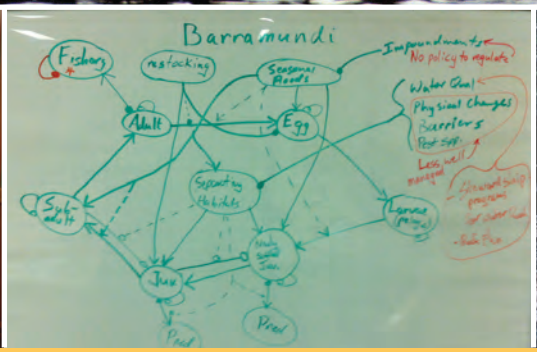
National Environmental Research Program

TROPICAL ECOSYSTEMS hub

Final Report

Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)



Catherine M. Dichmont, Leo X.C. Dutra, Ingrid van Putten, Roy Deng, Randall Owens, Eddie Jebreen, Carolyn Thompson, Ricardo Pascual, Michael Warne, Ross Quinn, Olivier Thébaud, John Bennett, Mark Read, David Wachenfeld, Julia Davies, Anna Garland, Malcolm Dunning, Michelle Waycott , Catherine Collier, Jeffrey M. Dambacher, Julia Playford, Rachel Harm, Neill Gribble and Roland Pitcher

Australian Government
Department of the Environment

Reef & Rainforest RESEARCH CENTRE

Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)

Project Leader: Catherine M. Dichmont

CSIRO: Leo X.C. Dutra, Ingrid van Putten, Roy Deng, Ricardo Pascual, Olivier Thébaud, Jeffrey M. Dambacher, Rachel Harm, Roland Pitcher

GBRMPA: Randall Owens, Carolyn Thompson, Mark Read, David Wachenfeld

Q-DAFF: Eddie Jebreen, Ross Quinn, Malcolm Dunning, Julia Davies, Anna Garland

DSITIA: Michael Warne, Julia Playford

DEHP: John Bennett

James Cook University: Catherine Collier, Neill Gribble

University of Adelaide: Michelle Waycott

Supported by the Australian Government's
National Environmental Research Program

Project 9.2 Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)

National Library of Australia Cataloguing-in-Publication entry:

Title: Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)

ISBN: 978-1-925088-67-0 (online PDF)

This report should be cited as:
Dichmont, C.M., Dutra, L.X.C., van Putten, I., Deng, R.A., Owens, R., Jebreen, E., Thompson, C., Pascual, R., Warne, M.St.J., Quinn, R., Thébaud, O., Bennett, J., Read, M., Wachenfeld, D., Davies, J., Garland, A., Dunning, M., Waycott, M., Collier, C., Dambacher. J., Playford, J., Harm, R., Gribble, N., Pitcher, R. 2014. Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR). Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (284p.).

Published by the Reef and Rainforest Research Centre on behalf of the Australian Government's National Environmental Research Program (NERP) Tropical Ecosystems (TE) Hub.

The Tropical Ecosystems Hub is part of the Australian Government's Commonwealth National Environmental Research Program. The NERP TE Hub is administered in North Queensland by the Reef and Rainforest Research Centre Limited (RRRC). The NERP Tropical Ecosystem Hub addresses issues of concern for the management, conservation and sustainable use of the World Heritage listed Great Barrier Reef (GBR) and its catchments, tropical rainforests including the Wet Tropics World Heritage Area (WTWHA), and the terrestrial and marine assets underpinning resilient communities in the Torres Strait, through the generation and transfer of world-class research and shared knowledge.

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for Sustainability, Environment, Water, Population and Communities.

Cover photographs: Trawler and Jetty: © Department of Agriculture, Fisheries and Forestry; Mackay workshop and Barramundi model: © Cathy Dichmont, CSIRO; Mangroves © CSIRO

This report is available for download from the NERP Tropical Ecosystems Hub website:
http://www.nerptropical.edu.au/research

December 2014

Contents

Figures

Tables

Abbreviations Used in this Report

Abbreviation	Description
DAFF	Queensland Department of Agriculture Forestry and Fisheries
DEHP	Department of Environment and Heritage Protection
DSITIA	Department of Science, Information Technology, Innovation and the Arts
JCU	James Cook University
FIFO	Fly in, fly out
NGO	Non-Governmental Organisation
NRM	Natural Resource Management
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
LMAC	Local Marine Advisory Committee of GBRMPA
LMAC RG or RG	Local Marine Advisory Committee Reference Group
MPA	Marine Protected Area
MSE	Management Strategy Evaluation

1 Non-Technical Summary

Stakeholder engagement is important for successful management, both to make effective decisions and to obtain support. However, in the context of coastal management, questions remain on how to effectively link decisions made in the catchment with objectives for marine biodiversity and fisheries productivity. Moreover, there is much uncertainty on how to best inform and elicit community input in a rigorous manner. A decision support process is described that elicits management objectives, priorities and management options using two case studies. The case studies show that demand for local input and regional management is high, but local conditions influence the relative success. Differences between case study outcomes highlight the importance of discussing objectives prior to suggesting management actions. In that regard, eliciting the broader community's objectives can now be undertaken cost effectively through new survey methods. Governance arrangements can be developed that link managers and community members, but continuity is essential. A big contributor to success is providing local information to the community group and embedding managers and influencers within the group. Of great value to positive outcomes were that the scientists, managers and community members were prepared to work together and offer enormous volunteer time to work towards a common solution.

Two case studies were selected to develop an overall method of using a regional management process with local community groups to develop local management options – Mackay and Bowen-Burdekin. These two case studies were chosen for what they have in common and also what separates them. Both case studies have in common that the rural area is mostly farming for which accelerated management activity has been directed to reduce the amount of sediment and nutrient runoff to the GBR. However, the two regions' ports are distinct in that, during the study period, a major proposed port upgrade with associated dredging in the Abbott Point area (just south of the Burdekin) was a source of conflict in the region and great controversy within Australia. Whereas the Mackay ports were well established and are presently not as controversial. The population size is also very different with Mackay having a far larger urban footprint with a growing city although this may have slowed down in recent years due to the general downturn in mining activity.

A hierarchical system of engagement was attempted in both regions. At the highest level, a community group, the Local Marine Advisory Committee (LMAC) run by GBRMPA was already established in the region. Its charter is to advise GBRMPA on local management issues (http://www.gbrmpa.gov.au/about-us/local-marine-advisory-committees). Since the LMACs met every quarter with a full agenda, a sub-committee was formed and called the LMAC Reference Group (RG). This was made up of LMAC members who volunteered for the group and additional members that would cover a broader skill set from people who were previously on the LMAC. The project lead facilitated the RG meetings, with a member elected as the RG chair.

The project team included "managers" (defined as people that either directly or indirectly influence management decisions) from QDAFF and GBRMPA, and social, economic, mathematical and environmental scientists from both State and Commonwealth agencies.

Within a few months of project engagement in the Bowen-Burdekin area, the Abbott point port expansion and associated dredging controversy meant that participation was minimal. An alternative approach was undertaken, but generally meant

engaging with individuals directly and separately. Interactions between the different RG and LMAC members were minimal. In Mackay, the RG was very successful and was used throughout the process.

At various stages in the process community and senior level managers' input was sought. All documentation was kept in a traceable format, i.e. iterations of all steps could be backtracked through the various meetings to its original source.

A local Mackay GBRMPA person devoted an enormous amount of time on support and engagement in between meetings. This support was essential and provided local continuity.

A sequence of broad steps were undertaken:

1. Qualitative modelling of the Mackay coastal system;
2. A review of existing objectives from government organisations, NGOs and NRM bodies that were directly or indirectly relevant to the region was undertaken (both case studies). These were collated by the RGs into a objective hierarchy – one for each case study;
3. A survey of the RG, LMAC and Mackay public was undertaken to ascertain the relative importance of different objectives. A new method was developed during this process;
4. An issues register, direct and indirect management options, and responsible agencies for each topic relevant to managing the coastal zone fisheries and biodiversity were developed through a series of workshop with experts and RG. These were combined into management strategies and is a separate printed product for use by Mackay residents and NGOs;
5. An impact assessment was undertaken to determine the relative importance of the different management strategies. These were then turned into as series of management-orientated products for use by relevant management agencies.

The project has uncovered a conundrum that does challenge the effectiveness of management because there can be a significant gap between the perception of managers with regards to their actions and outcomes and the perception of the community as to the effectiveness (and wisdom) of the management action(s).

A review of the successes and failures of the two case studies by the project team were undertaken through questionnaires to the Mackay RG and managers.

The final and main product of the project is a semi-quantitative generic elicitation framework that ultimately provides a prioritised list of management options in the context of clearly articulated management objectives that has broader application to coastal communities in Australia and beyond. It comes with detailed instructions, and generic objectives and management strategies.

2 Acknowledgements

This work would not have been possible without the incredible input from the Mackay and Burdekin community. Most notably, those that helped us tirelessly in Mackay as members of the Mackay LMAC Reference group and individuals we interviewed in Burdekin.

We developed a survey in Mackay to gauge residents' opinions of what matters to them with regard to coastal management, and more than 100 completed what was a taxing survey. These respondents also helped recruit other survey participants. Some of the participants attended an in-person sessions held in Mackay and stayed to give us robust advice on the survey design. These comments were instrumental in us developing a new method, which has resulted in a method journal paper on survey techniques. Special mention must be made of Carolyn Thompson, GBRMPA, Mackay – her involvement and tireless work was probably the most significant factor allowing us to get real traction in Mackay.

We thank the reviewers of the report.

This research was funded by the Department of Environment; the Commonwealth Scientific and Industrial Research Organisation; the Queensland State Department of Agriculture Fisheries and Forestry; the Great Barrier Reef Marine Park Authority; the Queensland State Department of Environment, Heritage and Protection; and James Cook University.

3 Introduction

The ecological pressure on the coastal zone has increased with time due to population growth and the social and economic importance of these areas (1). However, successful management of this zone is important as they also contain many iconic and threatened species (such as dugongs, water birds, turtles) and also key habitats (wetlands, seagrass, mangroves). The coastal zone of the Great Barrier Reef in Australia experiences the impacts of cumulative effects, most notably nutrient, sediment and contaminants from rural and urban land sources (2). However, managing cumulative impacts can be seen as a "wicked" problem because interactions within and among the social, economic and ecological systems are highly complex, non-linear and mostly unknown, which has often led to management failure (3, 4). Science is seen as having been developed to solve "tame" problems (4).

Two solutions have been put forward to address this dilemma: (a) Adaptive management, which involves iterative decision making, via evaluating the outcomes from previous decisions and adjusting subsequent actions on the basis of this evaluation (5, 6), and (b) effective stakeholder engagement. If these two are undertaken in combination the processes form essential planks to achieving effective environmental management, being through good information, development of identity, institutions and incentives (7).

In the coastal zone, governance is complex with many organisations and associated institutions designated to manage the system (local, regional and national) and many forms of ownership (government, semi-government, public open access, private). To some the solution is to create boundary organisations either through a non-government organisation (NGO) or develop collaborative efforts between scientists and government organisations. Boundary organisations cross the boundary between science and government as a network by drawing on both sides to facilitate evidence based decisions (8). These organisations attempt to solve problems by meeting three criteria, which are: a) creating opportunities and incentives for boundary products, b) facilitating participation of actors from different sides of the boundary and c) establishing or strengthening links between politics and science (amongst others). Examples of these boundary organisations can be seen in the health sector (9) and waterways (10).

Whether attempting management with or without these boundary organisations, stakeholder or community engagement is seen as crucial to success (11, 12). Similarly the scale of management should include local input into regional management rather than only distant high level and scale management (12). Stakeholder engagement has been successfully applied in many single use applications such as fisheries. Often engagement has been established through technical and management boundary organisation (13) or various forms of devolved management such as through Territorial User Rights (14). However, moving from stakeholder engagement to community engagement has been generally not been undertaken as many scholars have presumed that these users could not self organise nor be representative (15). In this review of "self-organised regimes" their findings supported Ostrom's eight design principles of local stable common pool resource management (15).

The Great Barrier Reef World Heritage Area (GBRWHA) includes the world's largest coral reef system, the Great Barrier Reef (GBR), stretching over 2,300 km of the

coastline of Queensland, Australia. Much of the reef is managed by the Australian Commonwealth's Great Barrier Reef Marine Park Authority (GBRMPA). Although GBRMPA manages the biodiversity assets and most activities therein, fisheries and much of the coastal zone inshore of 3nm are managed by various other agencies such as the Queensland State Department of Agriculture, Forestry and Fisheries (DAFF), and local councils. There is growing interest and success in engaging local coastal communities to achieve reef management goals. NGOs have played a key role through engaging especially with the farm community (http://reefcatchments.com.au/). Although these NGOs are in many aspects boundary organisations, they have until recently only concentrated on a few impacts areas. In the coastal zone of the GBR, the community values the GBR highly (16) and as such there is a great wish to be involved in local management. It is understood that a) it is difficult to regulate all impacts that affect the GBR coast and reef so stakeholder support is essential, and b) given the size of the area and its complexity, it is not possible to have both regional and local knowledge without local input.

In a perfect world this would generate voluntary compliance and regulation. However, the challenge is how to effectively link decisions made in the catchment by multiple management authorities with objectives that determine outcomes for marine biodiversity and fisheries productivity while including community input. In an increasingly connected community in Queensland, social media has become an increasingly useful medium to focus public opinion (for example the 2014 GetUp campaign against a port development – https://www.getup.org.au/campaigns/great-barrier-reef--3/protect-our-reef/protect-our-reef). However, these are seen as not engaging science, management and community in a non adversarial long-term framework as described in Cox, Arnold and Tomás (15). There are several case studies and suggestions of what constitutes successful engagement. A successful case study was Arsland and Cahantimur (2011) in Turkey which was based on the idea that community intelligence could be influential to the decision making process, but demonstrated that there are practical considerations with the continued community engagement including scheduling and other time commitments. Many emphasise the importance of gaining trust and respect (17), and models of engagement (18) and moving beyond simple models of linked socio-ecological systems and the perception that most resource users are the same (the "panacea") (19).

This project was primarily aimed at biodiversity outcomes, focusing on inshore multi-species fisheries management. Two case studies (Mackay and Bowen-Burdekin) were used to test and further develop a semi-quantitative management strategy framework. For Mackay, where the full process was completed, a prioritised management strategy was developed for management impact.

4 Background

Management Strategy Evaluation (MSE) is an approach to informing stakeholders of the likely consequences, costs and benefits of choosing particular management decisions (across all uses) on ecosystems such as the Great Barrier Reef. It uses an iterative procedure to assist stakeholders in formulating objectives and assessing trade-offs between social, economic and ecological outcomes. MSE serves as a filter to identify which policies and methods have the potential to meet stated objectives, and to answer critical questions, such as how fast we have to adapt, how much we need to understand and what do we need to learn.

The MSE approach involves developing models (whether expert driven or process based) using the best available knowledge to capture the key attributes of each significant component of the management problem. This includes processes underlying the evolution of biophysical systems, human uses of ecosystems and their socio-economic drivers, and the three major components of an adaptive management strategy – monitoring, assessment and management decision processes. The approach is based on a framework that integrates all these components into a single, interacting simulation environment.

CSIRO has pioneered coastal MSE, which has now been applied in four regions including tropical systems like the Ningaloo reef (20, 21) and south-east Queensland(22, 23) (where they considered cumulative impacts and catchment management) and within the GBR itself(24) (where previous work has taken a fisheries-oriented focus). The range of coastal MSE applications work has called on a variety of approaches including qualitative models of system function and statistical emulators., These can be used in an interactive setting with stakeholders to elicit the broad strategic insights that can be derived from the integration of knowledge in an MSE framework. At the other extreme, whole-of-system models (i.e. detailed process models) have also been used; these provide the ability to explore specific strategies at varying levels of detail under a wide range of scenarios, but with longer development and run time.

Based on this breadth of experience, a staged approach to the MSE was proposed. It involved an initial scoping phase that consisting of a) scoping of the project, b) data and information gathering, c) stakeholder elicitation of objectives and d) understanding key processes. The second phase centred on the elicitation and assessment of management strategies using a qualitative MSE in the GBR region. This consisted of a) developing management strategies, b) assessing the relative impact of the management strategies against the objectives and c) determining the steps required for implementation. The form of the MSE in Phase 2 will be dictated by what is uncovered during Phase 1, but the MSE will not be quantitative (given the resources available and end user priorities), but will rather focus on a qualitative modelling approach.

It was essential that the management strategy evaluation framework and identification of management strategies be developed in a collaborative and

interactive environment with managers and others stakeholders. A tiered approach of establishing a joint stakeholder-researcher group, which will iteratively develop strategies and examine results, was proposed. Key stakeholders (e.g. GBRMPA, DAFF, DSITIA and DEHP) were part of the research project and members of a project steering committee. Both these processes ensured that the MSE framework and management strategies developed are relevant and embedded within the management system.

