management	(-)	++	0	0
	Fertiliser application rate ~ requirements	-	(0)	+	0
Grazing	Stocking rate ~ carrying capacity	+	(+)	(0)	0
	Nitrogen application rate ~ requirements	+	(0)	(+)	0

3.1.1 Cost of reducing pollutant loads

Large reductions in end-of-river discharge of sediments and dissolved inorganic nitrogen (DIN) are required to meet Reef Plan targets. Approximately 80% of DIN originates from sugarcane in Wet Tropics catchments, while large sediment losses are associated with grazing lands (Brodie and Waterhouse 2009). The sugarcane industry has several options for cost-effective means of achieving improvements in water quality (e.g. reducing tillage, and rates of fertiliser and herbicide application) (Table 2). MTSRF modelling of different land management practices for sugarcane and bananas predicted that zero tillage with cover in fallows/inter-rows reduced fine sediment loads in run-off and increased profitability for sugarcane. However, maintaining cover in inter-rows incurred a small cost in bananas. In some areas under grazing, matching stocking rates to pasture carrying capacity leads to a small reduction in sediment delivery as well as an increase in profitability (van Grieken *et al.* 2010b).

Nitrogen is applied by sugarcane growers at rates that frequently exceed standard industry recommendations (Hateley *et al.* 2006) and soluble forms, such as DIN, can run-off the land or leach into adjacent waterways. In the Tully-Murray catchment, it was estimated that total DIN (available for run-off and leaching) could be reduced by almost 50% without any additional cost (this study does not include transitional costs such as capital investments) using industry recommended BMPs as well as 'aspirational' practices (Figure 3) (Roebeling *et al.* 2007b). These 'aspirational' practices hold the potential for water quality improvement however, commercial and technical viability has not been established, and therefore caution must be taken with interpreting the results. The model can identify costs of water quality pollution targets at the plot and catchment level, which showed that some sugarcane land in the Tully-Murray catchment is operated below the environmental-economic optimum (the point at which maximum water quality improvement is achieved without incurring a financial loss). Further analyses (van Grieken *et al.* 2010b) confirmed earlier findings that reducing negative impacts on water quality by improving agricultural management practices in the Tully-Murray catchment can be achieved with a financial benefit to landholders.

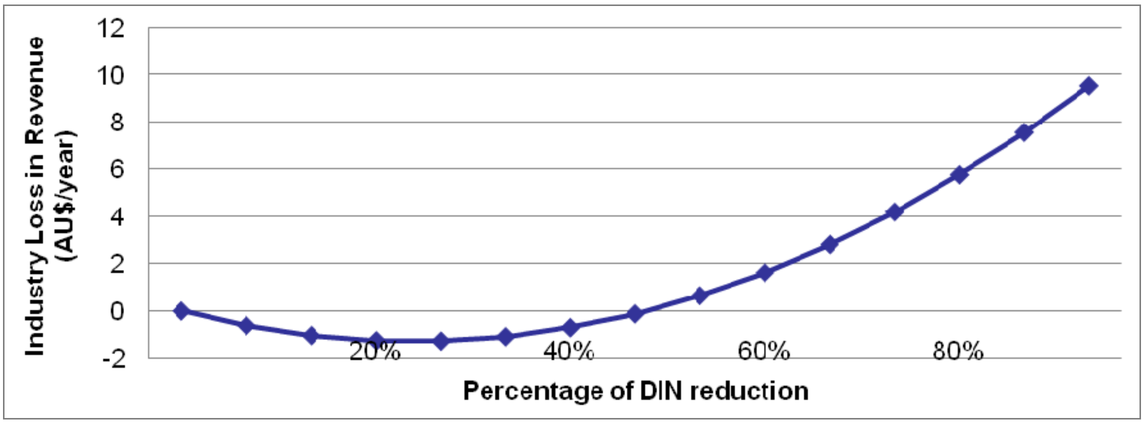

Figure 3: Abatement cost curve for the Tully-Murray catchment. The *y*-axis presents the annual loss in revenue (million AU$/year) by the industry, and *x*-axis presents the percentage of DIN reduction (by adopting win-win and win-lose management practices, as well as reducing sugarcane agricultural area) (Roebeling *et al.* 2007b).

For the GBR catchment, net present value (or investment) analysis showed that increased benefits from improved practices (e.g. through reduction of inputs and labour) can offset potential investment costs incurred by a landholder. Furthermore, there may be hidden costs and/or social barriers associated with changing practices that influence the full realisation of beneficial outcomes (van Grieken *et al.* 2010b).

Analyses of the effects of improved management practices on the delivery of DIN from sugarcane farms in the Burdekin catchment support those from the Tully-Murray catchment (van Grieken *et al.* 2010a, 2010b). The Burdekin catchment has the highest rate of nitrogen fertiliser application of any sugarcane producing region in Australia (Thorburn *et al.* 2007) and by matching nitrogen application rates to crop requirements and moving towards zero tillage with legume fallows there may be economic gains and reduced DIN delivery.

It is important to note that the costs and benefits of changing management will vary for each individual grower and will depend on their starting point and individual property scenario. Therefore, each circumstance needs to be carefully considered before making a change in land management practice.

3.1.2 Influence of climate change and population growth

Including assessment of the effects of climate change and population growth to modeling of which BMPs are likely to be most effective showed that in many cases the cost-effectiveness of BMPs at the plot-level were unaffected, i.e. BMPs remain proportionally effective in reducing pollutant delivery. However, there may be significant increases in the delivery of pollutant loads to the GBR by 2070 if pollution from residential uses exceeds that from agricultural uses. Consequently, attaining water quality targets under greater population growth may require implementation of BMPs in urban areas as well as agricultural. Further development through the MTSRF of an integrated model linking ecosystem and industry outcomes to potential climate change impacts on BMPs is underway (Wooldridge 2010).

3.2 Understanding social attitudes

There is an increasing awareness and acceptance that natural resource management (NRM) is fundamentally about people management and communication (e.g. Cary *et al.* 2002, Vanclay 2004). Many researchers, including MTSRF-funded work, and NRM agencies have recognised the value of improved understanding of the diversity of rural landholders to better target initiatives and the development of agricultural policies and programs (e.g. Specht and Emtage 1998, Emtage and Specht 1998a, 1998b, 1999, Emtage *et al.* 2001, Bohnet 2004, Bohnet *et al.* 2007, Butler *et al.* 2007). Emtage and others (2009) employed a market structure analysis based on survey data in the Wet Tropics region (Emtage and Herbohn 2008) to identify groups of landholders with similar behavioural attitudes towards NRM issues (i.e. the groups are internally homogenous but externally heterogeneous). The study analysed how the adoption of BMPs varied between groups in relation to their level of interest in the topic and purpose of land ownership, and whether any differences were related to varying communication behaviours, beliefs, values and socio-economic circumstances. Given that landholders in the Wet Tropics region are involved in a number of different industries (e.g. cropping, grazing, and native vegetation management), the challenge was to represent 'interest' appropriately across different land uses. Hence factors that apply to all landholders, such as the preparation of property management plans and participation in government NRM programs, were used as the basis for characterising groups.

Five groups were identified that most clearly illustrate variations in rural landholders in the Wet Tropics region (see Emtage *et al.* 2009 for detailed analysis of group characteristics):

Group 1 (20%) has a high level of interest in NRM, but low levels of BMP adoption (the 'concerned but unengaged' group).

Group 2 (20%) has medium levels of interest in NRM and adopting BMPs (the 'multiple objectives' group).

Group 3 (10%) has a low level of interest in NRM, but relatively high levels of BMP adoption (the 'production orientated' group).

Group 4 (40%) has low levels of interest in NRM issues and adopting BMPs (the 'disconnected and conservative' group).

Group 5 (10%) has high levels of interest in NRM activities and adopting BMPs (the 'well-connected and progressive' group).

Factors affecting landholder interest in NRM issues and uptake of BMPs have been investigated through the MTSRF by Emtage and others, and relate to the primary purpose for land ownership (Table 3) and use (Table 4), with members of Groups 2, 3 and 5 predominantly involved in agricultural production, especially cropping. Approximately half of the members of the two remaining groups are not involved in agriculture as a commercial activity. A relatively high proportion of the members of Groups 1 and 2 are in the 'hobby farm' and 'conservation' categories (Table 3).