5 Overview of Methods

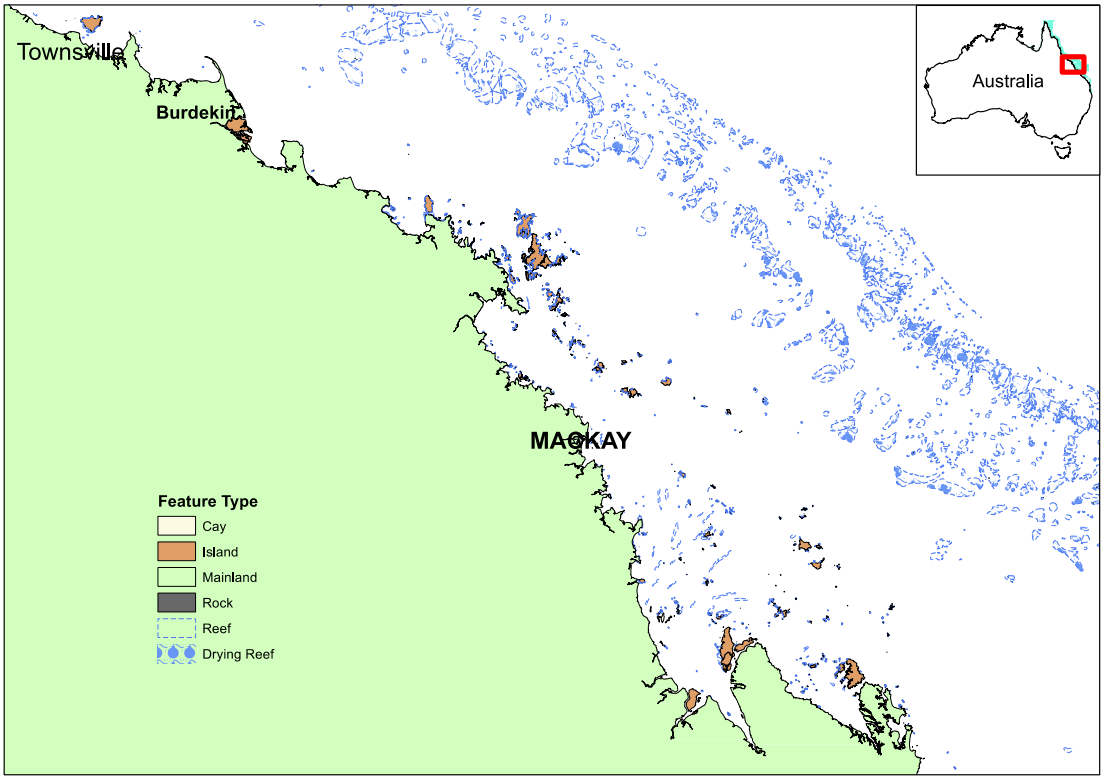


Figure 1. Map showing the area of the two case studies south of Townsville and the Mackay surrounds.

5.1 Case studies - description

Two coastal regions within the GBRWHA area were chosen as case studies (Figure 1).

Mackay was chosen as it represented a growing city of about 167,000 people (25) and a large associated Fly in and Fly out (FIFO) community due to the local mining industry. It also has an active port, Hay Point, just south of Mackay with the main export being coal. Another major economic driver and employer in the region is sugar cane, where the cane is locally grown and refined into sugar. In terms of natural assets it has a national park, many beaches, offshore islands, inshore and offshore reefs that are part of the Great Barrier Reef. The environment is tropical with the marine environment characterised by very large tidal ranges, key habitats such as mangroves and seagrass, and threatened, endangered and protected (TEP) species groups such as dugongs, turtles and inshore dolphins.

The Bowen-Burdekin Shire has a population of about 26,000 people (25) and is approximately 60 km south of a major city Townsville (and north of Mackay) with Ayr and Home Hill as its main towns. It is a region characterised as being mainly rural with sugar cane farming as the major source of economic development and employment.

These two case studies were chosen for what they have in common and also what separates them. Both case studies have in common that the rural area is mostly farming for which accelerated management activity has been directed to reduce the amount of sediment and nutrient runoff to the GBR. However, the two regions' ports are distinct in that, during the study period, a major proposed port upgrade with associated dredging in the Abbott Point area (just south of the Burdekin), which was a source of conflict in the region and created great controversy within Australia. Whereas the Mackay ports were well established and are presently not as controversial as the Abbott Point development. The population size is also very different with Mackay having a far larger urban footprint with a growing city although this may have slowed down in recent years due to the general downturn in mining activity.

5.2 Framework of steps

The process was to use a local community group to elicit a series of information and inter-active engagement. The steps were:

1. Select a community group;
2. Undertake qualitative models of environmental coastal key assets of the region;
3. Elicit coastal management objectives;
4. Weight these objectives relative to each other;
5. Develop management "strategies";
6. Undertake a relative impact assessment of each strategy; and
7. Develop management implications for hand-over to various managers (Figure 2).

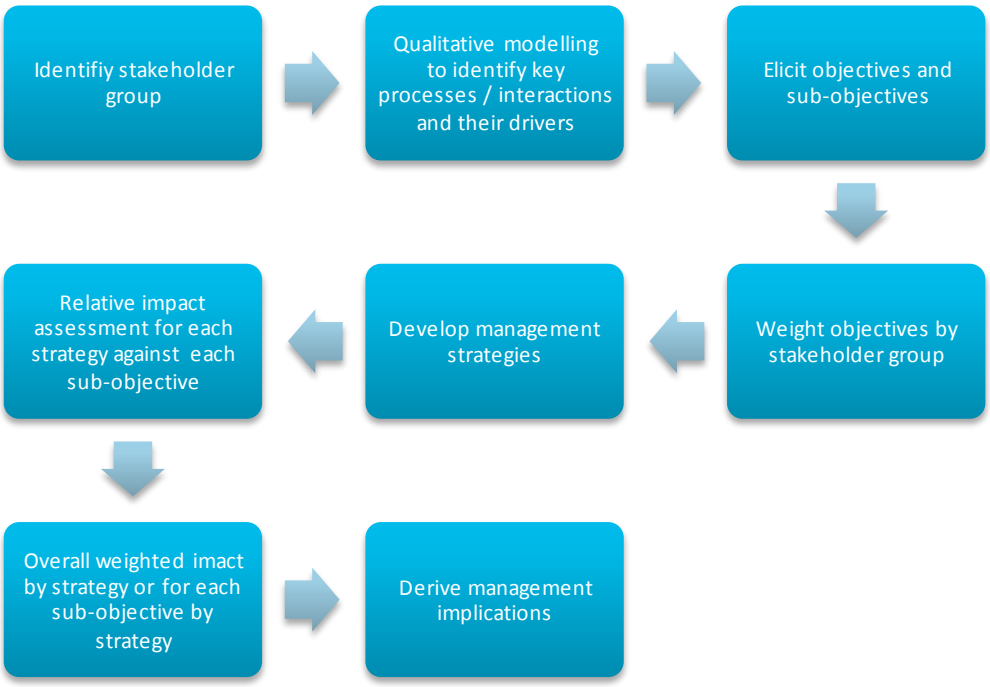


Figure 2. Overview of the full method applied to the Mackay case study. Only stages one to three were undertaken in the Burdekin case study.

6 Selecting a local community group

An existing group for each region was selected, but needed to fall into one of the following categories:

- Volunteers
- Membership not necessarily representation of the region
- A small scale Non-government organisation (NGO)
- Membership selected through an advertised selection process
- Some regional status
- Membership of locals (except for State and Federal agency members)

For ease and representativeness, the same type of community group was selected in each region – the Local Marine Advisory Committee (LMAC) (http://www.gbrmpa.gov.au/about-us/local-marine-advisory-committees) – that covered the case study regions. The Mackay LMAC boundaries (Midge Point in the north to Broadsound in the south) were used as the boundary for the Mackay case study. Since the (then) newly formed Bowen/Burdekin LMAC covered both the Burdekin and Bowen shires (Haughton River in the north to Yeates Creek in the south and includes Giru, Ayr and Bowen communities) these were ultimately used as the Burdekin-Bowen case study boundaries. The coast was defined as being the tidal region to 12 nm offshore. The membership of these two committees consisted of a GBRMPA representative, a local councillor, members of the community (including the local indigenous group) and major stakeholders such as the Port. Since this community group only met every three months with a full agenda, they were approached to create a volunteer group called the LMAC Reference Group (RG) to meet on a more regular basis and provide in-depth input. Given that not all members of the LMAC volunteered for this group, its membership was bolstered by names provided by the LMAC who subsequently volunteered for RG membership through a GBRMPA staff member directly requesting this person's attendance.

The engagement process was mostly with the LMAC RG, with updates and occasional input or endorsement of a finalised product from the LMAC (Figure 3). The project team only occasionally interacted with the general public and, when they did, it was undertaken as a joint venture between the LMAC and the community. This public engagement was particularly intensive during the objective weighting stage.

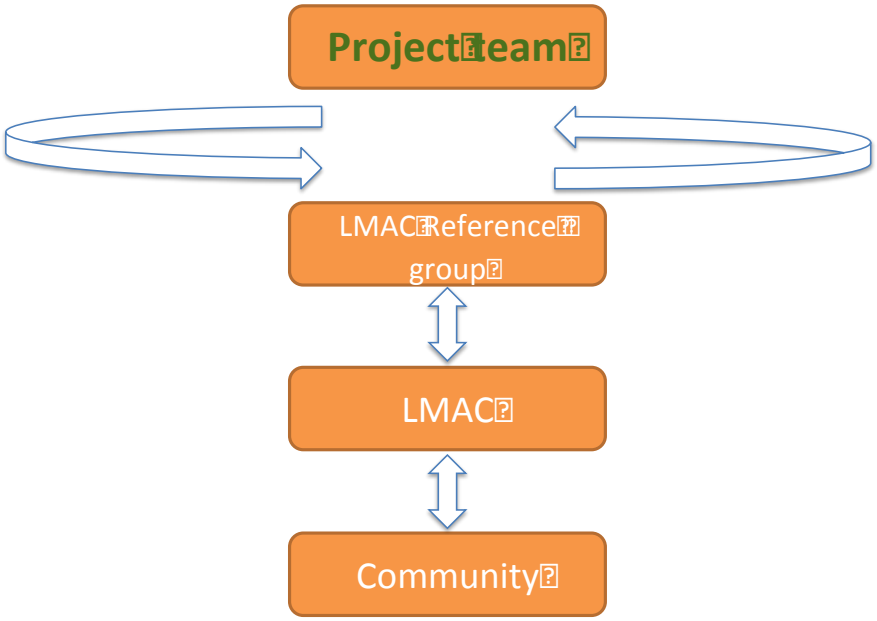


Figure 3. Community engagement process used in Mackay and attempted in Burdekin.

In Mackay this group met more than 15 times over a period of 2 years and was a very successful and active volunteer group. However, this process was not successful in Burdekin. Although the RG was formed and used for the qualitative modelling process, attendance was low. Several presentations to the LMAC did not bolster this group and as such it was disbanded. The reasons for this are several fold, but most notably that a previous project developing local fisheries options in the area had created wide spread animosity and conflict, and as such, LMAC members – some of whom were part of this previous process – were unwilling to undertake a similar process. Also, a major proposed port upgrade with associated dredging in the Abbott Point area (just south of the Burdekin) was a source of conflict in the region and great controversy within Australia.

As a result, only the first three stages of the process (Figure 2) were successfully undertaken in the Burdekin, whereas it was completed in Mackay.

7 Elicitation of objectives and their relative importance

Defining goals and objectives is a critical component of what constitutes adaptive natural resources management because they provide the basis on which management strategies can be designed and evaluated. In this study the aim is: (i) to apply and test a collaborative method to elicit inshore fisheries and biodiversity management objectives for the coastal zone in the Great Barrier Reef, Australia; (ii) to understand the relative importance of management objectives for different community members and stakeholders (iii) to understand how the diverse perceptions about the importance of management objectives can be used to support multiple-use management in Australia's iconic Great Barrier Reef. Management goals and objectives were elicited and weighed using the following steps: (i) literature review of management objectives, (ii) development of a hierarchy tree of objectives, and (iii) ranking of management objectives using surveys methods. The overarching goals developed by the community group were: (1) Protect and restore inshore environmental assets; (2) Improve governance systems; and (3) Improve regional (socio-economic) well-being. Interestingly, these goals differ slightly from the usual triple-bottom line objectives (environmental, social and economic) often found in the literature. The objectives were ranked using an Analytical Hierarchical Process, where a total of 141 respondents from Queensland undertook the survey. The environment goal received the highest scores, followed by governance and lastly well-being. Our results indicate that in terms of management goals and objectives for the Great Barrier Reef coastal zone, stakeholder perceptions converge and there is strong agreement on what they value as important. Industry, non-governmental- and governmental organisations have their own goals and objectives for the coastal zone, but they must consider community and stakeholder pressures. Converging stakeholder perceptions provides strong opportunities to facilitate strategic alliances and achieve mutually beneficial goals and objectives. However, there needs to be strong leadership to coordinate negotiations and engagement within and between stakeholders. The approach to elicit and rank goals and objectives, as developed in this study, can certainly be used to effectively support coastal resource use management by providing an avenue for local communities to provide input and feedback on stated objectives, and the way in which objectives can be achieved.

7.1 Introduction

Clearly defining and prioritizing management objectives is a critical part of what constitutes adaptive natural resources management (NRM) because it helps managers and stakeholders evaluate the effectiveness of management interventions and identify data and information gaps (26, 27). Establishing and prioritizing management objectives is difficult as it may involve intense stakeholder negotiations (28) to make the inevitable trade-offs required to manage natural

resources (29, 30). To complicate matters, objectives are sometimes implicit rather than explicit in management procedures, or they are not well articulated (31, 32). As a result, conflicts between stakeholders can (and do often) occur (26, 33). Conflicts and challenging negotiation processes happen because individuals and groups rate environmental, social, economic and cultural objectives differently based on their values and assumptions about the current state of the resource and their expectations for its future state (34, 35). For example, when managing an ecological system, the objectives of industry, community, conservation, or political groups are often different (36). As a result, the process of defining and prioritizing management objectives to support decision-making and policy implementation is strongly influenced by power groups and leaders, especially in multiple-use areas, such as the coastal zone (36).

Defining and prioritising management objectives for NRM is therefore essential for a broad vision to develop on how natural resources should be used and managed. Targets, which are explicit or implicit in management objectives, are necessary to evaluate progress and management strategy effectiveness. Measurable targets also provide a clear purpose for decisions, providing accountability and defensibility for the decisions made (37). A process to clearly define and prioritise management objectives therefore supports NRM because it facilitates negotiation process between managers and stakeholders to take place and thus increase the appreciation of the trade-offs involved with decisions (37, 38), thus overcoming some of the difficulties involved in NRM.

In this section we describe the outcomes of a project where the authors worked with a community group, coastal managers and the general public from Mackay (Great Barrier Reef, Australia) to elicit and prioritise management objectives related to inshore fisheries and biodiversity in the coastal zone. The aims of the research were: (i) to apply and test a collaborative method to elicit management objectives from a community group, (ii) to understand the relative importance of management objectives to different stakeholders, and (iii) to understand how the diverse perceptions about the importance of management objectives can be used to support multiple-use management in Australia's iconic Great Barrier Reef.

7.2 Methods

The whole process of objective elicitation and obtaining their relative importance took place through a series of steps:

- undertaking a literature review;
- refining these by combining, adding and deleting to a more manageable amount;
- turning the final list into a hierarchical tree;
- using a hierarchical decision analysis process to elicit relative importance of the objectives in the hierarchy, and

- analysis of these results to provide an importance score to each of the objectives.

The process described above was the same in both case studies, but the elicitation process was very different. In Mackay, the RG and LMAC was used to develop objectives and a hierarchy from the review of objectives, but in the Burdekin this was obtained through direct and interactive contact with individuals or small groups.

The data gathering stage followed in the two case study areas (i to iv) and the role of setting objectives in the overall MSE process (1 to 7) is outlined in Table 1.

Table 1: Relationship between the stages of the overall project for Mackay and the Bowen-Burdekin.

	Overall project steps (Dichmont et al in prep)		**Steps of this current project in Mackay**	**Steps of this current project in Bowen-Burdekin**
1	Select a community group (see Section 6)		Local Marine Advisory Committee LMAC sub-committee and LMAC	LMAC members
2	Undertake qualitative models of environmental coastal key assets of the region (see Section 8)		Qualitative models were developed for three meetings with the RG	Qualitative models were developed for two meetings with the RG (similar to Mackay), but very low attendance so this was stopped and sub-group disbanded
3	Elicit coastal management objectives (see Section 7)	(i)	Literature review of existing objectives for the region and higher level objectives for fisheries and natural resources	Literature review of existing objectives for the region and higher level objectives for fisheries and natural resources
		(ii)	Existing objectives not categorised but provided as a list	Existing objectives categorised according to level (high, med, low)
		(iii)	Objectives list from the literature provided at the workshop/meeting for sub-committee members' consideration and discussion	Provision of list of medium level objectives prior to the interview
		(iv)	Sub-group meeting to determine abbreviated list of critical objectives Sub-committee member awareness and knowledge of each other's responses.	One to one or small group interviews to determine list of objectives Anonymity of responses between respondents
		(v)	Agreement on the set, summarising and rewording of objectives by the stakeholder group at a meeting	Email confirmation and comment on wording and summarising of objectives from stakeholders
		(vi)	Hierarchical tree developed at the workshop /meeting by the stakeholder group. Categorisation and grouping of objectives flowed from the stakeholder group discussion. Final support (after small edits) by the LMAC.	Researchers to reword and summarise list of objectives into Hierarchical tree with predefined groups of objectives (environmental, socio-economic, and governance)
4	Weight objectives relative to each other (see Section 7)		Objectives weighted by LMAC and sub-group.	Tentatively planned *(weighing of objectives can be implemented at LMAC session if members choose to do so)*
			Weighing of objectives by public via survey form and	Not planned at this stage *(weighing of objectives by*

	Overall project steps (Dichmont et al in prep)	Steps of this current project in Mackay	Steps of this current project in Bowen-Burdekin
		open evening survey sessions	*public may be implemented if LMAC or other local organisation choose to do so)*
5	Develop management "strategies" (see Section 10)	Management actions developed by stakeholders after weighing of objectives.	Presently little LMAC support for this process
6	Undertake a relative impact assessment of each strategy (see Section 10)	Impact assessment of management actions by stakeholders and relevant managers.	N/A
7	Develop management implications for hand-over to various managers (see Section 10	Individually with managers and in written form to management agencies.	N/A

7.2.1 MACKAY

Objectives review

An extensive review of existing stated objectives in the grey and published literature, and web sites of organisations and institutions relevant to Mackay was undertaken. Existing stated objectives were categorised as social, economic and sustainability objectives. The literature searched included local councils (e.g. the Mackay City Council), local coastal organisations (e.g. Queensland Bulk Ports), local NGOs (e.g. Reef Catchments), State Government organisations and their relevant legislations (e.g. the Environment, Protection and Biodiversity Act of the Department of Environment that relates to species such as turtles and dugongs) and Federal Government organisations and their relevant legislations (e.g. the Environment, Protection and Biodiversity Act of the Department of Environment, formerly DSWEWPAC, that relates to species such as turtles and dugongs). The literature search involved: (1) a web search for documents from government, NGOs, industry and community organisations using key words such as "management objectives Mackay", "Fisheries objectives Mackay", and "biodiversity objectives Mackay", and (2) a review of academic peer-reviewed literature, which included previous reviews such as fisheries management objectives for the QLD state (34) and conservation objectives (37, 38).