Table 3: The primary purpose of land ownership (%) for the five groups of surveyed landholders with similar behavioural attitudes (Emtage *et al.* 2009).

Cluster group	Primary purpose for land ownership (%)				
	Agriculture	Conservation	Hobby / lifestyle farm	Residential	Other
1	40	15	23	22	-
2	72	8	10	8	-
3	94	3	3	-	-
4	49	3	18	24	6
5	90	7	-	3	-
All respondents	**60**	**7**	**14**	**16**	**3**

Pearson's chi square value = 71.120, d.f. = 16, sig. <0.000. Twelve cells (48%) have an expected value count less than 5.

Table 4: Land use type (%) for the five groups of surveyed landholders with similar behavioural attitudes (Emtage *et al.* 2009).

Cluster group	Primary land use type (%)				
	Residential only	Grazing	Cropping	Grazing and cropping	Other
1	22	13	22	-	43
2	7	19	38	14	22
3	-	31	49	12	8
4	24	18	23	7	28
5	4	18	50	21	7
All respondents	**16**	**18**	**31**	**9**	**26**

Pearson's chi square value = 62.00, d.f. = 16, sig. <0.000.

Behavioural change can be described as a multi-stage process, starting from a state of non-awareness of a problem through to contemplation (becoming aware of a problem), preparation, action and maintenance, and ending with the ‘termination’ stage; the stage at which the behaviour has become routine and accepted by the individual (Kotler and Lee 2008). The process of behavioural change need not be linear. Previous research has indicated that the relationships between attitudes to environmental management and the adoption of behaviours thought to improve the environment are not simple and are influenced by a range of other factors that act as incentives or disincentives to adoption (Cary *et al.* 2001). Market segmentation studies provide information for developing strategies to assist in increasing awareness and ultimately changing beliefs and behaviour. In some instances, the same strategy may be applied uniformly across the community. However, there is often a need to develop different strategies for each behavioural group based on select characteristics of their profiles.

For example, the level of interest in NRM issues of each group was reflected by differences in attendance at short courses on land and water management, participation in government NRM programs, preparation of property management or business plans and the use of environmental management systems (EMS). Members of groups ‘engaged’ in NRM activities (Groups 3 and 5) have high levels of attendance in short courses, involvement in government NRM programs, plan preparation and use of EMS (Tables 5-7) (Emtage *et al.* 2009). The ‘production orientated’ (Group 3) landholders were strongly motivated to build their enterprises and find information from productivity sources. The ‘well-connected and progressive’ (Group 5) landholders are characterised by their strong interest in both NRM issues and in building their businesses. They rated all information sources as useful and regularly attend meetings with Landcare, industry and NRM groups. Group 5 had an ‘information rich’ decision making style and high level of integration in social networks making it relatively easy to communicate about BMPs. The ‘multiple objectives’ (Group 2) are equally motivated to manage their property for commercial, environmental and social outcomes. They are most interested in vegetation management and have adopted a number of recommended vegetation management practices, but are less likely to have adopted industry-based BMPs than members of the two ‘agriculture dominated’ groups.

The participation rates of Groups 2, 3 and 5 in NRM activities contrast dramatically with those of Groups 1 and 4 which have low levels of participation. The ‘concerned but unengaged’ (Group 1) landholders were engaged in vegetation management practices, but not other recommended practices such as property planning or short course attendance. Members of this group were less involved in social groups relating to agriculture and land management than those in Groups 2, 3, and 5. The ‘disconnected and conservative’ (Group 4) landholders comprise 40% of the total sample, half of whom are involved in agriculture. Group 4 has low levels of interest in NRM matters, as well as low rates of adoption of BMPs, low interest in property goals, low levels of participation in industry or environment groups, and relatively low levels of trust for other people and institutions. Further, they rate the usefulness of information sources as low.

Table 5: Percentage of surveyed landholders who have attended a short course on property management or have participated in a government NRM program in the last five years, by group (Emtage *et al.* 2009).

Cluster group	Have attended a short course (%)[a]	Involved in government NRM program in the last five years (%)[b]
1	8.1	6.1
2	50.9	32.1
3	91.7	47.2
4	10.9	0
5	86.2	59.3
All respondents	**34.7**	**17.9**

[a] Pearson's chi square value = 141.28, d.f. = 4, p. <0.000.
[b] Pearson's chi square value = 92.27, d.f. = 4, p. <0.000.

Table 6: Percentage of surveyed landholders with an existing property management or business plan, by group (Emtage *et al.* 2009).

Cluster group	Whether landholder has written a property or business plan (%)		
	No	In progress	Yes
1	82.4	11.8	5.8
2	42.9	10.7	46.4
3	8.8	17.7	73.5
4	90.8	4.2	5.0
5	18.5	14.8	66.7
All respondents	**64.6**	**9.5**	**25.9**

Pearson's chi square value = 139.65, d.f. = 8, p. <0.000.

Table 7: Percentage of surveyed landholders who are currently using a recognised farm or environmental management system (Emtage *et al.* 2009).

Cluster group	Currently using a recognised farm or environmental management system (%)	
	No	Yes
1	96.9	3.1
2	85.2	14.8
3	47.2	52.8
4	98.4	1.6
5	55.2	44.8
All respondents	**85.7**	**14.3**

Pearson's chi square value = 88.80, d.f. = 4, p. <0.000.

These results suggest that in the Wet Tropics region, strategic activities targeting each group differently are required to increase the adoption of BMPs. While a positive attitude to environmental management is important, landholders will only act if they believe something is important.

Economic and social impediments to practice change vary between regions, complicating the design of policies to achieve practice change (Brodie *et al.* 2009). These impediments have been studied in various locations, including the Tully Murray catchment. Based on the farmer profiling done by Bohnet (in van Grieken *et al.* 2009) the results represent farmers' likelihoods to adapt to management practices or management practice systems in the Tully-Murray catchment. The study classifies farmers and their suggested ability and/or willingness to change. Change is defined as converting to a management practice that is improving water quality.

Survey results indicated that many landholders do not perceive environmental degradation to be an important issue but identified weed management as the most important on-property NRM issue. Therefore, although in theory practice change could occur immediately with minimal financial cost, social values and attitudes have an influential role in driving interest in and concern about environmental issues and the uptake of BMPs. Results also indicate that campaigns aimed at raising awareness and strengthening the attitudes of 'production orientated' landholders would be more effective than strategies aimed at changing behaviour, since they already have a relatively high rate of BMP adoption. Maintaining high levels of engagement in this group is likely to be best achieved through continued support for short courses run by industry groups and through targeted pest and weed management (the main NRM issue of concern). It is also important to continue to supply credible evidence that there are connections between farm practices and environmental health, and more specifically that the adoption of BMPs does result in marked improvement in the health of natural resources.

In contrast, converting the high levels of interest of the 'concerned but unengaged' landholders into behavioural change is likely to pose some challenges for promoting improved practices, as many of the members of this group are not full-time farmers and will face time constraints during standard working hours. Members of Group 1 place a fair degree of trust in 'media' information sources and could be contacted through these channels on topics of high interest to them (e.g. vegetation management) or through groups they have a high level of trust in, such as Landcare groups. However, changing the behaviour of the 'disconnected and conservative' landholder is unlikely to be achieved in the short-term given their lack of awareness about and interest in NRM issues, together with their low level of trust in others, low use of external information sources, and lack of motivation with respect to improving their landholdings. The first step to encouraging these landholders to improve their practices requires convincing them of the need to address NRM issues.

More broadly, the attitudes of the 'disconnected and conservative' landholder are common to other parts of rural Queensland and Australia, where many landholders do not perceive the health of the environment to be under threat (Emtage and Reghenzani 2008, Greiner *et al.* 2003, Byron *et al.* 2004, Lockie and Rockloff 2004). In managing natural resources, strategies are required to convince landholders of the importance and value of changing management practices (Stanley *et al.* 2005).