On the 5th of December 2012, the project team presented and discussed the initial list of social, economic and environmental management objectives for the Mackay inshore region sourced from the literature with the Mackay LMAC RG. A draft document containing the overall objectives found in the literature was circulated to participants prior to the meeting. During the meeting the original list of objectives from the literature was discussed and modified with the group. Participants also had the opportunity to send their personal notes and comments to the project team after the meeting.

In January 2013 the project team prepared an updated list of objectives following the RG inputs. The process of preparing the document included refining the initial list of objectives via aggregation, addition, exclusion and re-wording of the original objectives. In the process RG members were aware of each other's responses and how the changes were considered in the updated list of objectives. The list was then used to develop an objective tree.

Objective tree

The initial list of objectives were categorised into three hierarchies, following the definitions from West (39): Goals (or high-level objectives, defined as the broad, high-level, final state being reached), sub-goals (Mid-Level, or intermediate state to be reached), and objectives (low-level or specific and shorter term state to be reached, which provides a clear purpose for decisions (37)). An initial hierarchy of management objectives for Mackay was drafted and circulated to the RG for additional discussions during a half-day workshop held on the 1st of March 2013. A revised (2nd draft) objective hierarchy was constructed based on inputs from participants during the March workshop and also from the Mackay LMAC on a separate meeting also held in March. The second draft of the objective tree was used in two workshops on the 15th and 19th of April 2013 with Brisbane-based project members and the Mackay LMAC RG, respectively, to start addressing the question of weights to be attributed to the different objectives, using the Analytic Hierarchy Process (details below).

In essence, the process of developing the objective tree included the provision to the RG of the list of objectives, which were narrowed down and refined into a more concise set by the project team and RG. This objective list was also iteratively modified and refined during the process – starting with developing the goals and then creating the sub-goals and objectives with the final or near final objective list. Although there were some goals, sub-goals and objectives that fell into a fourth level, this level was later removed as the three levels were seen as sufficient and the fourth level as both incomplete and too detailed. Since the weighting process used a method that considers pairwise comparison, a maximum of three branches were allowed for any one goal, and sub-goal.

Relative importance of goals, sub-goals and objectives

Relative weights for goals, sub-goals and objectives were obtained using two decision analysis methods based on the same mathematical principles, and three survey elicitation methods. The first was the Analytical Hierarchical Process (AHP) (34, 40) that was obtained using an Excel set of worksheets with Visual Basic add-ins to undertake the Saaty analysis for consistency (34). A maximum of ten per cent inconsistency was allowed before the comparison was deemed unusable and the respondent was asked to modify their selection. AHP is based upon the construction of a series of pairwise comparison matrices, which compare goals, sub-goals and objectives to one another. One of the advantages of the pairwise comparison method is that it makes the process of assigning weights cognitively easier because only two elements are compared at any one time instead of all objectives being compared to each other simultaneously.

Three special sessions were organised for respondents to complete the AHP surveys. The first was held in Brisbane on the 15th of April 2013 with resource managers who were part of the project. A second session was held with the RG in Mackay on the 19th of April 2013. The third AHP survey was held in the Mercy College (Mackay) from

July 8-12 2013 for inputs from the general public. In all sessions computers were set up with the AHP excel program and after an introduction about the project by the Project Team, respondents were asked to complete the survey. The surveys for the general public were advertised through paid newspaper advertisements, three separate radio interviews, paid Facebook advertisement, and the project website (http://www.csiro.au/gbr-mse). The project team and RG also used their own networks to recruit potential respondents.

Respondent feedback alerted the project team to the fact that respondents felt that the consistency tests required as part of the AHP method was manipulating them into providing a result by design and was not accepting their own actual score. The Excel survey was also perceived as tedious and long-winded. As a result the project team developed a second, mathematically identical but cognitively easier method, which uses a combination of the Point Allocation (PA) method (41) and AHP – hereafter called the Hierarchical Point Allocation method (HPA). In the HPA method applied by the research team respondents were asked to allocate 100 points to each combination of the goals, sub-goals, objectives (as one does with the AHP).

The project team quickly implemented the paper version in an online survey (SurveyMonkey™). Community respondents who attended public session at Mercy College had the option of choosing between the AHP Excel program, a paper version of the HPA, or the online HPA survey. After the public session at the Mercy College the online HPA survey was advertised more broadly and made available to the larger Queensland community from 8 to 10 July 2013. The project team developed a second online survey that was visually more appealing and more closely resembled the paper version (the SurveyMonkey™ survey was also retained as it was already previously advertised). The link to the Survey was available on the project website (address to the survey is: http://seek.hosting.exacttarget.com/EventManagement/EventPage.aspx?ispbk=clear&SUBID=-1&JOBID=18905231&MID=84905).

Data analyses were undertaken in R (R Development Core Team 2007) and the default settings are used to present the results in box and whisker plots. This means that the box shows the median (second quarter: Q2) and the first and third Quartile (Q1 and Q3). The upper whisker is the $\min\left[\max(x); Q3 + 1.5(Q3 - Q1)\right]$ of the data vector x and the lower whisker is $\max\left[\min(x); Q1 - 1.5(Q3 - Q1)\right]$. Any values outside these whiskers are shown as outliers.

Defining stakeholder groups

Additional information was obtained from surveys participants in terms of the stakeholder group they identified with. Stakeholder groups fitted into four broad categories: a) 'residents', b) 'resource users', which includes fishers, mining, farmers, c) 'government', including Local, State and Commonwealth, and also GBRMPA as an organisation representing government, and d) 'other', which includes scientists, conservation organisations, and students (Table 2). The survey also asked respondent to identify their place of residence (Table 3).

Table 2. Stakeholders and stakeholder groups.

Stakeholder	Stakeholder group
Aboriginal and Torres Strait Islander	Others
Charter Fishing	Resource users

Commercial Fishing	Resource users
Commercial seafood processing	Resource users
Conservation Organisation	Others
Diving	Resource users
Farmer	Resource users
Fisheries Compliance	Government
Fisheries Management	Government
Grazier	Resource users
Great Barrier Reef Marine Park Authority	Government
Local Government Councillors	Government
Local Resident	Resident
Marine Services Industry	Resource users
Mining	Resource users
NRM Group	Others
Other	Others
Port Authority	Resource users
Queensland Parks and Wildlife Service	Government
Recreational Fishing	Resource users
Scientists	Others
State Government	Government
Student - High School	Others
Student - Tertiary	Others
Tackleshops or RSI	Resource users
Tourism	Resource users

Table 3. Respondents' by regions.

Regions	
Caloundra to the NSW Border	South of Cairns to Bowen
Other	South of Double Island Point to Caloundra
Repulse Bay to Clairview (Mackay)	South of Yeppoon to Baffle Creek
South of Baffle Creek to Double Island Point	Torres Strait to Cairns
South of Bowen to Repulse Bay	

7.2.2 BOWEN-BURDEKIN

Objectives review and objective tree

As per Mackay, the project undertook a web and literature review of all available documents at the regional, State and Federal government levels along with the NGOs and relevant private sector bodies. Two initial, but unsuccessful, workshops to develop objectives were held in the Bowen-Burdekin before the reference-group was subsequently disbanded. Instead three separate visits were made to the Bowen-Burdekin region for the purpose of gathering stakeholder perceptions of objectives

using one-on-one or small group semi-structured interviews (during October and November 2013).

As opposed to Mackay where the Mackay LMAC RG was used to collate these into a smaller set of objectives, this was done through a series of individual or small group meetings with people from the LMAC or nominated by the LMAC as willing to help in this process (but not able or willing to contribute through a series of joint workshops). A total of 15 people were interviewed in the Bowen-Burdekin using a semi-structured method addressing five broad questions:

According to you:

1 What are the main objectives (reasons) for managing inshore natural resources in the Bowen-Burdekin area?

On the basis of this existing information (presenting a list of objectives):

2 Are any objectives missing?
3 Are any objectives irrelevant?
4 Do any objectives need rewording?
5 Can any objectives be combined with others?

The duration of the interviews ranged from one to two hours. Even though the number of interviewees was relatively small some additional interviewees would have been beneficial. A wide stakeholder group was represented with a different area of expertise or interest (including recreational-, commercial-, charter fishers, port authority, farmers, municipal representatives, environmental groups, and NRM groups).

Prior to the undertaking of the interviews in the Bowen-Burdekin, the researchers communicated with respondents via email or phone about the aim of the project and the interview format. The objectives that were made available to the respondents prior to the interview were pre-defined into three categories (environmental, socio-economic, and governance). These categories were based on the experience in the other case study location (Mackay) and they are also the most common categories found in the literature (Pascoe et al 2013). In most cases, additional information was communicated at the time of the interview and at the request of the interviewee. The interviews were administered in the interviewee's location of choice.

After the interviews, the respondent's objectives information was transcribed by the researchers. The objectives were collated into a document or an email and, so as to gain confirmation the objectives had been accurately transcribed by the researchers, each respondent was given the opportunity to check and change their objectives.

A complete list containing all objectives obtained from the interviews was subsequently compiled by the researchers. This combined list that linked objectives to respondents were not seen by anyone other than the project team. This was to ensure confidentiality of respondents. However, both the complete list of environmental – socio-economic, and governance objectives (from which the respondent IDs were removed) and the 3-level hierarchical objectives tree (in which the objectives were summarised) were emailed to the respondents for further consideration and confirmation.

7.3 Results

7.3.1 MACKAY

Overview

The process of objective elicitation can be reviewed using Table 4 to Table 10, and the list of references therein. The first three of these tables are the initial literature review divided into three broad categories (these are the key tables that show the original list of objectives and their sources without any modification and can be used by others if required); whereas Table 7 is the initial attempt by the RG to collate, delete, rephrase or add any of these objectives. Here they were placed in a long list to not lead the RG with respect to the choice of the top objectives. The hierarchy development starts with Table 8, which is the first attempt at producing the hierarchy – this was also the first attempt at dividing the objectives into three high level objectives. Several iterations took place with the RG and the LMAC, with the final (and third iteration) producing the final hierarchy – Table 10. The hierarchies were always shown as a tree (Figure 4 and Figure 6) and a table. The latter figure also represents the final tree for Mackay. It is important to note that the wording, structure and final tree (structure and wording) were very much a product of the RG and LMAC, with the project team only acting as facilitators.

Objectives review

An extensive review of grey and published literature, and web sites of organisations and institutions relevant to Mackay was undertaken and divided into social (Table 4), economic (Table 5) and sustainability (Table 6) objectives. These included local councils (e.g. the Mackay City Council), local coastal organisations (e.g. Queensland Bulk Ports), local NGOs (e.g. Reef Catchments that works with the local community to improve the condition of natural resources), State Government organisations and their relevant legislations (e.g. the Environment, Protection and Biodiversity Act of the Department of Environment that relates to species such as turtles and dugongs) and Federal Government organisations and their relevant legislations (e.g. the Environment, Protection and Biodiversity Act of the Department of Environment, formerly DSWEWPAC, that relates to species such as turtles and dugongs). The full list was provided to the LMAC RG and these were refined through a combination of LMAC RG meetings and project team input based on this advice (Table 7).

Table 4: Social objectives relating to natural resource management from the literature (ref (42) is a review which contains the original sources).

Objective	Possible Indicator	Sector and references
1. Maintain (or maximise)	• Number of people employed in the sector	NRM in general, agriculture, mining and fisheries (42)

	employment	• Seasonal versus full time employment	Agriculture (42)
		• Employee satisfaction	Mining (42)
		• Proportion skilled/unskilled labour	Agriculture (42)
		• Number of boats	Fisheries (42)
		• Security of employment	Fisheries (42)
2.	Maintain communities	• Proportion of income derived from the sector	Fisheries (42)
		• Proportion of regional employment in the sector	Fisheries and forestry (42)
		• Community involvement in management	Fisheries and forestry (42)
		• Indirect economic impacts (on local economy)	Forestry and recreational fishing (42)
		• Number of small vessels (symbiotic relationship between small vessels and the community)	Fisheries (42)
		• Not specified	Agriculture, mining, fisheries (42)
		• Profitability of the sector/ viability of the fishing enterprise (necessary for strong local communities)	Fisheries (42)
		• Index of activity (catch) flowing through port	Fisheries (42)
		• Tourism links to fisheries	Fisheries (42)
		• Community participation on NRM activities (e.g. water quality sampling programs)	NRM Group (42)
3.	Maintain social capital	• Level/intensity of social networks	Forestry and agriculture (42)
		• Social networks (bonding, bridging and linking)	Fisheries and aquaculture (42)
		• Education level (stock of social capital)	Fisheries (42)
		• None given/ not specific	Fisheries (42)
4.	Maintain (or enhance) family income/ livelihoods	• Family income	Forestry, agriculture, fisheries (42)
		• Resource dependency (share of income from resource)	Fisheries (42)
		• Security of fishing rights (could also be a sub-objective)	Fisheries (42)
5.	Equity	• equal distribution of income	Fisheries (42)
		• equitable allocation	Fisheries (42)
		• perception of equitable allocation/access to the resource	Fisheries and forestry (42)
		• changes in access to fishing areas	Fisheries (42)
		• not specific	Fisheries (42)
6.	Ensure health and safety	• Safety at sea	Fisheries (42)
		• Community Safety	Local Government (43, 44)
		• Ensure safe working conditions	Aquaculture and forestry (42)

	• Quantity / supply of drinking water • Nutrient (TN, TP) • DO concentrations • Turbidity • Algal status (Chl-a) • Bacteriological quality • Litter / debris • Oil and Grease • Coarse sediment • Planning documents for sewerage and STP upgrades • Development of sewerage and water pricing models to support budget decisions.	Local Government (43, 44)
7. Conserve traditional activities, culture and products	• Not specified	Agriculture, NRM in general and fisheries (42)
	• Importance of fishing to fishers (survey) (attachment to lifestyle)	Fisheries, aquaculture, recreational fishing (42)
	• Relationship between natural resource (e.g. forest) and local human cultures is acknowledged as important	Forestry (42)
8. Maintain/improve recreational access to natural resource	• Recreational catch rates • Charter boat catch rates • Probability of catching "big" fish • Recreational access (forestry)	NRM in general, Fisheries, Forestry (42)
9. Maintain/enhance resilience	• Links to maintaining social capital	Fisheries (42)
	• Perception of risk, ability to plan, ability to cope, level of interest (links to maintaining communities)	Fisheries and aquaculture (42)
	• Resilience scoring (fishers' resilience)	Fisheries (42)
10. Enhance quality of life	• Not specified	Mining (42)
	• indicators of quality of life: overall satisfaction, satisfaction with their employment, satisfaction with their fishing activities (catches), satisfaction with access arrangements, physical and mental health, measures of social capital that reflect community life	Fisheries (42)
11. Avoid social exclusion	• Public perception of the industry	Fisheries (42)
12. Minimise conflicts between alternative users • Gear conflicts • Interacting fisheries • Recreational / commercial	• Number of conflicts • [Foresters] and local users of the resource	Fisheries (42) Recreational fishing (42) Forestry (42)
13. Food supply	• Quantity and quality supplied to the market • Diversity of landed catch	Fisheries (42) Agriculture (45)
14. Management stability	Number of management changes per year	Fisheries (42)

15. Management acceptability	• Participation in management process • Level of awareness • Number of fishers in an organisation • Accepted by all stakeholders	Fisheries and Forestry (42)
16. Ease of management implementation	• Existence of comprehensive laws and regulations • Frequency of information dissemination • Financial support for enforcement • Performance of enforcers	Fisheries and Forestry (42)
17. Social profile baseline information has been established (Links to vulnerability and community resilience)	education level; years participating in fishing; generations of family involved in fishing; fishing methods/licences held/equipment; length of residence in current hometown; household spending profile; ethnic characteristics; number participating in relevant fishing sector; number of people dependent on those employed or participating; median age; gender; income.	Fisheries and Forestry (42)
18. Facilitate social cohesion and awareness through active engagement	• Community participation on NRM activities (e.g. water quality sampling programs)	Mackay Whitsundays NRM Group (46)
19. Conserve cultural and indigenous heritage		Ports (47)
20. Build community capacity to address development challenges and take advantage of emerging opportunities.		Mining (48)
21. Promote social well-being		Community Organisation (49)
Traditional/indigenous fisheries		
1. Conserve traditional activities and products	• Proportion of diet acquired from "wild" foods	Forestry (42)
2. Maintain social capital	• Level of involvement with decision making	Forestry (42)
	• Level of interaction with industry	Aquaculture (42)
	• Long term rights for indigenous use	Aquaculture (42)
3. Development/ provision of alternative livelihoods	• Level of financial support for additional livelihoods • Success of additional livelihood implementation • Inclusion of women in the management process	Fisheries (42)

4. Assist the Trustees' vision and objective for the local Aboriginal people over the next 20 years through: • **Capacity building** • **Education and training** • **Cultural** • **Governance**		Mining (48)

Table 5. Economic objectives from the literature.

Objective	Possible Indicator	Sector and references
1. Improve the region's standard of living	Family income	Local Government (43)
2. Maintain and/or improve the community's lifestyle	House affordability Median Size of new residential lots	Local Government (43, 50)
	Fair prices to consumers and producers	Agriculture (45)
3. Improve the flow of resources, human and financial, into and within the Mackay region to the advantage of the community as a whole		Local Government (43) Agriculture (45)
4. Diversify the regional economy (produce enough to expand the volume of exports)		Local Government (43) Agriculture (45)
5. Promote a strong, competitive and diverse economy throughout the region by supporting and investing in sustainable business development and local employment opportunities.		Local Government (50)
6. Provide assistance to industries to enable them to adjust to a changed market situation		Agriculture (45)
7. Maximise economic profits for fisheries as a whole	• Economic profits in the fishery • Return on investment • Secure levels of living of farmers	Fisheries (51) Agriculture (45)
8. Maximise economic profits	• Economic profits in the different fleet segments (objective and weightings differentiated by fleet segment)	Fisheries (42)
	• Household income	Agriculture (45)

Objective	Possible Indicator	Sector and references
	• Supply and demand of production	Agriculture (45)
9. Ensure vessels are economically sustainable	• Positive vessel profits • Gross revenues from fishing	Fisheries (42)
10. Maximise economic performance of supporting sectors (included as a social/community objective above)	• Economic performance of local supporting industries	Fisheries (42)
11. Minimise management costs • Industry compliance costs • Government costs	• Compliance costs to industry • Total management costs (recoverable and non-recoverable) • Infrastrucutre costs	Fisheries (42) Ports (47)
12. Maximise employment (usually seen as social objective)	• Level of employment in fishing • Number of vessels • Level of employment in associated sectors	Fisheries (42) Recreational Fishing (42) Agriculture (45)
13. Improve fishing productivity	• CPUE • Profit per day fished • Profit per tonne landed • Average revenue per boat	
14. Improve industry value	• Gross Value Product (GVP)	Fisheries (42)
15. Minimise variability	• Variability in harvest • Supply and demand • Prices	Fisheries (42) Agriculture (45)
16. Raise the level of living of farmers	• Price • Family income	Agriculture (45)
17. Provide comparability of income between incomes in the farm sector and the non-farm sector	• Household Income	Agriculture (45)
18. To give orderly marketing, i.e. to remove the competitive struggle among growers	• Price	Agriculture (45)
19. Encourage efficient production		Agriculture (45)
20. Orient production towards more favoured areas	• Productivity	Agriculture (45)
21. General objective: in time of depression to offset effects of depressed conditions then expected to be temporary	• Price	Agriculture (45)
22. Manage urban growth and build Queensland's regions through: • Supporting QLD's regions through statewide infrastructure development and regional jobs creation • linking Queensland through efficient and integrated transport options; and • building on the strengths of Queensland's diverse regions.		State Government & Ports (47)

Objective	Possible Indicator	Sector and references
23. Growing a diverse economy and creating jobs by: • expanding market access, export and trade opportunities; and • diversifying and strengthening the economy through value adding, productivity growth and the development of future growth industries		State Government & Ports (47)
24. Assure Port development will follow "development guidelines", which cover a range of criteria including: • environmental management; • site layout and building design; • access, parking, circulation; • landscaping; • safety and hazard management; • setbacks and buffer requirements; • infrastructure requirements; • extractive industry; • stormwater management; • erosion and sediment control; and • other NQBP requirements for new development at the Port of Mackay.		Ports (47)
25. Consider State interests in the Mackay region, including: • state infrastructure including state controlled roads; • regional planning.		Ports (47)
26. Ensure industry growth opportunities across the northern Bowen Basin and Mackay are taken advantage of in a timely manner in a way that effectively and sustainably manages growth	• Elaboration of Master planning exercise involving federal, State and Local Government, REDC and industry representation	Mining (52)

Table 6. Resource sustainability/conservation objectives in Mackay from the literature.

Objective	Possible Indicator	Sector and references

Objective	Possible Indicator	Sector and references
	• Nutrient (TN, TP) • DO concentrations • Turbidity • Algal status (Chl-a) • Bacteriological quality (inc. blue green algae) • Litter / debris • Oil and Grease • Coarse sediment	Local Government (43, 44)
1. Improve water and stormwater quality to protect environmental values	• Freshwater o Dissolved inorganic Nitrogen (DIN) o Dissolved Inorganic Phosphorous (DIP) o Chl-a o Diuron (herbicide) o Atrazine (herbicide) o Hexazion (herbicide) o Ametryn (herbicide) o Simazine (herbicide) o Thebuthioron (herbicide) o pH o Coliforms o Total Phosphorous (TP) o Ammonia o Temperature o TOC o Al o Fe • Freshwater (event based) o Total suspended solids o PN o DIN o PP o DIP	State Government (53)
	• Macroinvertebrates	State Government (54)
2. Enhance and protect the environment assets of the region, ensuring a protected/preserved natural environment for future generations	• Finalise Beach Management Plan. • Development and implementation of Erosion and Sediment Control Program. • Number of implementation actions from Mackay Regional Council Beach Plans	Local Government (50)
3. Ensure sustainable fisheries target / by-product species	• Sustainable target species • Biomass of each group	Fisheries (42)
4. Achieve maximum sustainable yield	• Maximum Sustainable Yield (special case of Ensure sust. Targ.)	Fisheries (42)
5. Minimise bycatch • TEP species • All species	• Bycatch of threatened, endangered, protected (TEP) species (number) • Total bycatch (number, weight)	Fisheries (42) State Govt. (55)
6. Minimise pollution	• Pollution level	Fisheries (42)
7. Biodiversity conservation (protection and restoration of terrestrial, freshwater, estuarine and marine ecosystems and habitat for native plants and animals)	• Water quality o DO o pH o Electrical conductivity o Water temperature o Clarity	Mackay/Whitsundays NRM Group (46) NRM (37)

Objective	Possible Indicator	Sector and references
	○ Filterable reactive phosphorus	
	• Percentage of land cleared • Percentage area of coastal development (for reptiles)	State Government (55)
	• Habitat damage • Area trawled	Fisheries (42)
	• Biodiversity index • Count of groups present • Depletion index	Fisheries (42)
	• Water quality ○ Herbicides (Ametryn, Atrazine, Diuron, Hexazinone, Tebuthiuron)	Mackay Government Water Quality (56)
8. Sustainable use of natural resources (maintain and improve the productability and profitability of resource based industries)	• Preparation of regional management plan • Targeted land types (hectares) • Number of species • Biodiversity processes	Fisheries (42) NRM (37)
9. Definition of water quality objectives • Ambient • event-based	• Document containing management objectives for a specific waterbody agreed by stakeholders	Mackay Government Water Quality (56)
10. Strength institutions, and promotion of co-operative governance and community involvement in conservation (also linked with social objectives)		NRM (37)
11. Feral animal control (pigs)	• Density of feral animals	State Government (55)
12. Weed control • Para grass • Hymenachne • Salvinia • Water lettuce • Water hyacinth	• Area of infestation	State Government (55)
13. Reduce catchment runoff • sediment and nutrients	• Sediment concentration • Nutrient concentration (N, P) • Seagrass cover	State Government (55)
14. Reduce the threat of boating strikes on marine fauna • humpback dolphin • Australian snubfin dolphin • Green turtle	• Number of reported incidents	State Government (55)
15. Minimise human-induced changes in water flow regimes	• Water Flow	State Government (55)
16. Improve land management practices (e.g. cattle grazing and trampling on plants (*Aponogeton queenslandicus*))		State Government (55)
17. Control illegal collection of wild plants (e.g. *orchid Phaius australis*) and animals (e.g spiders *Selenocosmia crassipes* and *Selenotypus plumipes*)		State Government (55)

Objective	Possible Indicator	Sector and references
18. Minimise road kills (northern quoll (*Dasyurus hallucatus*)	• Number of reported incidents	State Government (55)
19. Minimise entanglement of dugongs and dolphins on shark nets	• Number of reported incidents	State Government (55)
20. Improve/gather information about key populations previously recorded in the region		State Government (55)
21. Consider State interests in the Mackay region, including: • tidal and coastal processes, vegetation and marine life; • acid sulfate soils; • water resources; • The Great Barrier Reef Marine Park;	• Water quality • Air quality • Biodiversity • Coastal resources • Amenity (visual and environmental; e.g. noise emissions)	Ports (47)

Intermediate simplified objectives

An intermediate table was produced where the RG collated, deleted rephrased or added objectives into a more cohesive product focused on coastal biodiversity and fisheries (Table 7) It was clearly articulated by the project team to the RG that objectives should be inclusive of differing views rather than exclusive.

Table 7. Updated objective Table after input from stakeholders during the meeting on the 5th of December 2012.

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
1	Board from workshop	Market Security: framework that allows the fisheries industry to prosper	Increased economic growth	Ensure overall profitable and sustainable natural resource based industries (1,5,10,15)	Economic	Well-being		Table 4, Objectives 9, 10, 21; Table 5 objectives 7, 8, 13, 14, 15, 18, 23
2	Board from workshop	Maintain communities	Increased social cohesion (2)		Social	Well-being		Table 4, Objectives 2, 9, 11, 21
3	Board from workshop	Maintain family income / livelihoods	Increased economic growth	Maintain or improve family livelihoods in the region (3,20)	Social, Economic	Well-being		Table 4, Objective 4, 10, 11, 21; Table 5 objectives 1, 2, 8
4	Board from workshop	Equity	Increased social cohesion (2)	Ensure equitable access (4)	Social	Well-being		Table 4, Objectives 5, 8, 10, 11, 21

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
5	Board from workshop	Profitable and sustainable natural resource utilisation	Increased economic growth	Ensure overall profitable and sustainable natural resource based industries (1,5,10,15)	Social, Economic	Well-being		Table 4, objectives 10, 21; Table 5, objectives 7, 13, 14, 21, 23; Table 6, Objective 8
6	Board from workshop	Family health	Maintain social capital (22)	Maintain and improve health and safety in region (6,23)	Social, Economic	Well-being	Reduce water fluoridation as Fluoride in Town water supply is a human health hazard (knocks out iodine, thyroid). 200 tonnes p.a. of fluoride enters the GBR	Table 4, objectives 6, 10, 21; Table 5 objective 2
7	Board from workshop	Remove barriers to diversification in the economy	Increase management effectiveness	Remove regulatory barriers to flexibility (7,8,11)	Economic	Governance	This is about (i) the fishing symbol system on licenses, which limits the ability for operators to move from fisheries in difficult situations (eg crab) to other fisheries; and (ii) about the inflexible zoning plan in the GBRMP	Table 5, objective 23

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
8	Board from workshop	Flexible Institutional Policies	Increase management effectiveness	Remove regulatory barriers to flexibility (7,8,11)	Social, Environmental	Governance	This is about (i) the fishing symbol system on licenses, which limits the ability for operators to move from fisheries in difficult situations (eg crab) to other fisheries; and (ii) about the inflexible zoning plan in the GBRMP	Table 4, objective 14; Table 6, Objective 10
9	Board from workshop	Food supply	Increased economic growth	Improved regional economic development (9, 25,28,29,30,32)	Social	Well-being	Education of the local community to different locally produced foods and their uses; diversification of the locally produced food products accessing the local markets	Table 4, objective 13, 21
10	Board from workshop	Encourage efficient production	Increased economic growth	Ensure overall profitable and sustainable natural resource based industries (1,5,10,15)	Economic	Well-being	by reducing waste, such as discards (and water use in the land-based sectors) + value adding for by-products	Table 5 objectives 13, 20, 21, 23
11	Board from workshop	Provide for creativity in gear technology	Increase management effectiveness	Remove regulatory barriers to flexibility (7,8,11)		Governance	This is about being able to try alternative fishing gear to protect endangered species (dugongs)	

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
12	Board from workshop	Compliance effectiveness (IUU; illegal, unreported, unregulated catches)	Increase management effectiveness	Increased compliance with environmental and resource use regulations (12,13)		Governance		
13	Board from workshop	Discourage poaching	Increase management effectiveness	Increased compliance with environmental and resource use regulations (12,13)		Governance		
14	Board from workshop	Minimise conflicts between alternative users	Increased social cohesion (2)	Minimise conflicts (14)	Social	Well-being		Table 4, objective 12, 21
15	Board from workshop	Ensure the harvest is sustainable	Increased economic growth	Ensure overall profitable and sustainable natural resource based industries (1,5,10,15)	Economic	Well-being	in the long run sustainable harvest guarantees future catches	Table 5, objective 7
16	Board from workshop	Minimise risk of climate change impacts on inshore biodiversity	Maintain connectivity between fresh and saltwater aquatic ecosystems (18)	Minimise human induced changes in waterflow regimes (39, 16)	Environmental	Environmental		Table 6, objective 15
17	Board from workshop	Weed control through harvesting (not poisoning)	Improve water quality	Increase in environmentally friendly feral and weed control strategies (37,17)	Environmental	Environmental	weeds can be used for composting, thus facilitating the diversification of the economy; this could also be linked to health objectives as will minimize the potential impacts	Table 6, Objective 12

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
18	Board from workshop	Fresh- and saltwater connectivity (inshore system)	Maintain connectivity between fresh and saltwater aquatic ecosystems (18)			Environmental	connectivity issues catchment to coast (fresh/salty) → maintain fish passages / connectivity from fresh to marine (also the case for turtles	
19	Board from workshop	Minimise risks of biosecurity threats	Conserve inshore living resources	Sustainable human use of marine resources (35,36,19)		Environmental		
20	Literature	Increase / maintain employment opportunities	Increased economic growth	Maintain or improve family livelihoods in the region (3,20)	Social, Economic	Well-being		Table 4, Objectives 1, 10, 11, 21; Table 5, objectives 12, 22
21	Meeting notes	Community involvement in management	Increased management support	Increased stakeholder engagement (21)	Social, Environmental	Governance	Councils, businesses, tourism, community groups, industry bodies, state & federal bodies, environmental bodies,, schools & universities	Table 4, Objectives 2, 11, 18; Table 6, Objective 10
22	Meeting notes	Maintain social capital	Maintain social capital (22)		Social	Well-being		Table 4, Objectives 3, 10, 11, 21
23	Meeting notes	Ensure safety at sea	Maintain social capital (22)	Maintain and improve health and safety in region (6,23)	Social	Well-being	Noted that this should be an outcome of all the objectives identified in the table under objective 6 are achieved	Table 4, Objective 6, 10, 21

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
24	Meeting notes	Conserve traditional activities and culture	Increased social cohesion (2)	Conserve traditional activities and culture (24)	Social	Well-being	Noted in workshop that this should include indigenous and non-indigenous traditional uses of inshore natural resources and areas; also noted by some that this is a difficult question due to the problem of illegal practices	Table 4, Objectives 7, 19, 21
25	Meeting notes	Build community capacity to address development challenges and take advantage of emerging opportunities	Maintain social capital (22)	Improve capacity, education and training (25)	Social, Economic	Well-being	Based on note that focuses on the need for supply (labour and resources) to meet demand when required; also could relate to some of the objectives described under "traditional/ indigenous fisheries", concerning assistance to Trustees, capacity building, education and training	Table 4, objectives 20, 21; Table 5, objective 23
26	Meeting notes	Management acceptability	Increased management support	Increased management acceptability (26,27)	Social	Governance	One comment is that commercial fishers are bitterly disappointed at regulation rather than support	Table 4, objective 15

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
27	Meeting notes	Ease of management implementation	Increased management support	Increased management acceptability (26,27)	Social	Governance		Table 4, objective 16
28	Meeting notes	Facilitate Flow of human and financial resources into the Mackay region	Increased economic growth	Improved regional economic development (9, 25,28,29,30,32)	Economic	Well-being		Table 5, objectives 3, 5, 6, 22, 23
29	Meeting notes	Economic profits of different sectors / segments in sector	Increased economic growth	Improved regional economic development (9, 25,28,29,30,32)	Economic	Well-being		Table 5, objective 8
30	Meeting notes	Sustainable economic performance of supporting sectors	Increased economic growth	Improved regional economic development (9, 25,28,29,30,32)	Economic	Well-being		Table 5, objective 10
31	Meeting notes	Sustainable management costs	Increased management support	Sustainable financial costs (31,27)	Economic	Governance	To industry and the public sector	Table 5, objective 11
32	Meeting notes	Develop efficient and integrated transport infrastructure	Increased economic growth	Improved regional economic development (9, 25,28,29,30,32)	Economic	Well-being		Table 5, objective 22
33	Board	Work towards meeting targets of reef plan	Improve water quality	Ensure Reef Plan water quality targets are met (33)	Environmental	Environmental	Herbicides must be phased out by 2015	Table 6, Objectives 1, 6, 13
34	Meeting notes	Enhance and protect the environment assets of the region, ensuring a protected /preserved natural environment for future generations	Conserve inshore living resources	Maintain habitat function and structure (eg plants, sand, rocks, ...) (34)	Environmental	Environmental	Comment 1: define E&SC & beach plans. Comment 2: not good indicators but this is biodiversity management.	Table 6, Objectives 2, 7, 9

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
35	Meeting notes	Ensure sustainable fisheries target / by-product species	Conserve inshore living resources	Sustainable human use of marine resources (35,36, 19)	Environmental	Environmental	Comment: make use of by-catch to produce fertilisers instead of dumping; Comment Leo: maybe part of economic objectives 10&15 above	Table 6, Objectives 3, 4
36	Meeting notes	Target by-catch	Conserve inshore living resources	Sustainable human use of marine resources (35,36, 19)	Environmental	Environmental	Comment: use "target" instead of "minimise"	Table 6, Objective 5
37	Meeting notes	Feral animal control	Improve water quality	Increase in environmentally friendly feral and weed control strategies (37,17)	Environmental	Environmental		Table 6, Objective 11
38	Meeting notes	Reduce the threat of boating strikes on marine fauna (humpback dolphin, Australian snubfin dolphin, green turtle, loggerhead, and flatbacks)	Conserve inshore living resources	Reduce impacts on TEP species (38)	Environmental	Environmental	Comment: should be captured general TEPs objective. Comment 2: Monitoring the actual populations is better than number of reported strikes; Comment Leo: this objective covers boat strikes, road kills and entanglement of dugongs, and dolphins on shark nets	Table 6, Objectives 14, 18, 19

#	Sources	Objectives	Objective -proposed rewording	Sub-objective	Initial classification	New proposed classification	Notes / Comments	Reference to literature
39	Meeting notes	Minimise human-induced changes in water flow regimes	Maintain connectivity between fresh and saltwater aquatic ecosystems (18)	Minimise human induced changes in waterflow regimes (39, 16)	Environmental	Environmental	Comment: already regulated; Comment2: Keyline / Planning remineralisation via rock dust	Table 6, Objective 15
40	Meeting notes	Improve land management practices (e.g. cattle grazing and trampling on plants (*Aponogeton queenslandicus*))	Maintain connectivity between fresh and saltwater aquatic ecosystems (18)	Improve land management practices (40, 41)	Environmental	Environmental	Comment: cell grazing	Table 6, Objective 16
41	Meeting notes	Control illegal collection of wild plants (e.g. *orchid Phaius australis*) and animals (e.g spiders *Selenocosmia crassipes* and *Selenotypus plumipes*)	Maintain connectivity between fresh and saltwater aquatic ecosystems (18)	Improve land management practices (40, 41)	Environmental	Environmental	Comment: proliferation may be beneficial!	Table 6, Objective 17

Objectives tree

The first proposed hierarchy was developed by the RG (Table 8). Here it was decided that the indicator column would not be used in the final tree. Wording and terminology became more important to the RG. The numbering system in brackets showed the numbers from the original list of objectives thereby allowing version control to the source of objectives.