3.3 Measuring social resilience to change

Managing for resilience of the GBR to future threats, including climate change, requires management actions that minimise current threats, such as declining water quality. MTSRF-funded research focussed on understanding the features of social resilience to predict and monitor the potential impact of changes in water quality and the policy interventions required to improve water quality on social systems at the community (Gooch *et al.* 2010), catchment (Ross *et al.* 2010) and whole of GBR catchment scales (Lynam *et al.* 2010). Social resilience is an exceptionally complex and difficult attribute to define and measure, and is related to the resources and adaptive capacity of a community to deal with change (Maguire and Cartwright 2008). Developing a framework for measuring, monitoring and reporting social resilience at three spatial scales – community, catchment and whole of GBR catchment – will enhance the capacity of local and regional level governance to manage for social and ecological change (Figure 4).

> **"Resilient communities are ones that predict and anticipate change; absorb, respond and recover from shock or disaster; and improvise and innovate in response to disaster – perceived or real."**
>
> Adapted from Maguire and Hagan (2007)

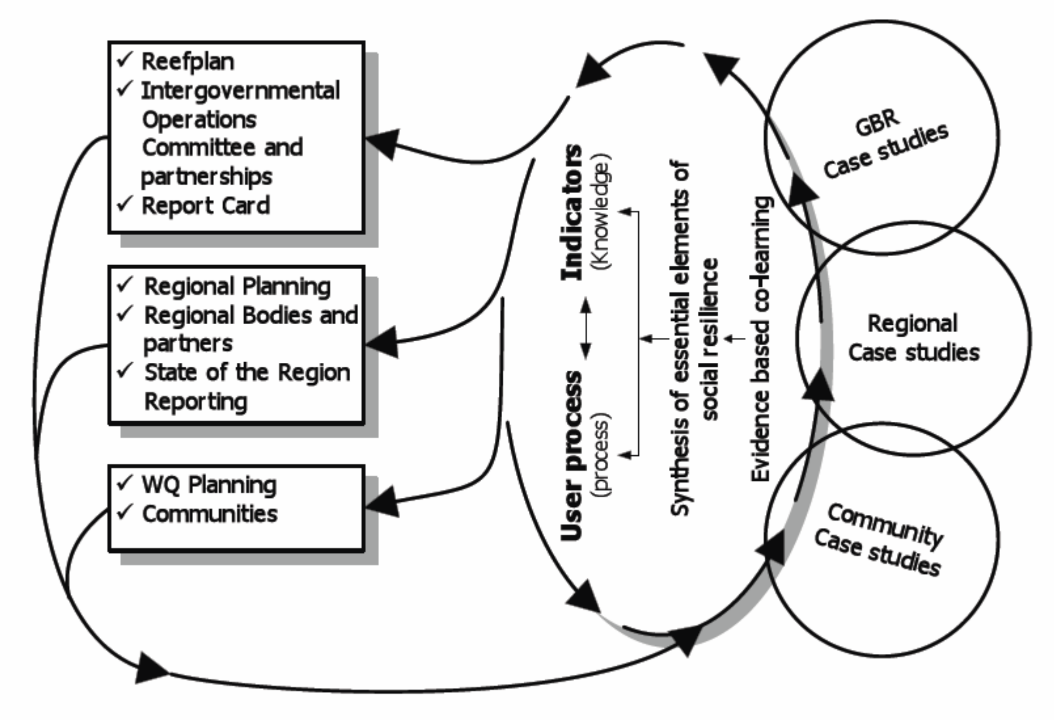

Figure 4: Conceptual diagram illustrating how a framework defining social resilience at three spatial scales can enhance the capacity to manage for social and ecological change across different levels of governance (Lynam *et al*. 2010, Ross *et al.* 2010, Gooch *et al.* 2010).

To identify features of social resilience, three parallel projects integrated a variety of information from sources that included stakeholder interviews, surveys, literature reviews, workshops and group discussions, and in-depth case studies on the social impact of major environmental and economic changes. Conceptual models of social resilience were developed through a collaborative process and used to select suitable indicators. Projects at the community and catchment scales used three dimensional linked social-ecological frameworks (Walker *et al.* 2006) to understand and describe the characteristics of social resilience. The three dimensions were (i) resilience, (ii) adaptability, and (iii) transformability, and these were used to guide the selection of key variables that formed the basis of 'domains' (broad themes) of qualitative indicators (Table 8; see Gooch *et al.* 2010 for further details).

Table 8: A community-scale example of how indicator domains and indicator variables align with statements that characterise community resilience. R = resilience, A = adaptability, T = transformability; representing the three dimensions of linked social-ecological systems used as the framework for selecting variables (Gooch *et al.* 2010).

Indicator domains	Indicator variables
1. People-place connections Integrated and holistic approaches to building resilient and sustainable communities that acknowledge human-environment interdependencies and connections.	R.5. Number of stewardship volunteer group R.9. Community visions and aspirations T.7. Extent of community restoration of waterways
2. NRM knowledge, learning and skills Individual and group capacity to respond to local needs and issues, improving knowledge.	T.5. Media coverage of issues T.8. Local knowledge
3. Social networks Processes and activities that build and support people and groups in a place.	A.1. Large networks and communication T.1. Networks beyond usual groups T.3. New cross-scale community-government partnerships
4. Empowering governance Processes, procedures and policies for community decision-making.	R.1. Agency willingness to enforce regulations R.2. Turnover of NRM agency staff R.3. Clarity of vision of NRM agencies A.2. Flexible institutional arrangements T.2. Receptiveness of regulatory and NRM staff to community concerns T.6. Enforcement of regulations by agencies
5. Futures thinking Individiual and group capacity to develop a shared vision for the future of their community that is ecologically sustainable, economically viable and culturally diverse.	T.4. Champions and leaders
6. Diverse and innovative economy Regional economy comprises a good selection of industry and services, and supports new and existing opportunities.	R.6. Extent of housing, mining, agriculture, fishing, tourism R.8. Viability of tourism, fisheries, agriculture, mining
7. Community infrastructure Appropriate services and facilities to support identified community needs.	R.4. Industry adherence to best management practice R.7. Costs of waterway restoration R.10. Community health and well-being

Qualitative indicators are statements that describe the characteristics of a resilient community. Similarities in the research approach (using data generated through interviews, group discussions, questionnaires and literature) at the community and catchment scales enabled the two sets of indicators and domains to be integrated into a common suite of resilience themes (Table 9). These resilience themes, together with their associated indicators, provided the qualitative indicators (i.e. statements) of social resilience that can be used to assist sectors at the community and catchment scales to adapt to significant change.

Table 9: Resilience domains (broad themes) (column 1) for describing social resilience at the community and catchment/region scales. These common domains were derived by comparing and contrasting emergent themes at the community (column 2) and regional (column 3) scales, respectively. Key words and phrases that describe the common domains are given in column 4 (Gooch *et al.* 2010, Ross *et al.* 2010). JCU = James Cook University, UQ = University of Queensland.

Captures both	Community (JCU)	Region (UQ)	Definitions / description
People-place connections	People-place connections	People-landscape connections (social-ecological thinking)	Identity, sense of place, stewardship, ecological footprint, resource use patters
Knowledge, Learning, Skills	Knowledge and learning	Knowledge and skills	Level of existing knowledge, access, learning by doing, awareness, having skills to respond, improving knowledge
Social Networks	Social networks and collaboration	Social networks and community building	Vertical and horizontal, bonding and bridging ties, capacity to be involved, community network focus, self-organising groups and institutions, trust
Engaged governance	Futures thinking		Innovation, creativity, forward planning, leadership
	Empowering governance (inc. leadership, planning, resources)	Engaged governance	Engaged, collaborative, enabling, participatory styles and structures of governance, social justice, equity, adaptable institutional arrangements, trust, enabling resources
Diverse and Innovative Economy	Diverse and innovative economy	Diverse and innovative economy	Multi-sectoral, adaptable, pro-active sustainable livelihoods between and within sectors
Infrastructure and services	Community infrastructure and services	Community infrastructure and services	Roads, boat ramps, hospitals, schools, picnic grounds, walking trails, recycling facilities

At the catchment scale, Ross and others (2010) studied the key social aspects of resilience at a nested set of scales, developing indicators of social resilience to inform local government, environmental management, Indigenous and social development organisations (Cuthill *et al.* 2008). These indicators enable these groups to understand social resilience in the contexts that they work in, and to assist planning and performance monitoring by those choosing to enhance social aspects of resilience through their management roles.

The study used six case studies in the Johnstone and Barron sub-catchments and their offshore areas to explore how communities in a region recovered from major changes. A total of 72 stakeholders shared their insights through in-depth interviews, into:

- dairy deregulation on the Atherton Tablelands,
- water allocation processes in the upper zone of the Barron River,
- declaration of the Wet Tropics World Heritage Area,
- rapid urban expansion in the Cairns coastal zone,
- third crown of thorns starfish outbreaks, and
- the institutional role of Girringun Aboriginal Corporation in enhancing social resilience.

These catchment case studies identified factors that are important for enhancing social resilience at both regional and community scales (Ross *et al.* 2010, Gooch *et al.* 2010):

- **People-place connections**: Integrated and holistic approaches that build resilient and sustainable communities by acknowledging human-environment interdependencies and connections.
- **Knowledge, skills and learning**: Individual and group capacity to respond to local needs and issues, and improving knowledge.
- **Community networks**: Processes and activities that build and support people and groups in a place.
- **Engaged governance**: Collaborative processes for regional decision-making (includes partnerships, planning, supportive and creative institutions).
- **Diverse and innovative economy**: Regional economy comprises a good selection of industry and services, and supports new and exciting opportunities.
- **Community infrastructure**: Appropriate services and facilities to support identified community needs.

Each case study provides valuable stakeholder insights into why these factors enabled their area to cope with a change, and how they drew on these factors in combination in order to adapt to meet the challenges involved.

The project treated these six factors as qualitative indicators of the strength of social resilience, and developed 50 ‘monitoring criteria’ to guide their measurement. For instance, ‘people-place connections’ can be indicated through:

- Stewardship (broad and/or regional focus);
- Level of attachment to community;
- Connection to country (Indigenous);
- Shared vision for community (broad and/or regional focus);
- Appropriate regional growth management strategies/initiatives/processes, based on the vision that looked to balance economic, social and environmental aspects of development; and
- Uptake of environmentally friendly technologies and practices.

The project provided measures for many of these, and derived and mapped baseline data, from national statistics wherever available. For instance, the proportion of population living in the same (statistical) local area for five years or more provides a useful proxy measure both for people-place relationships and social networks.

The project proposed that its partners and other managers could manage for social resilience on three possible levels:

- Being aware of social resilience context, without intention to intervene (‘acknowledge it’);
- Making constructive use of social resilience characteristics in management actions (‘use it’); or
- Meeting environmental and other mandates in ways that simultaneously enhance social resilience (‘grow it’).

At the whole-of-GBR catchment scale, researchers considered resilience as a function of four types of adaptations, ranging from proactive (*prevention* and *preparation*) to reactive (*response* and *recovery*) (Lynam *et al*. 2010, Bohensky *et al.* 2010). The likelihood of adapting to changes in water quality or to management actions aimed at improving water quality was related to the ability of social groups to take high levels of preventative, preparatory, response and recovery (PPRR) actions. The capacity of a group to take effective PPRR actions was conceived to be dependent on four interrelated factors: a sense of community and social cohesion (Lochner *et al.* 1999), community competence (Lochner *et al.* 1999), collective efficacy (Zaccaro *et al.* 1995), and availability of resources (Figure 5).

The conceptual model of adaptive capacity provided the framework for the development of draft indicators (Table 10) that were tested for robustness in explaining and predicting the adaptive capacity of 'groups' using a Bayesian Belief Network (BBN) model. BBN models describe relationships among indicators in terms of probabilities and are useful in highly complex and uncertain situations. The model can readily be updated as new knowledge becomes available, which is important as predictions of social resilience are dependent on the relationships between variables and the quality of data used to develop the model (see Bohensky *et al.* 2010 for further discussion of BBN models).

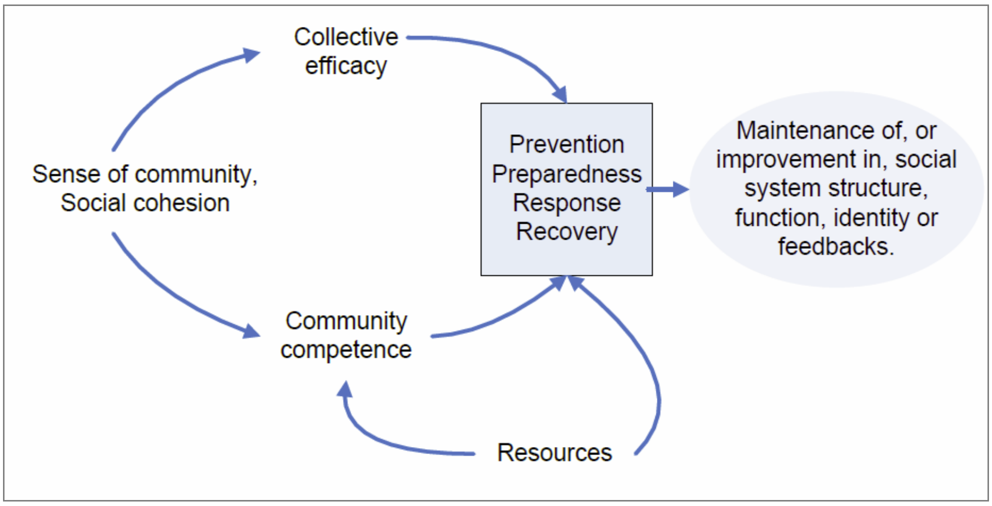

Figure 5: Conceptual model of factors enhancing the likelihood that a social system in the GBR will successfully adapt to water quality change or interventions to improve water quality (Lynam *et al.* 2010).

Table 10: Current set of selected indicators for assessing the adaptive capacity and resilience of social systems to change at the whole-of-GBR scale (Lynam *et al.* 2010).

Current best list of indicators of social resilience	Broad category
1. Understanding of biophysical-social linkages	Group knowledge and capacity building
2. Biophysical system understanding	
3. Social system understanding	
4. Trusted and useable science	
5. Access to technical experts or technical information	
6. Long-term strategic decision making processes	
7. Debate	
8. Power to take action and affect change	
9. Access to resources and incentives for experimentation	
10. Collectively established goals	
11. Strategic plan to achieve goals	
12. Solutions or activities that achieved intended outcomes	
13. Well-connected to social networks	Networks and links to other organisations
14. Cross-scale networks	
15. Organisational power	
16. Organisational coordination	
17. Congruence between government resource allocations (funding, support) and desired outcomes	
18. Economic wealth status	Other (economic and environmental)
19. Economically viable enterprises	
20. Intact/healthy environment	

Results of this MTSRF-funded research identified that contextual knowledge is essential in interpreting the modelled adaptive capacity of a given social system as the relationships between indicators are not certain. However, a larger data set is likely to increase the robustness of the model and result in greater understanding of the way in which different combinations of variables drive the likelihood of adaptation. The model provides an understanding of the likely level of adaptation, both proactive and reactive, in a given social system. Indicators to which adaptation states are most sensitive are those which give the most information about the adaptive capacity. Future application of the model results will provide data that can feed back into improving the model of social resilience and further refining the set of indicators. An important output of this research is the development of a User's Guide that will assist stakeholders to implement their own data collection and evaluation using a BBN model (Lynam *et al.* 2010).

4. Adaptive governance to enhance GBR resilience

MTSRF-funded research has shown that effective management and strategic investment in improving water quality will minimise some climate change risks in the short-term by facilitating enhanced GBR resilience (see the companion report 'Water quality and climate change: managing for resilience' by Johnson and Martin 2011). The Australian and Queensland governments have initiated a number of key plans and strategies aimed at improving water quality (e.g. Reef Plan 2009, Reef Rescue, Water Quality Improvement Plans (WQIPs)), however setting pollution targets, and improving land management practices alone will not guarantee water quality improvements. Achieving improved water quality also requires strategic and effective planning that considers potential barriers to success, such as the rate of BMP uptake (Section 3.2), landholder typologies (in van Grieken *et al.* 2009), and existing institutional and governance arrangements (Robinson *et al* 2011). The mechanism by which change is introduced may greatly influence the rate of adoption and therefore the success of any plan, because leverage for change occurs in different ways, particularly within industries that tend to be 'isolated' (i.e. social networks with high density and low reachability; Weeks *et al.* 2002).