Table 8. Proposed objective hierarchy after inputs from the Mackay Reference Group discussed on March 01, 2013. Numbers in parentheses refer to the objectives presented in Table 7.

Level 1	Level 2	Level 3	Indicators
Protect and restore inshore environmental assets	Maintain connectivity between fresh and saltwater aquatic ecosystems (18)	Improve land management practices (40, 41)	
		Minimise human induced changes in water flow regimes (39, 16)	
	Improve water quality	Ensure Reef Plan water quality targets are met (33)	
		Increase in environmentally friendly feral and weed control strategies (37,17)	
	Conserve inshore living resources	Sustainable human use of marine resources (35,36,19)	
		Maintain habitat function and structure (eg plants, sand, rocks, ...) (34)	
		Reduce impacts on TEP species (38)	
Improved governance	Increased management effectiveness	Increased management support	Creativity in NRM use techniques (11)
			Flexible zoning (7,8)
			Diversification in the economy (7)
	Increased management support	Increased compliance with environmental and resource use regulations (12,13)	
		Increased management acceptability (26,27)	Rational and proportional legislation (26,27)
			Increased information dissemination (27)
		Increased stakeholder engagement (21)	Involvement of private developers / corporate responsibility (-)
			Increased community involvement in management (21)
		Sustainable financial costs	

Level 1	Level 2	Level 3	Indicators
		(31,27)	
	Increased management integration (policy, regulation, implementation) (-)	Increased policy integration (-)	
		Increased regulatory integration (-)	
		Increased implementation integration (-)	
Improved regional well-being	Increased economic growth	Improved regional economic development (9,28,29,30,32)	
		Maintain or improve family livelihoods in the region (3,20)	
		Ensure overall profitable and sustainable natural resource based industries (1,5,10,15)	
	Increased social cohesion (2)	Minimise conflicts (14)	
		Conserve traditional activities and culture (24)	
		Ensure equitable access (4)	
	Maintain social capital (22)	Maintain and improve health and safety in region (6,23)	Increased workplace safety at sea (23)
			Increased family health (6)
		Improve capacity, education and training (25)	
		Maintain social infrastructure	

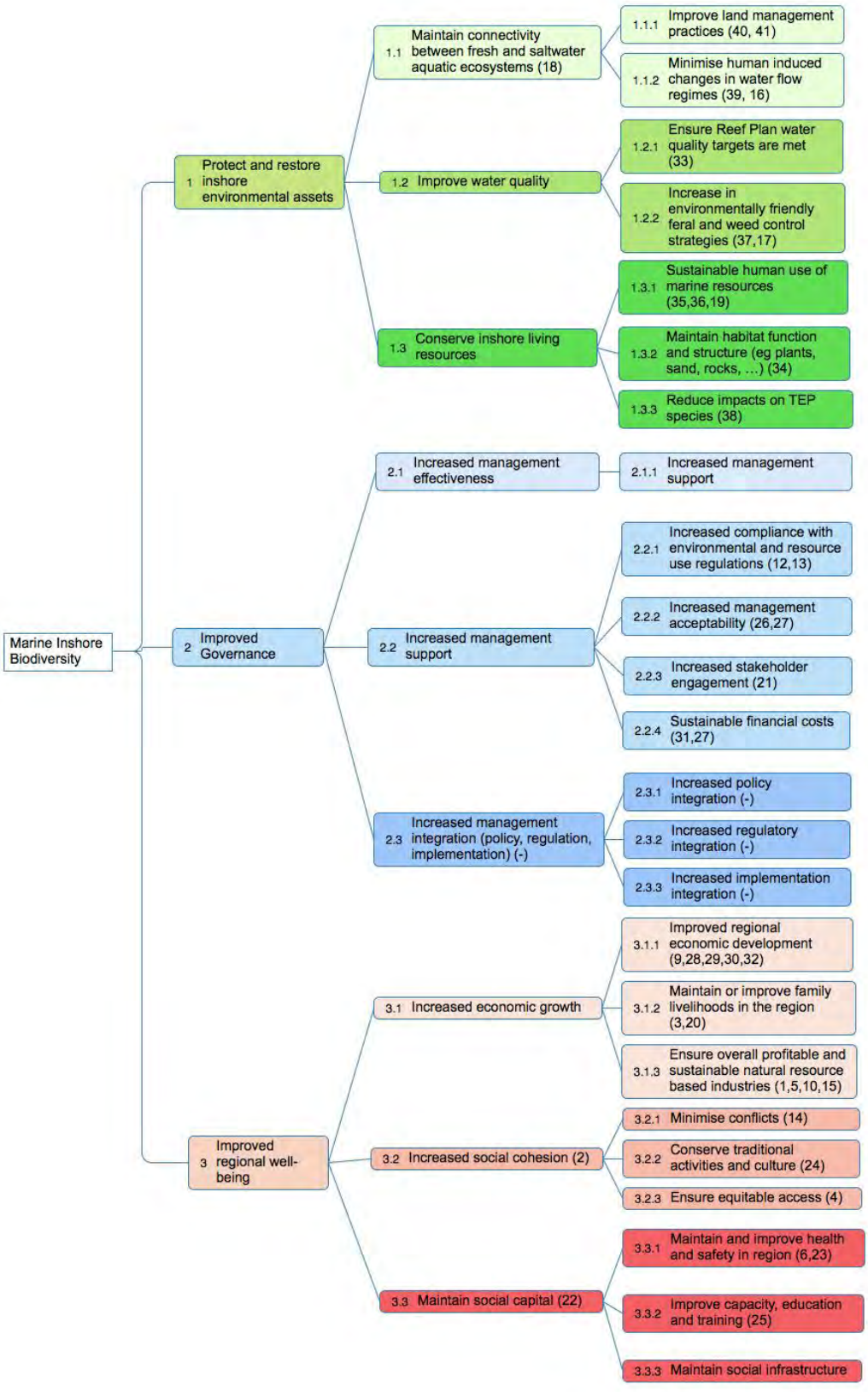


Figure 4. Initial objectives hierarchy discussed with the Mackay reference group on the 1st of March 2013.

The revised objective hierarchy for the management of inshore biodiversity in the Mackay region (Figure 6 and Table 9) is composed of three main branches, which are called: (1) Protect and restore inshore environmental assets; (2) Improve governance systems (i.e. leadership, institutions, rules and decision-making processes involved in managing inshore biodiversity); and (3) Improve regional well-being. Each of these branches contains additional sub-levels, described in the table below.

Table 9. Second draft objective hierarchy after meeting held with LMAC March 2013 showing levels (branches of the tree) and descriptors of the objectives presented in Figure 5.

Level	Name of Branch	Descriptor
1	Protect and restore inshore environmental assets	Overarching environmental objective for the region
1.1	Improve ecosystem connectivity	Connectivity between catchment, fresh- and salt-water habitats
1.1.1	Reduce direct impacts of infrastructure and development	Minimise the negative impacts to biodiversity associated with the strong development currently occurring in the region
1.1.2	Minimise human induced changes in water flow regimes	Maintain water flow regimes to allow for catchment to coast connectivity
1.2	Improve water quality	Reduce sediment and nutrient runoff into waterways and reefs
1.2.1	Ensure Reef Plan water quality targets are met	Meet regional water quality targets
1.2.2	Increase in environmentally friendly feral and weed control strategies	Control invasive species to improve water quality. When possible this control should avoid/minimise the use of chemicals
1.2.3	Reduce influx of pollutants	Reduce the use of chemicals used in agriculture and industry and its disposal in waterways. Also involves reduction of sediment and nutrient runoff
1.3	Conserve inshore living resources	Ensure long-term conservation of the inshore living resources and their support systems
1.3.1	Sustainable human use of marine resources	Ensure sustainable harvesting of living resources; Reduce waste and human footprint of extractive activities, and improve re-use of by-products
1.3.2	Maintain habitat function and structure	Maintain/restore habitats for their biodiversity values
1.3.3	Reduce impacts on Threatened, Endangered, Protected (TEP) species	Minimise accidental strikes and kills of fauna and flora (e.g. dugongs, turtles, quolls)
2	Improve governance systems (i.e. leadership, institutions, rules and decision-making processes involved in managing inshore biodiversity)	Improve leadership, institutions, rules and decision-making processes involving government, citizens, public associations, private businesses, and non-governmental organisation, for the management of inshore biodiversity and its uses
2.1	Increase management effectiveness	Increase the effectiveness of management systems by removing barriers to flexibility
2.1.1	Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)	Remove regulatory barriers that impede creativity in the development of alternative techniques to harvest natural resources, to increase flexibility in zoning arrangements and remove regulatory barriers that impede the diversification of the economy
2.1.2	Increase compliance with environmental and resource use regulations	Discourage illegal, unreported and unregulated activities, and encourage compliance with existing regulations

Level	Name of Branch	Descriptor
2.2	Increase management support	Increase support towards inshore biodiversity management systems through increased management acceptability, increased stakeholder engagement, ensuring that management costs are sustainable and increase compliance with environmental and resource use regulations
2.2.1	Increase management acceptability	Increase management acceptability through rational and proportional legislation, and increased information dissemination
2.2.2	Increase stakeholder engagement and community ownership/stewardship	Increase stakeholder engagement through involvement of private developers / corporate responsibility and community involvement in management to foster community ownership/stewardship
2.2.3	Sustainable financial costs	Minimise industry compliance costs and government enforcement costs, including recoverable and non-recoverable total management costs and infrastructure costs
2.3	Increase management integration	Improve the integration of management systems in policy, regulation and implementation, across Local, State and Commonwealth levels
2.3.1	Increase policy integration	Coherent and integrated policies across Local, State and Commonwealth levels
2.3.2	Increase regulatory integration	Coherent and integrated regulations across Local, State and Commonwealth levels
2.3.3	Increase implementation integration	Coherent and integrated management implementation across Local, State and Commonwealth levels
3	Improve regional economic and social well-being	Improve the long-term well-being of the region's people by promoting economic growth, increasing social cohesion and increasing social capital
3.1	Increase economic growth	Promotion of regional economic development, including natural resource based industries, to maintain or improve family livelihoods
3.1.1	Improve regional economic development and industry diversity	Increase the flow of human and financial resources into the Mackay region, develop efficient and integrated infrastructure, increase the local market opportunities for locally produced foods
3.1.2	Improve family livelihoods in the region	Enhancement of quality of life via increasing employment opportunities and family income
3.1.3	Ensure that natural resource based industries are profitable and sustainable	Maximise industry value, economic profits and productivity, and minimise price variability
3.2	Increase social cohesion	Increase social cohesion of the regional communities through minimising conflicts between stakeholders, conserving traditional activities and cultures and ensuring equitable access to inshore areas and resources
3.2.1	Minimise conflicts between stakeholders	Minimise conflicts between different users of the inshore marine area and resources
3.2.2	Conserve traditional activities and cultures	Preserve the traditional and cultural relationships between natural resources and areas and local human cultures (aboriginal and non-aboriginal)
3.2.3	Ensure community equity	Ensure equitable access to inshore areas and resources
3.3	Increase social capacity	Increase social capacity to act, through health improvement and investment in social capital development

Level	Name of Branch	Descriptor
3.3.1	Improve workplace and family health and safety in the region	Improve safety in the workplaces, as well as physical and mental family health and safety in the region
3.3.2	Improve education, training, social infrastructure and networks	Improve the social capital at both individual level (education, training, …) and collective level (physical infrastructure – hospitals, schools, … - as well as networks and community groups) providing the regional community with the capacity to address development challenges and take advantage of emerging opportunities

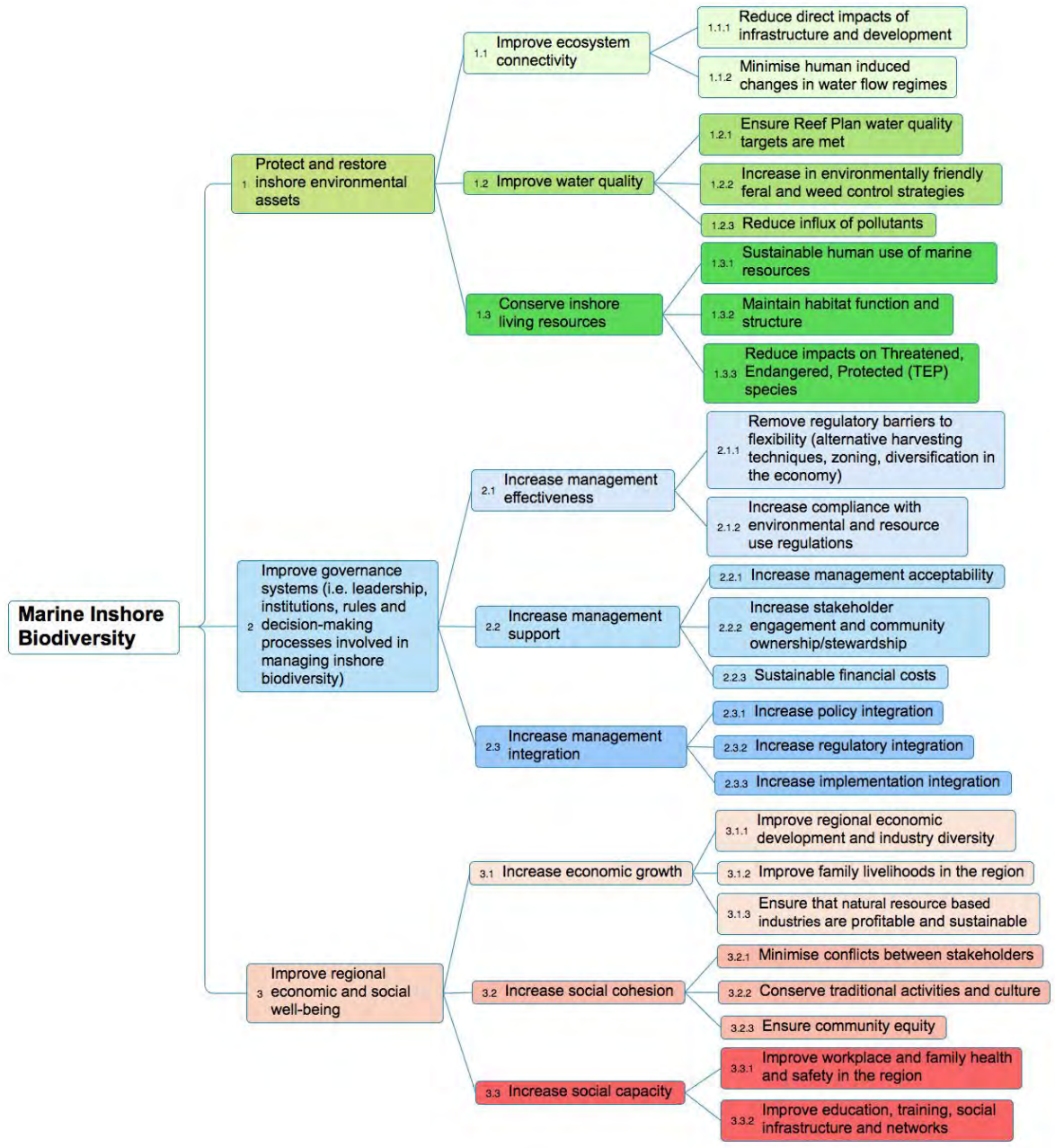


Figure 5. Objective hierarchy for inshore biodiversity management in the Mackay region, based on input from the Mackay Reference Group and LMAC.

The third and final revised objective hierarchy for the management of inshore biodiversity in the Mackay region (Figure 6 and Table 10) is composed of three main branches, which are called: (1) Protect and restore inshore environmental assets; (2) Improve governance systems (i.e. leadership, institutions, rules and decision-making processes involved in managing inshore biodiversity); and (3) Improve regional well-being. Each of these branches contains additional sub-levels, described in the table below.

Table 10. Third and final revised Objective hierarchy showing levels (branches of the tree) and descriptors of the objectives presented in Figure 6.

Level	Name of Branch	Descriptor
1	Protect and restore inshore environmental assets	Overarching environmental objective for the region
1.1	Improve ecosystem connectivity	Connectivity between catchment, fresh- and salt-water habitats
1.1.1	Reduce direct impacts of infrastructure and development	Minimise the negative impacts to biodiversity associated with the strong development currently occurring in the region
1.1.2	Minimise human induced changes in water flow regimes	Maintain water flow regimes to allow for catchment to coast connectivity
1.2	Improve water quality	Reduce sediment and nutrient runoff into waterways and reefs
1.2.1	Ensure Reef Plan water quality targets are met	Meet regional water quality targets
1.2.2	Increase feral animal control and environmental friendly weed control strategies	Control invasive species to improve water quality. When possible weed control should avoid/minimise the use of chemicals
1.2.3	Reduce influx of pollutants	Reduce the use of chemicals used in agriculture and industry and its disposal in waterways. Also involves reduction of sediment and nutrient runoff
1.3	Conserve inshore living resources	Ensure long-term conservation of the inshore living resources and their support systems
1.3.1	Sustainable human use of marine resources	Ensure sustainable harvesting of living resources; Reduce waste and human footprint of extractive activities, and improve re-use of by-products
1.3.2	Maintain habitat function and structure	Maintain/restore habitats for their biodiversity values
1.3.3	Reduce impacts on Threatened, Endangered, Protected (TEP) species	Minimise accidental strikes and kills of fauna and flora (e.g. dugongs, turtles, quolls)
2	Improve governance systems (i.e. leadership, institutions, rules and decision-making processes involved in managing inshore biodiversity)	Improve leadership, institutions, rules and decision-making processes involving government, citizens, public associations, private businesses, and non-governmental organisation, for the management of inshore biodiversity and its uses
2.1	Increase management effectiveness	Increase the effectiveness of management systems by removing barriers to flexibility

Level	Name of Branch	Descriptor
2.1.1	Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)	Remove regulatory barriers that impede creativity in the development of alternative techniques to harvest natural resources, to increase flexibility in zoning arrangements and remove regulatory barriers that impede the diversification of the economy
2.1.2	Increase compliance with environmental and resource use regulations	Discourage illegal, unreported and unregulated activities, and encourage compliance with existing regulations
2.2	Increase management support	Increase support towards inshore biodiversity management systems through increased management acceptability, increased stakeholder engagement, ensuring that management costs are sustainable and increase compliance with environmental and resource use regulations
2.2.1	Increase management acceptability	Increase management acceptability through rational and proportional legislation, and increased information dissemination
2.2.2	Increase stakeholder engagement and community ownership/stewardship	Increase stakeholder engagement through involvement of private developers / corporate responsibility and community involvement in management to foster community ownership/stewardship
2.2.3	Sustainable financial costs	Minimise industry compliance costs and government enforcement costs, including recoverable and non-recoverable total management costs and infrastructure costs
2.3	Increase management integration	Improve the integration of management systems in policy, regulation and implementation, across Local, State and Commonwealth levels
2.3.1	Increase policy integration	Coherent and integrated policies across Local, State and Commonwealth levels
2.3.2	Increase regulatory integration	Coherent and integrated regulations across Local, State and Commonwealth levels
2.3.3	Increase implementation integration	Coherent and integrated management implementation across Local, State and Commonwealth levels
3	Improve regional economic and social well-being	Improve the long-term well-being of the region's people by promoting economic growth, increasing social cohesion and increasing social capital
3.1	Increase economic growth	Promotion of regional economic development, including natural resource based industries, to maintain or improve family livelihoods
3.1.1	Improve regional economic development and industry diversity	Increase the flow of human and financial resources into the Mackay region, develop efficient and integrated infrastructure, increase the local market opportunities for locally produced foods
3.1.2	Improve family livelihoods in the region	Enhancement of quality of life via increasing employment opportunities and family income
3.1.3	Ensure that natural resource based industries are profitable and sustainable	Maximise industry value, economic profits and productivity, and minimise price variability

Level	Name of Branch	Descriptor
3.2	Increase social cohesion	Increase social cohesion of the regional communities through minimising conflicts between stakeholders, conserving traditional activities and cultures and ensuring equitable access to inshore areas and resources
3.2.1	Minimise conflicts between stakeholders	Minimise conflicts between different users of the inshore marine area and resources
3.2.2	Conserve traditional activities and cultures	Preserve the traditional and cultural relationships between natural resources and areas and local human cultures (aboriginal and non-aboriginal)
3.2.3	Ensure community equity	Ensure equitable access to inshore areas and resources
3.3	Increase social capacity	Increase social capacity to act, through health improvement and investment in social capital development
3.3.1	Improve workplace and family health and safety in the region	Improve safety in the workplaces, as well as physical and mental family health and safety in the region
3.3.2	Improve education, training, social infrastructure and networks	Improve the social capital at both individual level (education, training, …) and collective level (physical infrastructure – hospitals, schools, … - as well as networks and community groups) providing the regional community with the capacity to address development challenges and take advantage of emerging opportunities

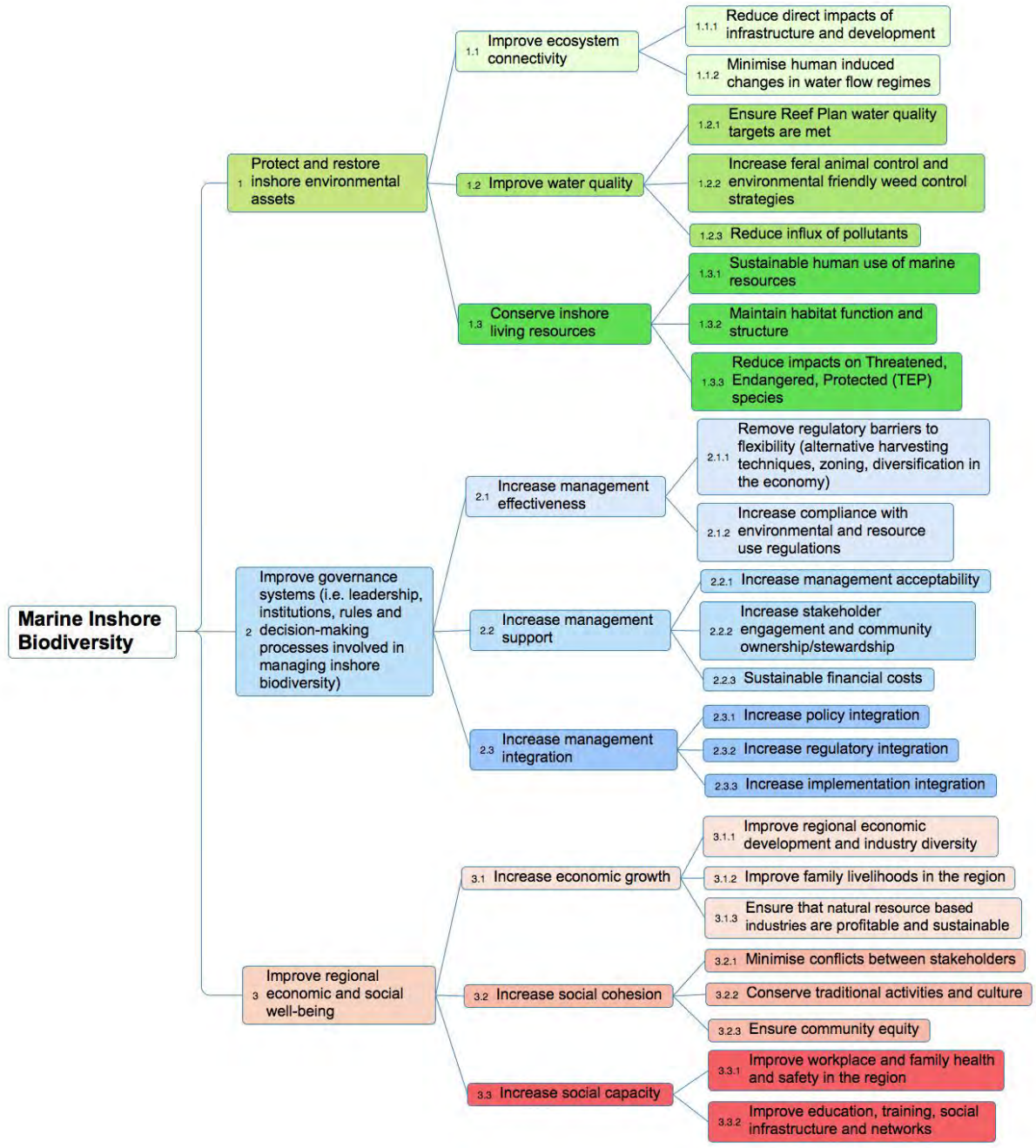


Figure 6. Third and final revised objective hierarchy for inshore biodiversity management in the Mackay region, based on input from the Mackay Reference Group and LMAC.

Breakdown of survey respondents

A total of 141 respondents undertook the survey (Figure 7), with the majority of respondents from the focal region of Mackay (n=92; Figure 7). The second largest number of respondents were from the region covering Caloundra to the New South Whales border, which includes

the Brisbane region. Of the total respondents, 32 undertook the AHP and 109 the HPA.

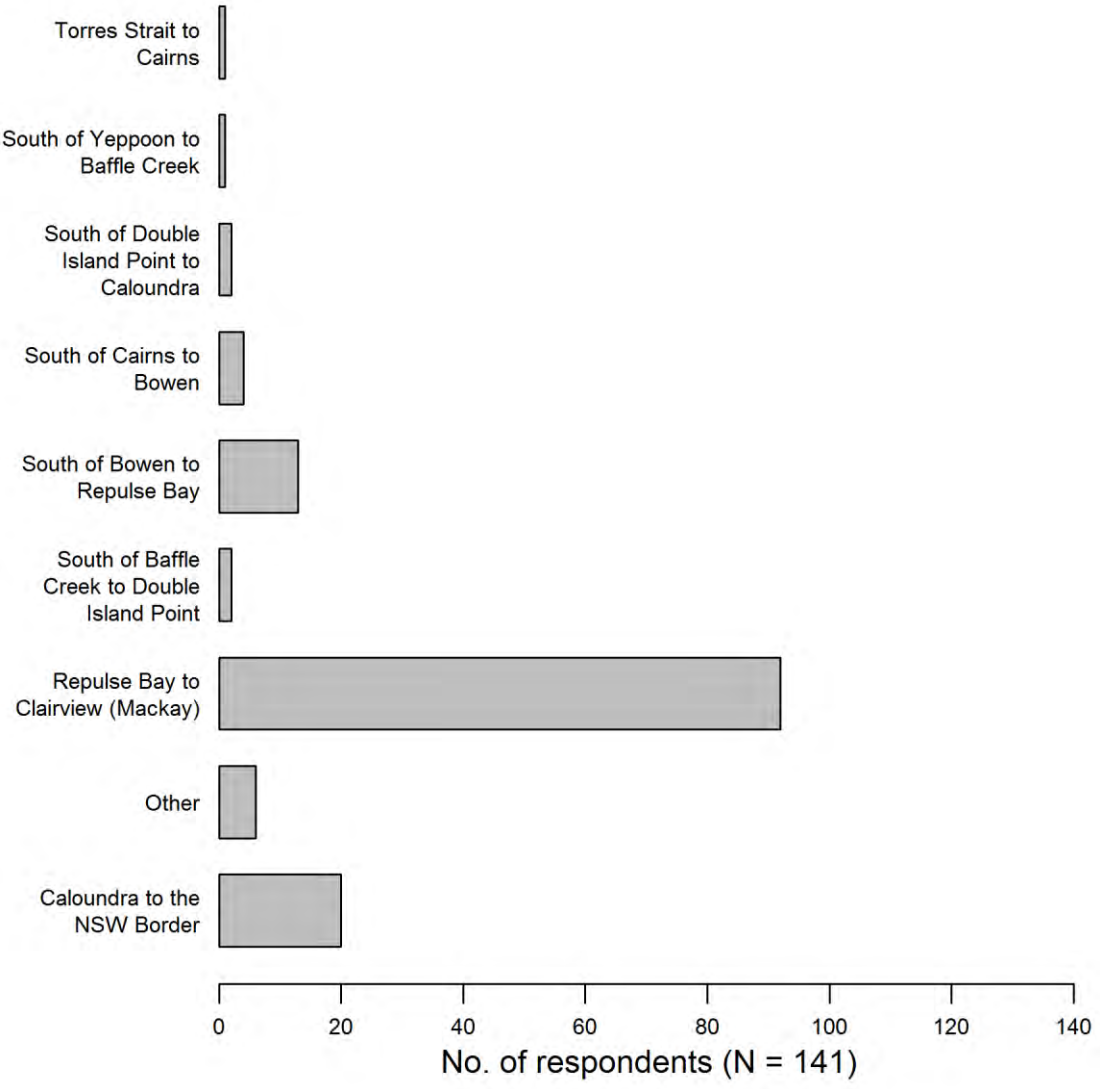
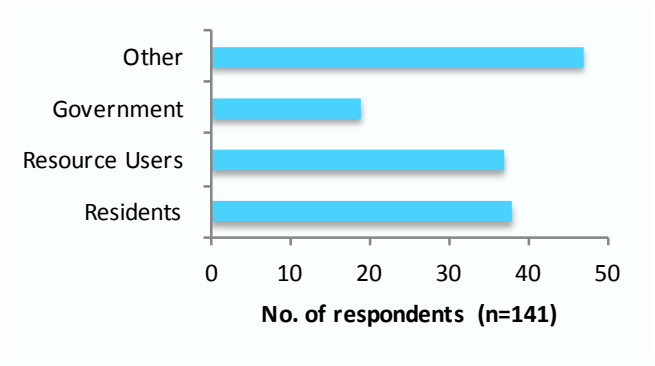
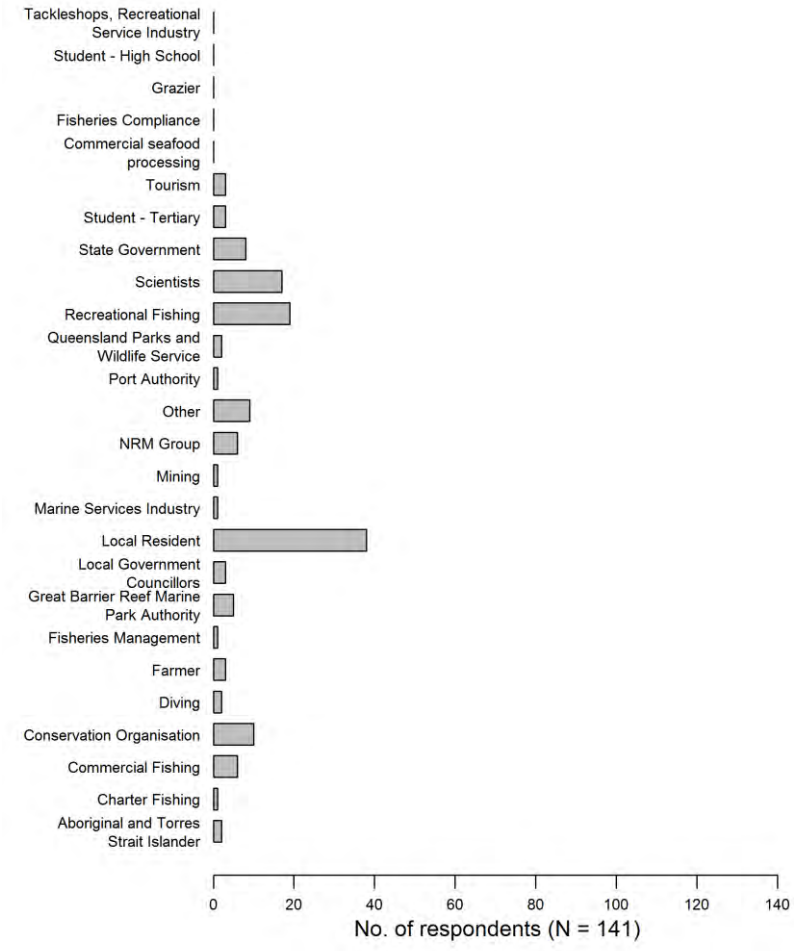


Figure 7: Total number of survey respondents by region.

The most common respondent group is 'Other', closely followed by 'Residents' and 'Government' (Figure 8A). Scientists were the major group under the category 'other' and recreational fisheries is the major respondent group under the category 'resource users' (Figure 8B).



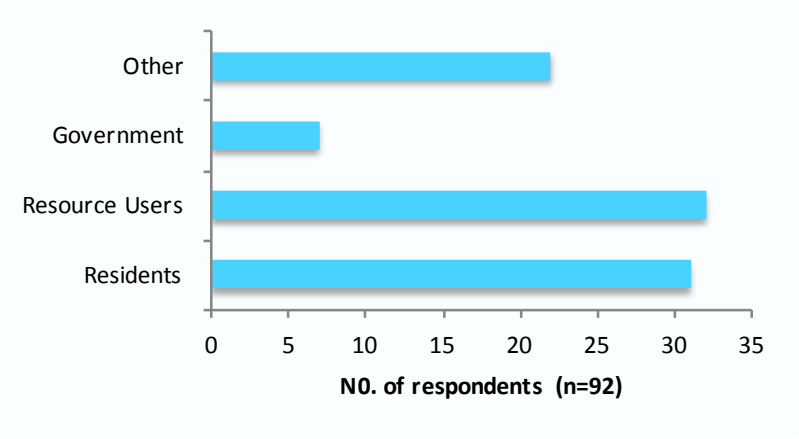
A



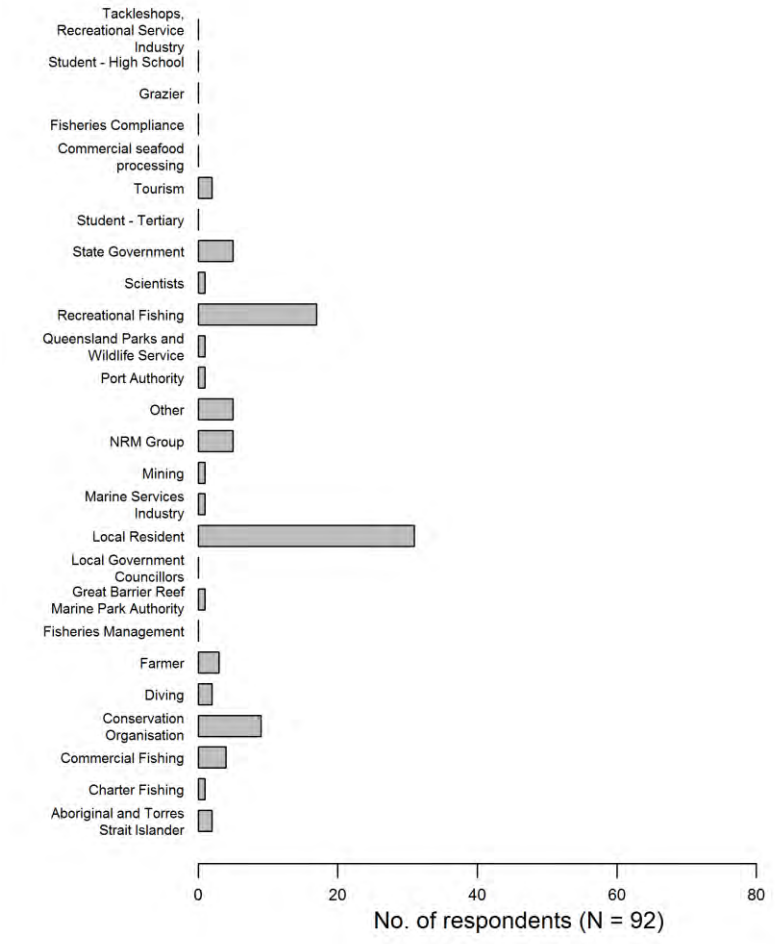
B

Figure 8: Total number of respondents for all survey respondents. A) Broader stakeholder categories, B) stakeholder groups as per survey questionnaire.

For the Mackay region (n=92) 'Resource Users', 'Residents', and 'Other' (Figure 9A) were the largest groups, mainly because there were no scientists (Figure 9B).