4.1 Adaptive partnerships

MTSRF-funded research has focused on developing specific tools and options to assist decision-makers in the challenging task of managing the GBR region for economic, social and environmental sustainability, despite the twin pressures of climate change and increasing population pressure. For example, Robinson and others developed a set of SMART (specific, measurable, achievable, realistic and timely) partnership criteria to assist stakeholders in determining individual capabilities and needs in the collective effort to negotiate and deliver water quality improvement plans. These criteria were based on the recognition that one of the greatest obstacles to improved management of water quality is the decreasing potential for coordinated action by multiple stakeholders (Lane and Robinson 2009). Thus, the criteria advocate adaptive and consensus-building approaches to collaborative arrangements established to achieve negotiated water quality targets (Robinson *et al.* 2011).

Using the SMART approach, partners can develop plans to meet water quality targets that suit the socio-economic context to:

- Determine whether existing collaborative arrangements adequately consider the *specific* purpose of proposed water quality management activities;
- Develop *measures* of success that are compatible among the relevant partners;
- Negotiate fair distribution of delivery costs and responsibilities among partners to ensure proposed water quality management activities are *achievable*;
- Align water quality activities with partner agendas and capabilities to ensure activities are realistic and *relevant* to partners; and
- Consider how delivery through partnerships can be *timed* to maximise benefits of proposed actions.

By systematically building partnerships in this way, partners can ensure resources are invested in institutional collaborations that have the greatest likelihood of successfully achieving desired and negotiated water quality outcomes. Applying the SMART criteria can effectively target regulatory strategies to address the various landholder constraints to the adoption of practice change (see Box 1). Strategies include measures to promote capacity-building for vulnerable areas, and measures that enhance future responsiveness to climate change. The criteria can also be applied to facilitate the restoration of riparian and wetland habitats as required under Reef Plan and Reef Rescue, and develop catchment scale monitoring and reporting frameworks to provide rigorous and consistent information on management responses for the whole GBR.

Box 1 – SMART criteria in action: the Tully-Murray WQIP

Managing nutrient loss from intensive agricultural land uses in the Tully-Murray catchment was identified as a priority in improving water quality both in-stream and in the GBR lagoon, with the need for focus on land management practices at the farm level. However, the delivery of improved land management practices requires cooperation between farm businesses, providers of technical and scientific knowledge, the commercial sector, and the public NRM sector in order to meet water quality targets (Taylor and Robinson 2010). The SMART criteria were used to guide focus group discussions between the agricultural industry and local government to assess the partnerships of Queensland's Tully-Murray Water Quality Improvement Plan (WQIP) (Table 11). The criteria were applied to design implementation strategies within production landscapes and within natural landscapes where ecological restoration values predominated, particularly riparian and wetland habitat restoration. At the catchment and regional scales, representative organisations for industry stakeholders provide the critical linking and brokering roles between the sectors, with potential influence on grower practice change. Achieving water quality targets and facilitating practice change requires a complex set of political, social, knowledge-based and institutional conditions to be met, highlighting the multiple actions implicit within the catchment scale that were identified using the SMART criteria as a basis for discussions (Robinson *et al.* 2011).

Table 11: An overview of the SMART criteria used to assess partnership needs for delivery of the Tully-Murray Water Quality Improvement Plan (Taylor and Robinson 2010).

Partnership Assessment Criteria	Explanation	Assessment of partnership needs for proposed Tully WQIP nitrate management delivery purposes
Specific	• Partnership supports specific place and purpose of activities	• Partnerships need to be flexible to support specific practices that nominally provide a balanced benefit to water quality and landholder needs. • Partnerships that support BMP practice uptake need to address spatial extent of intervention. This can be variable between Tully's landholders and agricultural production communities.
Measurable	• Compatible measures of delivery and partnership success identified	• WQIP monitoring and evaluation frameworks need to integrate scientific and management expertise to judge deliver progress that incorporates economic and social criteria, and determine appropriate thresholds for management practice change.
Achievable	• Thresholds for commitment to delivery identified • Partnerships and activities are within existing institutional boundary conditions	• There is still a need for local, regional and policy arrangements to clarify partner roles to align effort and address concerns that agencies are doing their 'fair share' to support WQIP delivery.
Relevant	• Partnerships and activities are understood and applicable to partners	• WQIP partnerships need to build on existing co-investment and activities that support local agendas plans and initiatives.
Timed	• Temporal dimensions of partnership and activity functions considered	• Partnerships established to support BMP incentives need to be responsive to the sequencing of actions and temporal variability (e.g. seasons, markets) affecting practice delivery. • Partnership commitments need to reflect and support the sustained effort required to meet Reef targets.

4.2 Collaborative decision-making

MTSRF-funded research has focussed on understanding partnership requirements and processes to support collaborative decision-making, by identifying attributes of knowledge integration as indicators of effective water quality governance (Taylor and Robinson 2010). These indicators were framed by the recognition that the achievement of water quality targets relies on an effective system of governance that is capable of facilitating the necessary cooperation and coordination between multiple environmental decision-makers and activities (Robinson *et al.* 2011). The integration of diverse participants' knowledge is a key requirement in adaptive approaches to environmental governance and planning that target issues of diffuse pollution (Kroon *et al.* 2009). 'Good governance' in this context is defined as the capacity of institutions such as regional bodies, government, and industry to individually and collaboratively promote the integration of knowledge. A framework (Table 12) was developed using the knowledge indicators to evaluate the performance of collaborative governance arrangements, and to inform the allocation of investments for water quality improvement.

Table 12: An assessment framework incorporating knowledge attributes for collaborative water governance. The framework was used to assess the delivery of Reef Rescue resources in the Wet Tropics NRM region (Taylor and Robinson 2010).

Knowledge sharing functions	Attributes	Application context
1. Integration	**Diversity** – multiple types of knowledge (local, scientific, policy relevant) are identified and recognised **Deliberation** – institutions support debate between knowledge holders to frame problem and build understanding **Inclusiveness** – knowledge sharing and problem framing processes accessible and inclusive	Scoping and problem / task framing stage For policy development / resource allocation decisions
2. Translation	**Credibility** – knowledge used to inform priorities and actions is credible in terms of trustworthiness and adequacy **Legitimacy** – decisions and supporting knowledge legitimised through appropriate representation **Salience** – the provision of knowledge and subsequent decision-making is timely and the type of knowledge is appropriate to problem context	Design and implementation stage To design policy implementation / resource prioritisation strategies
3. Adaptation	**Relevance –** measure of success or thresholds are cooperatively developed and are relevant to partners views on 'good' implementation **Roles** – to monitor and evaluate impact in their respective domains agreed amongst partners **Responsibilities** – for sharing results from implementation (i) between partners and (ii) between scales of delivery, e.g. local-regional, are articulated **Capacity –** partners have the capacity to incorporate insights from review or monitoring into their own institutional behaviours	Feedbacks for learning / assessing program effectiveness
4. Impact	**Outputs and outcomes** – monitors and reports on efficacy of partnerships to achieve water quality (and other negotiated) goals May have short- and long-term components and deliver social (i.e. building institutional capacity) and biophysical (i.e. improved water quality) benefits	Determines progress towards intended outcomes and positive / negative consequences

The framework was used to evaluate and improve regional grant delivery processes under Reef Rescue in the Wet Tropics region by incorporating new insights into existing collaborative structures and decision-making processes. Application of the indicators revealed that impediments to effective implementation can be mitigated by explicit consideration of roles, responsibilities, cost-sharing and accountability arrangements as part of the initial stage of policy implementation. A timely feedback system provided an agenda to guide improvements and strengthen partnerships, with a focus on regular communication between partners, enhanced engagement of partners in the planning and setting of priorities, and the further development of tools, processes and procedures to support efficient and effective program delivery (Taylor and Robinson 2010).