A



B

Figure 9: Number of survey respondents for the Mackay region. A) Broader stakeholder categories, B) stakeholder groups as per survey questionnaire.

Relative importance

Overall, the environment goal was given the highest weighting score in all regions (Figure 10 and for Mackay (Figure 11). Interestingly respondents in all regions scored the governance goal as more important than the well-being goal.

Broken down by stakeholder groups, most groups gave the environment objectives the highest weighting score. Only 'commercial fishers' and 'high school students' ranked the governance objective the highest (Appendix A). There were variations in the weighting of the second highest goal between stakeholder groups. 'Others' ranked the governance goal second highest, while 'Government' and 'Resource users' weighted the well-being goal second highest. There was no clear preference between governance and well-being goals for 'Residents' (Figure 12).

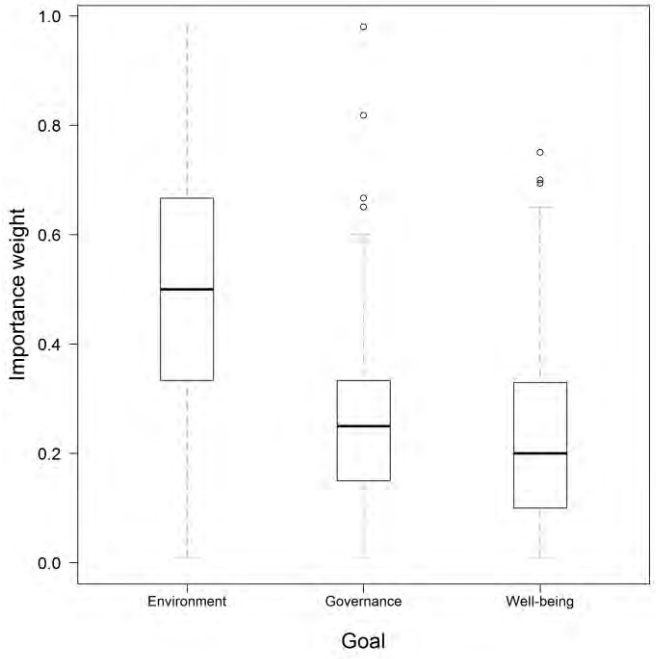


Figure 10: Box and whisker plot of the relative weights of the high order objectives by region.

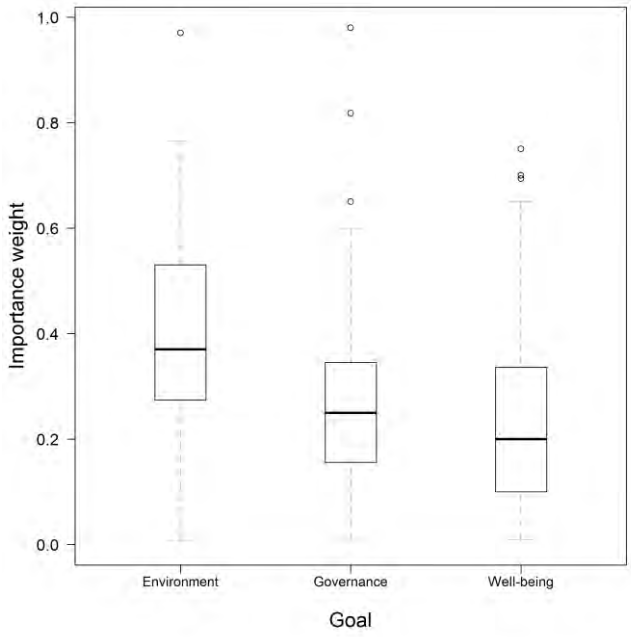


Figure 11: Box and whisker plot of the relative weights of goals for the Mackay region.

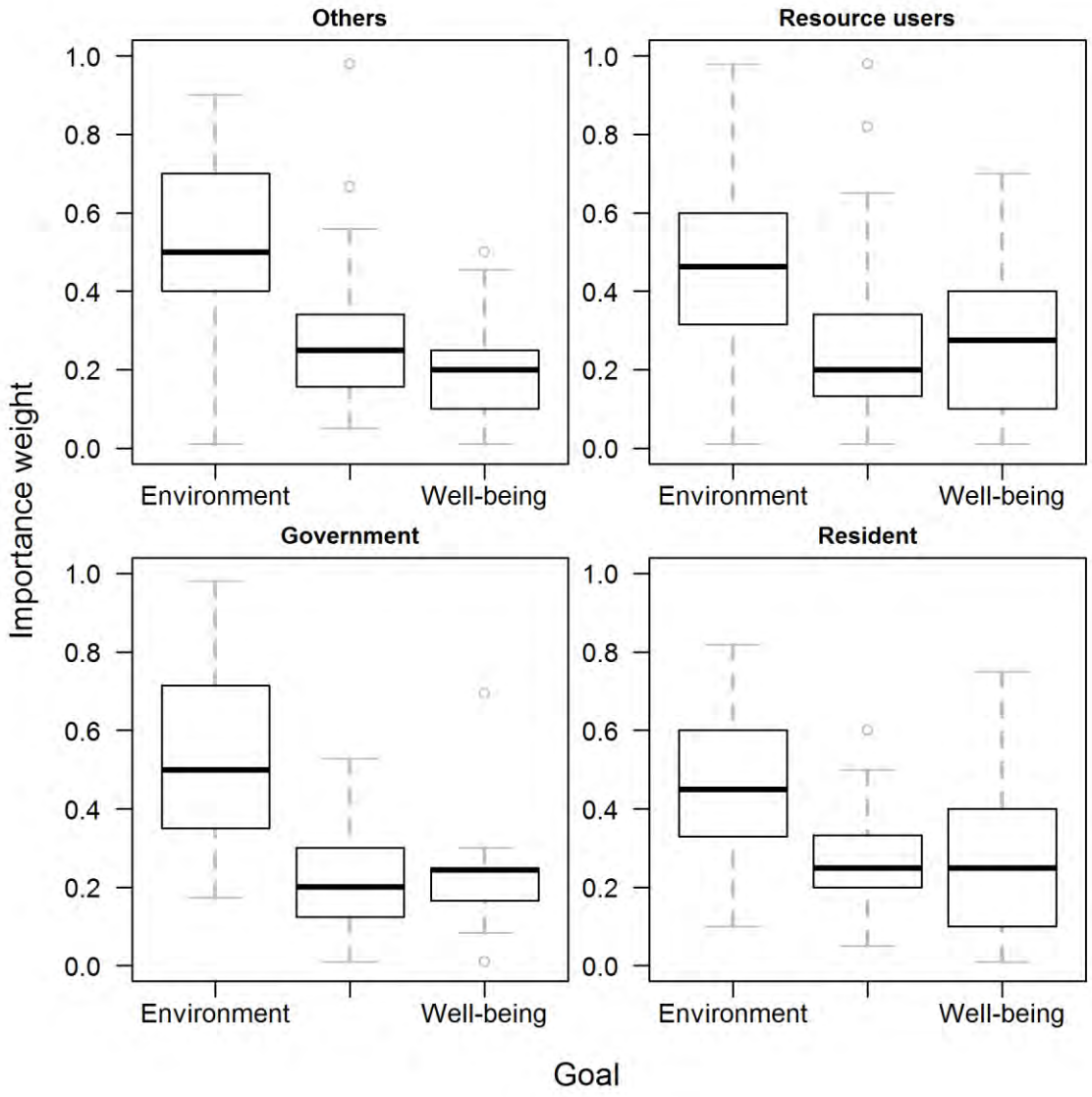


Figure 12: Relative weights of goals per stakeholder group.

For the all regions results, at the level of objectives (Figure 10), there were outliers for many of the objectives. This suggests that either the objectives were valued very differently by some respondents or some may have had problems interpreting some of the questions (57). For the Mackay region the number of outliers was fewer and the objectives are given relatively similar weightings (Figure 11). This gives support to the hypothesis of misinterpretation of the questions in the other regions as most objectives were Mackay-focused and Mackay respondents may have been able to relate better to them.

The three highest ranked objectives for all regions fit under the Environment goals. These are: 1.1.1 (Reduce direct impacts of infrastructure and development), 1.2.3 (Reduce influx of pollutants), and 1.1.2 (Minimise human induced changes in water flow regimes) (Figure 10).

For the governance objectives, the top three ranked objectives were 2.1.2 (Increase compliance with environmental and resource use regulations), 2.2.2 (Increase stakeholder engagement and community ownership/stewardship), and 2.1.1 (Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning,

diversification in the economy). The lowest ranked governance objectives were 2.3.1 (Increase policy integration) and 2.3.2 (Increase regulatory integration).

For the well-being goal, the three highest ranked objectives were 3.3.2 (Improve education, training, social infrastructure and networks), 3.2.3 (Ensure community equity), and 3.3.1 (Improve workplace and family health and safety in the region). The lowest ranked objective was 3.1.2 (Improve family livelihoods in the region) (Figure 13)

When looking at Mackay only, the sequence for environmental and governance objectives is the same as for all regions (1.1.1, 1.2.3, and 1.1.2, and 2.1.2, 2.2.2 and 2.1.1, respectively). For the well-being objectives the first two preferred objectives were similar to all regions (3.3.2 and 3.2.3, respectively), but the third preferred objective for Mackay respondents was 3.2.2 (Conserve traditional activities and cultures) instead of 3.3.1 (Figure 14).

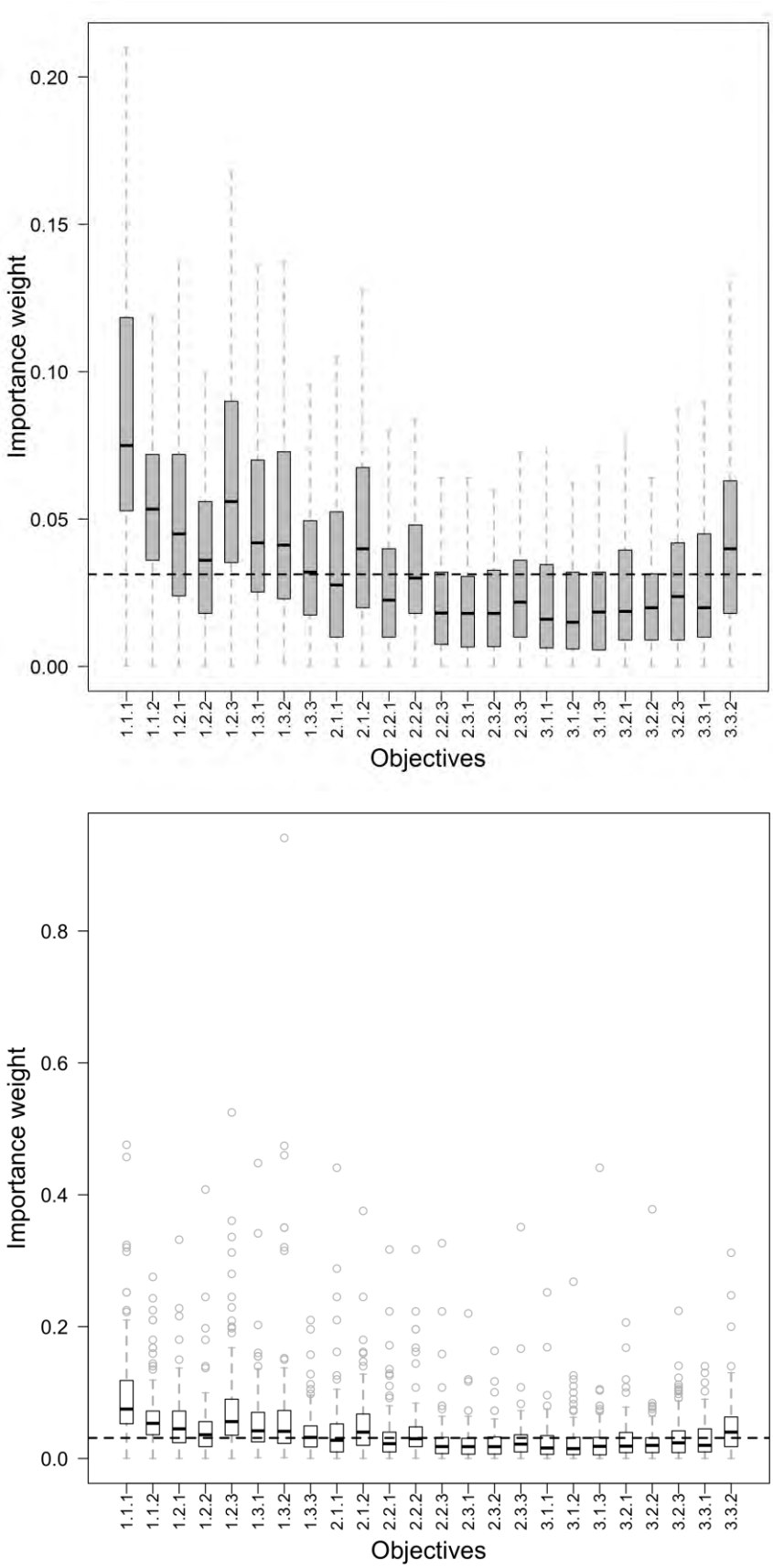


Figure 13: Box and whisker plot of the relative weights of objectives for all regions with (top) and without (bottom) outliers.

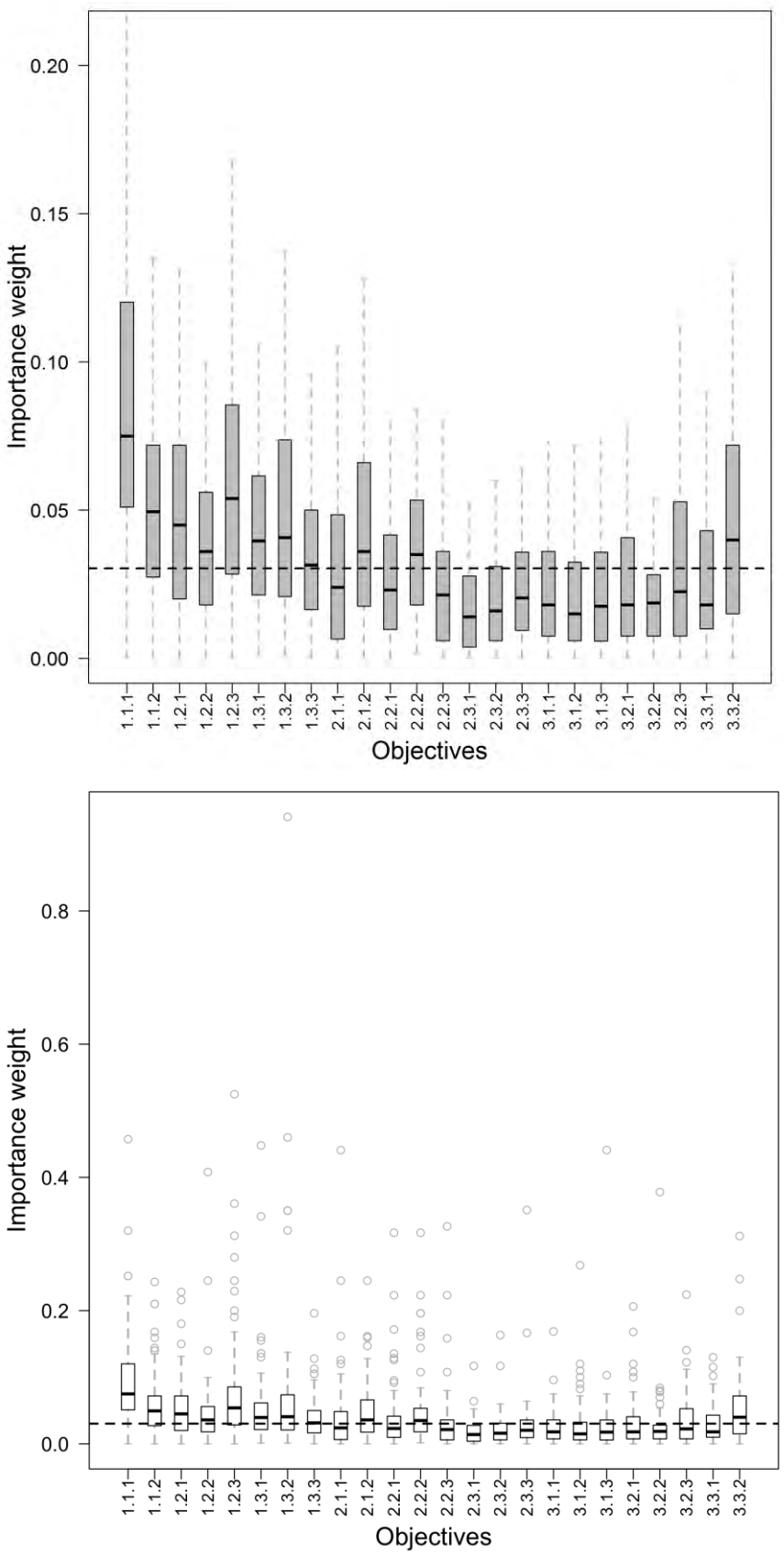


Figure 14: Box and whisker plot of the relative weights of the objectives for the Mackay region with (top) and without (bottom) outliers.

7.3.2 BOWEN-BURDEKIN

Objectives review

The literature review undertaken in the Burdekin was provided in an Excel format with the first worksheet articulating the high level objectives (Figure 15). The subsequent worksheets provided the objectives in two formats: as suggested medium and low level objectives; and divided into environmental, social, economic, community, and management and institutions. The last worksheet was the reference list.

Please think of at least 5 important objectives (reasons) for managing inshore natural resources in the Bowen-Burdekin area

As an example - in fisheries people often say the objective of managing a fishery is:
to have a profitable industry; to maintain healthy communities; to conserve fish stocks;
to maintain indigenous connections; to apply collaborative management.

To help you think about this question in another way - imagine you can look 20 years ahead in time,
what would you like to have achieved by managing the inshore natural resources of the Bowen-Burdekin?

Please outline your 5 (or more) objectives below

#	Objective (short name)	Description of objective
i		
ii		
iii		
iv		
v		

Figure 15: Excel worksheet to elicit the high level objectives from participants in the Bowen-Burdekin area.

Table 11: Medium and lower level objectives provided from the literature to Bowen-Burdekin participants under the environmental category.