Alternative ways of integrating scientific, local and other types of knowledge to inform management and planning activities form a central analytic tool in the assessment of cooperative arrangements and approaches established to deliver WQIPs. Application of the framework has the potential to improve collaborative approaches to water quality improvements more broadly across the whole GBR, by identifying critical knowledge attributes that determine the success or otherwise of co-operative planning and implementation of environmental policy.

4.3 Policy instruments to promote BMP uptake

The mechanism by which practice change is introduced may greatly influence the rate of adoption and therefore the success of any plan, because leverages for change occur in different ways, particularly within industries in the GBR. Applying market-based instruments (e.g. taxes and subsidies) to water pollution from terrestrial activity in the GBR catchment could result in cost-efficient, optimal social outcomes (Shortle *et al*. 1998). The cost-effectiveness of BMPs was assessed in Section 3.1 (Roebeling *et al.* 2007a, 2007b), to estimate regional socio-economic and environmental consequences of different policies. Combining this information with a typology of farmers (van Grieken *et al.* 2009) can yield more insight into likely adoption rates and guide NRM strategies to affect change in landholder behaviour. A case study by van Grieken and others assessed the cost-effectiveness of various market-based instruments in mitigating dissolved inorganic nitrogen (DIN) pollution from sugarcane, horticulture and grazing in the Tully-Murray catchment (van Grieken *et al.* 2010b). The market-based instruments assessed (using EESIP) were input and output based taxes and subsidies.

In the Tully-Murray catchment, sugarcane and horticulture are the most economically important industries, accounting for about 50% and 40% of regional agricultural income, respectively. In comparison, grazing accounts for 7% of regional agricultural income. Results indicated that industries in the Tully-Murray catchment respond differently to the instruments assessed. Since N-fertiliser is not a big contributor to the production of beef and timber, these industries will not be impacted by instruments that focus on reducing N to the same extent as the sugarcane and banana growing industries. This approach provides a good indication of market-based policy options and likely adoption rates prior to implementation or allocation of resources.

In a second modelling exercise, van Grieken and others (2009) combined the typology of farmers with production system simulation and cost-benefit analysis to assess likely adoption rates and estimate regional socio-economic and environmental consequences of different policies. They also incorporated variation in the size of the farming enterprise, since small farms may face production constraints or higher costs per hectare. However, it is imperative that transaction costs (e.g. the time spent learning about new equipment and management practices, training, enforcing and monitoring) are to be included in order to give an accurate representation of the total cost of implementation at the catchment scale (Horan and Ribaudo 1999, Kampas and White 2002, Coggan *et al.* 2010). From a policy perspective, it is important to note that gross margins will vary spatially and landholders will have varying costs of transitioning to improved practices. Finally, the highly variable nature of diffuse source water pollution and short-term responses to the policy instruments may affect the estimates of cost-effectiveness (Shortle *et al.* 1998, Bouman *et al.* 1998, Kampas and White 2002).

4.4 Who pays? The burden of practice change

There is a balance between reducing terrestrial sources of water quality pollutants through improved land management practices and maintaining the importance of agriculture to the Australian economy. Land use decisions by individual landholders are most likely to occur in response to incentives (Wills 1997) rather than regulation, and where costs are minimal. There are many BMP options that are likely to result in improved water quality with little or no cost to the landholder. In fact, improved nutrient management may result in efficiencies and cost savings in the farm operation as well as benefits to water quality (Section 3.1), which is considered an incentive to landholders. However, to meet the targets of regional water quality improvement strategies and secure long-term community and government support to farm in wet tropical environments or adjacent to World Heritage assets, landholders may be required to adopt management practices that incur a significant cost (van Grieken *et al.* 2009). Thus, the debate has centred on the burden of cost: who pays if public benefits result in private costs on-farm?

One approach is to use a mix of positive and negative incentives (disincentives) and to distribute the costs and benefits across public and private sectors (Taylor 2010). Positive incentives generate a positive change, and disincentives are in place to stop an action with negative environmental outcomes. Positive incentives include non-financial (e.g. information and support) or financial measures. The use of financial or non-financial mechanisms depends on the nature of the threat, landholder motivation, and the level of private costs and/or benefits (Reeson 2007). Positive incentives are most appropriate when the public benefit is greater than the private cost, and when the private cost is not large (Coggan and Whitten 2008). Disincentives are appropriate when the public cost is greater than private benefit and the private benefit is likely to be large (Coggan and Whitten 2008). The Australian Government, through the Reef Rescue initiative, has recognised the need to provide financial assistance to communities and industries facing the challenge of halting and reversing the decline in water quality entering the GBR. Achieving the objectives of Reef Plan and the *Great Barrier Reef Protection Amendment Act 2009* will rely on a partnership between all levels of government, industry, community and landholders (Sections 4.1 and 4.2).

Hence, rather than view the system as segmented, with landholders distinct from the beneficiaries of water quality improvement, there is a need to link landholders to ecosystem services. However, current planning and management activities in the GBR do not adopt an ecosystem services approach, and the importance of managing socio-ecological resilience has been largely overlooked (see Folke *et al.* 1998, Cumming *et al.* 2006). Evaluating ecological service provision is difficult, and the links between ecological functions and services become increasingly complex with greater distances downstream (Butler and van Grieken 2009). The nature of diffuse water quality impacts from land-based industries on coastal and marine environments adds additional layers of complexity to the management task. These layers can include ecological scales that do not match easily with jurisdictional or socio-cultural boundaries (Robinson *et al.* 2009). The challenge facing management institutions is to fit water quality management to the spatial scale of the ecosystem: there is evidence that institutional scales (small) do not match ecosystem service scale (large) in water quality regulation. Complementary institutional and ecological scales promotes positive feedback loops, improved adaptive capacity and enhanced maintenance of ecosystem services. Other imperatives involve designing local management actions that meaningfully nest within GBR-wide objectives. Establishing payments for ecosystem services has the potential to create tighter network links between landholders and the GBR, leading to adaptive co-management. In 2007, a survey of 350 tourists from Cairns to Port Douglas revealed 60% thought water quality was having an adverse impact on the GBR, with 37% willing to pay to contribute to incentives for farmers to change land management practices (median of $8 per head) (Butler and van Grieken 2009). Thus, there are many benefits of an ecosystem services approach to managing water quality in the GBR.

5. Management frameworks

Internationally and locally there have been innovative efforts to develop participatory monitoring and reporting frameworks that fit partner needs and focus on integrated project delivery (reviewed in Robinson *et al.* 2011). These frameworks incorporate principles of collaborative learning that emphasise the learning and communicative processes involved in resolving conflict and building consensus, rather than focussing only on the outcomes. Approaches that enable continuous assessment of progress by stakeholders need to be considered in the development of a cross-regional framework to support adaptive governance of GBR water quality (Taylor and Robinson 2010). For example, the Reef Water Quality Partnership (RWQP) is a collaborative partnership that focused on supporting regional water quality planning in the GBR; MTSRF researchers used this arrangement as a case study of management frameworks in NRM (Lane and Robinson 2009, Robinson *et al.* 2011). The RWQP was established to co-ordinate water quality target-setting, monitoring and reporting so as to link management actions in the catchments to the health of the GBR ecosystem. A MTSRF research team in cooperation with a RWQP Scientific Advisory Panel sub-group and other stakeholders, contributed to the development of a protocol for supporting the adaptive management of water planning at the regional and catchment scales. The policy and planning assumptions underlying adaptive management practices in GBR catchments are integrated into the protocol (Figure 6). The aim of the protocol is to assist water quality managers (particularly WQIPs) to explicitly state and test the logic of their plans or strategies to determine the efficacy of management actions and partnerships in delivering targets and meeting objectives. For example, the protocol includes steps to build and test knowledge used to inform the setting, management and evaluation of water quality targets for improved accountability. An adaptive approach to management has many advantages in situations where there is significant uncertainty, and may assist in:

- Reducing the pressure on initial decisions, which are seen as ‘provisional’;
- Developing explicit models of how a system does or should operate; and
- Establishing a learning environment that facilitates the incorporation of new knowledge and improves connections between stakeholders.

As stakeholder experiences accrue following implementation of an adaptive management strategy, there will be the opportunity to translate those experiences and knowledge into improving existing mechanisms of planning and governance.

A framework that will effectively link management actions in the catchments to the health of the GBR ecosystem must incorporate broad industry and community perspectives about the benefits of good water quality, the cost of deteriorating water quality, local biodiversity values, and the total (social and economic) costs and benefits of delivering given water quality outcomes from a proposed intervention (Taylor and Robinson 2010). Inherent in any approach is the need to consider different scales of management and different logic in the mode of policy implementation (Robinson *et al.* 2009). A cross-regional framework that incorporates monitoring and reporting, the sharing of outcome evidence across catchments to inform further action, and negotiated collective responses based on observational evidence is required to address the different logics and assertions inherent at different scales of management (Taylor and Robinson 2010). Effective networks between stakeholders at multiple levels are critical in resolving and averting potential conflicts between sectors and between different scales of activity. The management tools and decision-making resources developed by the MTSRF team are not limited to achieving targeted improvements in water quality; rather, they have broader application in establishing governance arrangements to facilitate the effective management of natural resources across multiple scales and involving multiple players. They are an important contribution to the impact of science in natural resource decision-making and governance.

1.1 Excerpt of Principles from the Protocol:

Principles underlying adaptive management for WQIPs reflect the integrated natural resource management setting in which these plans are designed, delivered and evaluated. They include:

1. **Recognition of different benefits and uses of adaptive management strategies**

Taking an adaptive approach to water quality planning and management ensures ***structured and iterative learning*** to inform and improve WQIPs. This includes improving management effectiveness of actions and targets and building and testing knowledge used to inform water quality target setting, management activities and evaluation. An adaptive management approach also supports improved ***accountability*** and auditing mechanisms of stakeholders and investors. In practice it helps identify the level of risk or uncertainty behind management measures and control actions, and to address the reasonable assurance requirements of WQIPs.

2. **Interdependence between catchment level and GBR-level adaptive management**

Adaptive management approaches at the catchment level need to be informed by insights and feedbacks from water quality partners at *all* levels (on-ground, catchment, regional and policy levels). That is, insights, improvements or risks identified at the catchment level may have implications for managers in other regions or at the GBR-level, and vice versa. Existing partnership forums and arrangements such as the Commonwealth-Queensland Joint regional NRM Steering Committee, Regional Coordination Groups and forums such as the Reef Water Quality Partnership's Regional Implementation Group and Scientific Advisory Panel are critical in the linking of adaptive approaches for water quality at different levels.

3. **Linking adaptive management strategies with different planning stages and contexts**

Adaptive management strategies should reflect the needs of each of the planning, implementation, monitoring and evaluation phases of WQIPs. This requires steps to ensure the adaptive management strategy meets program requirements but is also tailored to the physical, social, cultural and economic conditions of individual catchments. Scope to incorporate less formal adaptive management and learning processes has been included in protocol steps.

Figure 6: Adaptive management strategies for the Great Barrier Reef Water Quality Improvement Plan (Eberhard *et al.* 2009).

To summarise, the approach used to guide management responses and responsibilities under the Reef Plan is often complex, and the link between management actions and specific water quality outcomes characterised by uncertainty. Research in the Wet Tropics suggests that the mix of stakeholders within water quality partnerships is often poorly negotiated at the catchment level and the diversity of contexts in which water quality plans are being negotiated results in different pathways to delivery. The complex socio-political challenges in establishing networks targeting water quality improvement are partly due to the existence of hybrid, network-type environmental governance structures that have developed as a consequence of repeated interactions between sub-groups of stakeholders (Robinson *et al.* 2009). For example, in the Fitzroy catchment, different agricultural industries (e.g. grazing, cotton, grain) utilise different, already established industry networks for information and influencing broad-scale adoption of sustainable land management practices for water quality improvement (Lockie and Rockloff 2004). Hence, incorporating these interest-oriented horizontal networks (between stakeholders) into a vertical network structure (across scales) is necessary to prioritise and achieve regional water quality targets. The effective management of broad-scale water quality together with the challenges associated with a rapidly changing climate requires a pragmatic and defensible monitoring, evaluation and reporting framework that enables adaptive responses to potential and cumulative impacts within complex environments.

6. Conclusions and management applications

6.1 Conclusions

MTSRF-funded research has delivered key information that will inform the application of resilience strategies that recognise social and cultural attitudes, and target areas of social resilience to change. The MTSRF has thus added to the small evidence base on community-scale resilience, and provided the first known systematically derived set of social resilience attributes effective at regional scales. Further, it fulfils the aim of social-ecological systems scholars to understand resilience at nested scales. The research expands on the range of social science concepts so far reflected in the research on social-ecological resilience at regional scales, and introduces economic thinking. Meanwhile it incorporates larger scales with the body of research on individual resilience.

This report has outlined how MTSRF-funded research has:

- Improved understanding of the socio-economic impacts of climate change on regional coastal centres;
- Evaluated the cost-effectiveness of implementing industry BMPs;
- Improved understanding of the effect of climate change and population growth on BMP uptake;
- Identified planning options to address socio-economic barriers to BMP uptake;
- Analysed policy instruments to promote cost-effective BMP uptake;
- Increased understanding of social resilience and developed indicators of social resilience to change in GBR catchments;
- Provided insight into the social indicators of adaptation likelihood for communities at different scales;
- Developed SMART criteria for establishing effective water quality partnerships;
- Developed knowledge indicators to evaluate collaborative governance performance;
- Developed a protocol to support adaptive management of water planning at the regional and GBR catchment levels; and
- Applied an ecosystem services approach to support decision-making in water quality management.

This knowledge will be invaluable in targeting specific sectors of the community to increase the effectiveness of water quality management efforts that enhance the resilience of the GBR to future climate change.

More specifically, if the decline in GBR water quality is to be reversed, there must be a greater focus on promoting uptake of BMPs across agricultural industries of concern in the GBR catchments. Recent compulsory compliance mechanisms and limited resources for implementation of practice change mean that it is important to select cost-effective practices that have the highest likelihood of delivering positive water quality outcomes and of having high adoption rates. Coordinated action and SMART institutional partnerships between state and federal agencies, NRM bodies, agricultural industries, landholders and research providers are required to minimise the risks associated with certain land uses. Non-use values need to be considered in evaluating the socio-economic cost of action versus inaction. Improving the quality of water entering the GBR lagoon will maximise the resilience of the ecosystem to a rapidly changing climate.

6.2 Management applications

Managers of the GBR and associated ecological and socio-economic studies require up-to-date knowledge of the impacts on the key assets and approaches to minimising and mitigating these impacts. In the case of climate change, researchers have identified that the most successful strategies for minimising the impacts of a changing climate at local and regional scales are associated with building and maintaining reef resilience. Managing the impacts of declining water quality on the GBR is the most prominent example of a suitable management approach. This report has summarised research undertaken through the MTSRF to identify the most effective ways to increase uptake of land management practices that improve water quality, with several findings directly applicable to managers (summarised below).

Land management practices that improve water quality have a vital influence on the spatial and temporal resilience of GBR ecosystems to climate change. Assessments of the environmental economics of practice change indicate that reducing negative impacts on water quality by improving agricultural management practices can be achieved with an economic benefit to landholders. However, improvements between different classes of management practices are likely to require additional investment through incentive programs. In addition, the capacity of landholders to seek and integrate new approaches to manage sustainable land condition is influenced by their socio-economic status, beliefs, values and attitudes. Therefore, outreach and incentive programs must consider the different behavioural characteristics and approaches to learning of landholder groups to ensure effective uptake of BMPs. Depending on the environmental susceptibility and social adaptive capacity, the conservation of the GBR will require a combination of approaches across multiple scales that include protection, transformation of social-ecological systems and localised capacity building.

Social and cultural attitudes play an important role in determining what management strategies are likely to be effective, and which require additional incentives or support. The results of MTSRF research reported here show how financial gain alone is not sufficient to elicit behavioural change in all landholders, and that incentives and engagement are required if managing for GBR resilience is to be successful.

This information can be used as an indicator in the prediction of the likelihood of change, or adoption of improved practices, relevant to target setting. Profiling of this nature across the GBR catchments would enable managers to identify areas of investment priority and provide insight into the type of management strategies that may be most successful in a particular location or farming community. Management needs to be cognisant of the behaviour and value systems of landholders to assist in targeting policies, programs and resources to affect on-ground behavioural changes for positive environmental outcomes.

Catchment scale studies have identified the key indicators of social resilience for the Great Barrier Reef region and its communities, which should be a focus for management action for those seeking to enhance social resilience, and measure, monitor and report on social resilience (Ross *et al.* 2010). Management can then identify the most suitable monitoring criteria and measures (or proxies) for these social resilience indicators, to contribute to 'State of the Region' reporting and to assist partners and other organisations in their planning and performance monitoring.

The identification of indicators of social resilience to change at the community and catchment scale (Gooch *et al.* 2010, Ross *et al.* 2010) provides a tool for management to implement adaptive co-management and stewardship of local waterways. In coastal regions where residents rely on water for a variety of economic and recreational activities, identifying residents' willingness and ability to respond pro-actively to changing water quality is fundamental for building capacity and managing community scale resilience. These indicators of social resilience are being integrated into the Reef Guardian Councils program to assist management (Great Barrier Reef Marine Park Authority and local government) target establish local waterway co-management arrangements.

MTSRF research at the catchment and community scale has provided essential knowledge that will allow management to convert resilience thinking into practice (Ross *et al.* 2010, Gooch *et al.* 2010). In identifying the social aspects of resilience which are most important in North Queensland, the MTSRF research provides avenues for management organisations to work in greater consciousness of their social contexts, and to work towards enhancing social resilience in the course of fulfilling their roles. The case studies offer a detailed understanding of ways in which the social resilience factors operate in marine and terrestrial social-ecological systems, showing opportunities for future management strategies. The findings reinforce the need for organisations to collaborate across traditional operational boundaries: for environmental management and Indigenous organisations to work more closely than ever before with the agencies responsible for regional planning and social development. The focus on indicators promotes an adaptive management approach, in which planning, provisional action, monitoring and evaluation, lead to continual improvement in practice.

The results generated through the BBN model of social resilience at the whole-of-GBR catchment scale can assist decision-making through three mechanisms:

- Enable evaluation of the likelihood of a social group proactively or reactively adapting to environmental change by knowing the state of a set of indicators for that social group;
- Enable identification of the factors with the greatest influence on the likelihood of adaptation and therefore provide targets for investments to improve adaptive capacity; and
- Enable monitoring of changes in social adaptive capacity.

Caveats include acknowledging the limitations of the current model structure and data set in deriving the results (Lynam *et al.* 2010). However, techniques are available for examining the robustness of results under different model scenarios and improving predictions of adaptive capacity (Lynam *et al.* 2009a, 2009b).

This research represents considerable advancement in the field of social resilience at different scales, and reinforces the need for organisations to collaborate across traditional operational boundaries in managing complex systems. Whilst the approaches to measuring resilience at the community/catchment and whole of GBR catchment scale resulted in some differences between sets of indicators, there is much overlap and the indicators may be used together at multiple scales in the GBR to explore questions regarding the resilience of broadly-dispersed social groups compared to that of locally-based, geographically distinct groups. For example, what are the likely social implications of investing $125 million in the Mackay Whitsunday region to achieve water quality targets under the Reef Plan? Could this investment increase the dependence of the community on external subsidies and hence reduce their capacity to act autonomously? What are the social implications of WQIPs on local communities?

Importantly, the indicators enable management agencies to take advantage of the resilience characteristics of communities to implement management strategies under conditions of high uncertainty in a way that enhances social resilience at multiple scales. However, the complex, dynamic and highly contextual relationships between many interrelated factors contributing to social resilience highlight the need for caution in interpreting predictions of social outcomes; even if data sets are relatively large. Management agencies must be aware that any given set of indicators reflect the 'adaptation likelihood' of a social system to change, rather than a linear relationship, and thus are not prescriptive in all contexts. Nevertheless, increased understanding of social resilience developed through the MTSRF will enhance the capacity of management agencies to anticipate and respond to major environmental challenges.

The results of MTSRF research assessing the cost-effectiveness of different policy instruments for implementing BMPs using two models (EESIP and PROFILE) has generated CSIRO Flagship research to develop protocols that assist water quality managers to incorporate uncertainty into management plans, and promote confidence in investments to improve water quality. The EESIP approach may be applied to evaluate the costs of practice change required to meet Reef Rescue targets, in addition to informing the setting of achievable goals for future pollution reduction. However, assessing the economics of various land management regimes in different agricultural systems and the cost-efficiency of improving practices has a wide range of practical applications across jurisdictional and socio-cultural scales, including:

- Informing private landholders of the financial and operational requirements of practice change;
- Informing WQIP processes in NRM regions;
- Highlighting the environmental benefits of practice change for targeted investments;
- Highlighting the heterogeneity in social factors for targeting management actions;
- Providing a decision-support tool to determine policy price mechanisms of delivery; and
- Linking economic ‘optimum’ levels of water quality improvement to the terrestrial environment.

6.3 Future directions

MTSRF-funded research has provided insight into the cost-effectiveness of many BMPs at the sub-catchment and industry scale, and preliminary identification of barriers to implementation. Further work is needs to quantify the long-term cost-effectiveness of BMPs at a whole of region level so that the effectiveness of price policy instruments in promoting BMP uptake by industry can be assessed. The critical next step however, is to identify all the socio-economic constraints to the adoption of BMPs for landholders, the community and institutions in order to target effective incentives schemes.

Understanding the factors motivating some landholders to adopt BMPs and the perceived barriers to adoption by others provides insight into the influence of attitudes towards the environment in determining the likely success of initiatives and programs. The principles applied by MTSRF researchers may be applied more broadly to improve the effectiveness and efficiency of strategies designed to facilitate the uptake of BMPs (e.g. grazing in the Burdekin region; Bohnet *et al.* 2007). There are several socio-economic factors linked to value systems that consistently differ between landholder types across different agricultural sectors (Emtage *et al.* 2006).

The robustness of social indicators of resilience in predicting the resilience, adaptability and transformability of communities to changes in water quality needs to be tested through a longitudinal study within distinct communities. Further development of a framework for testing and measuring the indicators will provide a useful tool for assisting stakeholder planning processes and contributing to ‘State of the Region’ reporting. Once tested and validated, application of the indicators will enable spatial and temporal assessment of the extent to which adaptive co-management builds community resilience to change. The indicators of social resilience also have broader applicability if used in conjunction with socio-economic and biophysical data, and may be expanded to reflect stewardship effort in areas such as waste management, urban water use and energy efficiency.

Monitoring for social resilience will be challenged by a paucity of data to support such a new concept, with the majority of social statistical data designed for socio-economic (and industry) policy-making, and measures very different concepts to social resilience, or to social sustainability. While some existing data may help describe social resilience, qualitative measures, new surveys, and proxies, are likely to be necessary to effectively monitor and evaluate social resilience (Ross *et al.* 2010).

Further, data is more readily available for understanding the social context in any region, than for monitoring and evaluating responses to particular interventions by managing agencies. National data, such as that derived from the census can be available at fine scales, but is more capable of demonstrating broad social trends than responses to particular management actions. Ultimately the end users of the social resilience research may require two types of information: (1) information capable of showing social context and trends; and (2) information more closely tailored to identifying responses to particular management actions (Ross *et al.* 2010).

Managing for resilience requires an understanding of the current pressures and future threats to the GBR ecosystem, and variables that can be used to measure impacts. Current research has focussed on key water quality parameters and only a single variable for climate change impacts – coral bleaching. This has many ancillary issues that need to be considered for a comprehensive approach to understanding climate change risks and impacts, and future research needs to identify a suite of suitable variables that can measure ecosystem resilience and possible effects on communities at different scales.

7. References

Note: References generated through MTSRF Program research are indicated by an asterisk (*).

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