Medium level obj.	Sub-obj. #	Lower level sub-objective description	Category	Sector & references
Improve the sustainable use of natural resources	a	Increase habitat protection to ensure continuation of productive recreational, indigenous and commercial fisheries activities.	Habitat & biodiversity	State Government (58)
	b	Improve biodiversity and ecosystem services through management practices designed to maintain productive capacity and prevent degradation of natural resources.	Habitat & biodiversity	Community organisation (59)
	c	Improve conservation and sustainable use of groundwater resources (quantity and quality) suitable for agricultural, industrial, environmental and domestic use	Freshwater flow	Local government (60), Community organisation (59)
	d	Increase water security and flow (surface and groundwater) of suitable quality for domestic, industrial and agricultural use.	Freshwater flow	NRM organisation (59)
	e	Increase adoption of economically and environmentally sustainable land management systems by land managers	Agriculture, development & other uses	NRM organisation (59)
	f	Improve the incorporation of the physical attributes of land in determining the suitability and location of development.	Agriculture, development & other uses	State Government (61)
	g	Ensure sustainable fisheries targets for main catch and by-product species	Fisheries	Fisheries (34)
	h	Achieve maximum sustainable yield in (recreational and commercial) fisheries	Fisheries	Fisheries (34)
	i	Minimise by-catch	Fisheries	Fisheries (34)
	j	Ensure effective and sustainable fisheries management and conservation of habitats for the use of future generations	Fisheries	State Government (58)

Medium level obj.	Sub-obj. #	Lower level sub-objective description	Category	Sector & references
Improve the environmental condition of natural resources	a	Conserve places of natural significance	Habitat & biodiversity	Commonwealth (62)
	b	Improve the ecological health of the GBR	Habitat & biodiversity	State Government (63, 64), Community organisation (65)
	c	Improve biodiversity and ecological conditions of native ecosystems for current and future generations	Habitat & biodiversity	Local government (66-68); Community Organisation (59, 69), Commonwealth (70)
	d	Protect all water bodies so their ambient water quality allows for the maximisation of environmental productivity, diversity and ecological processes	Habitat & biodiversity	Community Organisation (59)
	e	Protect and restore terrestrial, freshwater, estuarine and marine ecosystems and habitat for native plants and animals	Habitat & biodiversity	NRM (34)
	f	Improve populations of significant species and ecological communities	Habitat & biodiversity	NRM organisation (59, 69), Commonwealth (70)
	g	Recognise, protect and maintain areas of high ecological significance	Habitat & biodiversity	State Government (61)
	h	Improve connectivity between freshwater river systems, fragmented coastal habitats and marine environments.	Freshwater flow	Community organisation (59), Commonwealth (62)
	i	Minimise pollution	Agriculture, development & other uses	Fisheries (34)
	j	Reduce the loss of sediment, nutrients and pesticides from agricultural land	Agriculture, development & other uses	State Government (63, 64), Community organisation (65)
	k	Promote sustainable land and water management practices to improve conditions of natural resources	Agriculture, development & other uses	Local government (65, 67, 71), State government (63, 64, 72, 73), Community Organisation (59)

Medium level obj.	Sub-obj. #	Lower level sub-objective description	Category	Sector & references
	l	Reduce spread and establishment of pest plants and pest animals - Prevent the introduction, spread and establishment of pest plants and pest animals	Agriculture, development & other uses	Local government (74), NRM organisation (69), Science (75); Community Organisation (59)
	m	Rehabilitate and conserve areas of Reef catchments that have a role in removing waterborne pollutants	Agriculture, development & other uses	State Government (64, 72)
	n	Minimise or avoid impacts of salinity on land and water resources	Agriculture, development & other uses	Community Organisation (59)
	o	Improve farm management practices in the Lower Burdekin to keep on-farm surface and ground water quality parameters within acceptable limits to ensure protection of significant RAMSAR wetland areas -	Agriculture, development & other uses	State Government (58)
	p	Improve conditions of native vegetation communities along all waterways and wetlands	Inland water & wetlands	Community Organisation (59)
	q	Protect coastal wetland environments	Inland water & wetlands	Community Organisation (59)

Table 12. Medium and lower level objectives provided from the literature to Bowen-Burdekin participants under the economic category.

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
Increase employment	a	Increase employment in the region	Employment & living standard	NRM, Agriculture, Mining and Fisheries (34)
	b	Increase youth employment opportunities	Employment & living standard	Industry (76)
	c	Increase employment in the fishing sector - Maximise employment in the fishing sector	Resource industry (fisheries - agriculture)	Fishing (34), Agriculture (45), Industry (76)
	d	Increase employment in sectors associated with the fishing industry (the supply chain)	Resource industry (fisheries - agriculture)	Fisheries (34), Recreational Fishing (34), Agriculture (45), Industry (76)
Improve family income and livelihoods	a	Raise the level of living of farmers and the community as a whole	Employment & living standard	Agriculture (45)
	b	Improve security of fishing rights	Resource industry (fisheries - agriculture)	Fisheries (34, 77)
	c	Provide comparability of income in the farming and the non-farm sectors	Business & markets	Agriculture (45)
Increase economic profits	a	Increase economic profits for agriculture and fisheries	Resource industry (fisheries - agriculture)	Fisheries (34), Agriculture (45)
	b	Increase economic sustainability of fishing vessels	Resource industry (fisheries - agriculture)	Fisheries (34)
	c	Maximise economic performance of fisheries related sectors like slipways, boat repair and maintenance, and processors	Resource industry (fisheries - agriculture)	Fisheries (34), Industry (76)
	d	Improve fishing productivity	Resource industry (fisheries - agriculture)	Fisheries (34)

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
	e	Improve profitability of the fishing sector and the viability of fishing enterprises	Resource industry (fisheries - agriculture)	Fisheries (34)
	f	Improve industry value (Gross Value Product (GVP))	Business & markets	Fisheries (34)
	g	Minimise variability in prices and production	Business & markets	Fisheries (34), Agriculture (45)
	h	Encourage orderly marketing by avoiding unfair competition	Business & markets	Agriculture (45)
	i	Increase efficiency in production	Business & markets	Agriculture (45)
Increase support for existing businesses	a	Encourage development and maintenance of local infrastructure and services and appropriate land use planning to encourage existing business and attract new business investment.	Business & markets	Local government (71)
	b	Provide assistance to industries to enable them to adjust to a changed market situation	Business & markets	Agriculture (45)
Improve conditions that will create and attract new business investments	a	Increase investments in quality horticulture production and processing to maximise benefits from the agriculture industry	Resource industry (fisheries - agriculture)	Local government (78), State government (79, 80)
	b	Increase agricultural production in areas most suitable in terms of, for instance, soil and climate	Resource industry (fisheries - agriculture)	Agriculture (45)

Table 13. Medium and lower level objectives provided from the literature to Bowen-Burdekin participants under the social category.

Medium level objective	Sub-obj. #	Lower level sub-objective description	Category	Sector & reference ID
Enhance quality of life	a	Improve employment satisfaction	Community health	Fisheries (34, 77), Mining (34), Local government (81, 82)
	b	Improve access to recreational activities	Community health	NRM, Fisheries, Forestry (34)
	c	Establish social profile baseline information to help to decide where and how to invest	Community health	Fisheries and Forestry (34)
	d	Promote, support and facilitate services to the community to enhance community pride, wellbeing and the quality of life enjoyed by residents	Community health	Local government (66-68), Fisheries (77)
	e	Improve the community's lifestyle and living standards that delivers increased income along with the potential to better education, health and environmental protection -	Community capacity & resilience	Agriculture (45), Industry (76), Local Government (78)
	f	Improve fishers satisfaction with fishing activities (catches)	Resource industry (fisheries - agriculture)	Fisheries (34, 77)
	g	Improve satisfaction with access arrangements	Resource industry (fisheries - agriculture)	Fisheries Pascoe, 2013 #3;Shaw, 2011 #17}
Improve equity	a	Improve equitable access to information, recreation, and lifelong learning	Community health	Local government (81)
	b	Improve equal distribution of income	Community capacity & resilience	Fisheries (34)
	c	Reduce social exclusion. Social exclusion refers to processes in which individuals or entire communities of people are systematically blocked from rights, opportunities and resources (e.g. housing, employment, healthcare, civic engagement, democratic participation and due process) that are normally available to members of society and which are key to social integration	Community involvement	Fisheries (34)
	d	Increase equitable allocation and access to the resource	Resource industry (fisheries - agriculture)	Fisheries (34)

Medium level objective	Sub-obj. #	Lower level sub-objective description	Category	Sector & reference ID
Improve education, training, and social networks (referred as social capital)	a	Improve education levels to enhance understanding of natural resources and associated issues	Community capacity & resilience	Fisheries (34), State Government (72), Community organisation (59)
	b	Increase capacity of the people in the Burdekin Dry Tropics for water quality management, through active involvement in scientific monitoring program	Community capacity & resilience	State Government (72), Community organisation (59)
	c	Increase training and capacity building for invasive animals and plants management	Community capacity & resilience	Local government (83)
	d	Support, bond, bridge and link social networks	Community involvement	Forestry, Fisheries and Aquaculture (34)
	e	Foster quality community-assisted monitoring projects	Community involvement	State Government (72)
	f	Improve awareness of groundwater and surface water quality issues in the Lower Burdekin farming community	Resource industry (fisheries - agriculture)	State governments (72)
Improve social infrastructure (e.g. schools, roads & public transport, hospitals)	a	Improve capacity of community to promote, support and facilitate development	Community capacity & resilience	Local government (66-68, 71)
	b	Increase community resilience to climate change pressures through planning and building of capacity	Community capacity & resilience	Commonwealth (62)
Improve health and safety	a	Improve physical and mental health	Community capacity & resilience	Fisheries (34, 77), Local government (81, 82)
	b	Improve communities' resilience to disaster impacts	Community capacity & resilience	Local government (71)
	c	Increase (Ensure) safe working conditions	Community health	Aquaculture and forestry (34)
	d	Improve access to natural resource to promote sports and leisure activities	Community health	Local Government (84)

Medium level objective	Sub-obj. #	Lower level sub-objective description	Category	Sector & reference ID
	e	Ensure water (rainwater, groundwater, surface water) that is always fit to drink	Community health	Community Organisation (59)
	f	Increase the supply of quality food. Increasing food quantity and quality can be achieved, for instance, by optimizing the supply chain, improving energy efficiency, better production processes, targeted marketing etc.	Community health	Fisheries (34), Agriculture (45)
	g	Air that is consistently healthy to breathe and an atmosphere that is aesthetically pleasing	Community health	Community Organisation (59); State Government (85)
	h	Improve Safety at sea	Resource industry (fisheries - agriculture)	Fisheries (34, 77)

Table 14. Medium and lower level objectives provided from the literature to Bowen-Burdekin participants under the community category.

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
Increase community well-being	a	Increase natural resource related recreational options to the local population (arts, sports, cultural)	Community health	Local government (71)
	b	Increase recreational access to natural resource	Community health	NRM in general, Fisheries, Forestry (34)
	c	Improve community engagement and cultural connections	Community health	Local government (81)
	d	Enhance community resilience	Community capacity & resilience	Fisheries and Forestry (34)
	e	Increase tourist visitation through fishing - e.g. encourage charter fishing	Resource industry (fisheries - agriculture)	Fisheries (34)
Increase community powers to achieve their aspirations	a	Improve transparent stakeholder engagement processes	Community empowerment	Local government (81), Commonwealth (62)
	b	Increase community empowerment to improve NRM by sustainable practices in harmony with the landscape	Community empowerment	Commonwealth (62), Community Organisation (59)
Increase the conservation of traditional activities, products and culture	a	Improve the relationship between natural resource and local human cultures	Community empowerment	Forestry (34)
	b	Recognise the region's significance for Indigenous people and their intrinsic connectedness to land and water	Indigenous capacity & values	Commonwealth Government (62)
	c	Improve conservation & traditional activities and products	Indigenous capacity & values	Forestry (34)
	d	Identify and protect areas, places or objects on property that are culturally significant to Traditional Owners	Indigenous capacity & values	Community organisation (86)

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
	e	Reduce negative impacts of feral animals on Aboriginal cultural values and assets and promote management by Aboriginal people	Indigenous capacity & values	Community organisation (59)
	f	Increase recognition of cultural values of feral animals	Indigenous capacity & values	Community organisation (59)
	g	Increase the provision of alternative livelihoods for indigenous people	Indigenous capacity & values	Fisheries (34)
	h	Increase conservation of places of cultural significance	Indigenous capacity & values	State Government (61), Commonwealth (62)

Table 15. Medium and lower level objectives provided from the literature to Bowen-Burdekin participants under the management and institutions category.

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
Minimise management costs	a	Reduce compliance costs to industry	Management costs	Fisheries (34)
	b	Increase compliance of management, use, development and protection of fisheries resources and fish habitats with legislation.	Management costs	State Government (58)
	c	Minimise total management costs (recoverable and non-recoverable)	Management costs	Fisheries (34)
	d	Minimise infrastructure costs	Management costs	Fisheries (34)
	e	Improve management of the Council's existing and future debt	Management costs	Local government (66, 68)
	f	Improve cost effective practices, monitoring, and compliance to improve the quality of water leaving farms	Management costs	Science (87)
Increase resource management decision making on basis of sound knowledge and understanding of ecosystem processes	a	Integrate indigenous and western know ledge system to support NRM	Integration	Commonwealth (62)
	b	Increase scientific rigour to understand causes, consequences and actions to improve conditions of natural resources	Approach	Community Organisation (59)

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
Improve the strength of institutions	a	Continue to develop systems and support programs that improve Council's environmental performance and provide sustainable outcomes	Approach	Local government (71)
	b	Identify and manage habitats utilised by marine species of importance to the community to promote proliferation of those species	Approach	Community Organisation (59)
	c	Increase efficiency and effectiveness of pest management actions including education and awareness	Approach	Community Organisation (83)
	d	Increase sustainable landscape by integrating conservation, primary production and community aspirations	Approach	Community Organisation (59)
	e	Increase environmental responsibility throughout the community	Collaboration	Local government (66-68); Community Organisation (59)
	f	Increase protection wetland systems of high environmental value and importance to the community (e.g. water quality degradation) and cooperatively managed	Collaboration	Community Organisation (59)
	g	Establish a comprehensive and representative conservation network consisting of good condition freehold and leasehold lands and conservation parks and reserves	Integration	Community Organisation (59)
Promote co-operative governance and community involvement in conservation	a	Flexible NRM policies to account for (spatially and temporarily) varying conditions	Approach	Community Organisation (59)
	b	Improve the co-ordination of on-ground activities to control invasive animals and plants	Collaboration	Community Organisation (83)
	c	Develop partnerships for management of invasive animals and plants	Collaboration	Community Organisation (83)
	d	Foster partnerships between Australian, Queensland, local governments and communities to deliver changes necessary to ensure a more balanced and regional approach to NRM	Collaboration	Community Organisation (59)
	e	Increase whole of government and whole of community participation to ensure synergies necessary to manage natural resources	Collaboration	Community Organisation (59)

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
	f	Increase effectiveness of communication between Traditional Owners and other stakeholders through the development of true partnerships	Collaboration	Community Organisation (59)
	g	Encourage the development of synergies between industries to minimise waste production and promote re-use and recycling of waste.	Collaboration	State Government (61)
	h	Increase engagement with the community and relevant stakeholders in the process of identifying, assessing and responding to the impacts of development	Collaboration	State Government (88)
	i	Increase community involvement in management	Collaboration	Fisheries and forestry (34)
	j	Reduce conflict between alternative resource users - Natural resource conflicts are disagreements and disputes over access to, and control and use of, natural resources (e.g. gear conflict, Recreational versus commercial fishing, tree felling and other forest uses). These conflicts often emerge because people have different uses and hold different values for resources such as forests, water, pastures and land, or want to manage them in different ways.	Collaboration	Fisheries, Recreational Fishing, Forestry (34)
	k	Increase involvement of the local community in catchment management activities such as water quality monitoring to create local ownership of waterways through education and involvement.	Collaboration	State and Local governments [9], Community organisation (59)
	l	Increase involvement of indigenous people in decision making process	Collaboration	Forestry (34), Community organisation (59)
	m	Increase capacity building of indigenous people (especially young aborigines) in participating in regional NRM	Collaboration	Community organisation (59)
	n	Develop and implement natural resource management projects in conjunction with the community and other partners to improve the natural environment in the Shire, particularly aquatic weed control, beach protection and land protection	Collaboration	Local government (71)

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
	o	Improve communication between managers, scientists and fishers on decisions affecting fishers' working lives	Fisheries	Fisheries (77)
	p	Increase Inclusion of fishers' knowledge, expertise and experience in scientific research and decision making	Fisheries	Fisheries (77)
Promote responsible and supportive governance arrangements	a	Increase management stability (e.g. number of management changes per year)	Approach	Fisheries (34)
	b	Increase management acceptability	Approach	Forestry and Fisheries (34)
	c	Increase easeness of management implementation	Approach	Forestry and Fisheries (34)
	d	Responsible governance, efficient service and administrative support for Council's operations and strategic initiatives	Collaboration	Local government (66, 68)
Promote the integration of policies, planning and management of development and growth	a	Increase recognition and protection of environmental, cultural heritage and community values	Protection of heritage and values	State Government (61)
	b	Promote a dynamic approach to integrated planning and management of development and growth that reflects community aspirations and enhances community lifestyle, diverse heritage and environment	Protection of heritage and values	Local government (66, 68)
	c	Improve sustainable environmental and production outcomes by having a successfully interactive groundwater and surface water strategy	Fresh water flow	Community Organisation (59)
	d	Identify and protect coastal assets from impact of development and public usage	Environmental impact	Community Organisation (59)
	e	Increase the delivery of natural and manufactured resources (products and services) from agriculture, industry and urban development, that are based on the principles of Ecologically Sustainable Development	Environmental impact	Community Organisation (59)

Medium level objective	Sub-obj #	Lower level sub-objective description	Category	Sector & reference ID
	f	Reduce impacts of development on the environment, including cumulative impacts, to meet the requirements of applicable government policies.	Environmental impact	State Government (61)
	g	Restrict incompatible land uses from establishing near industrial developments	Environmental impact	State Government (61)
	h	Achieve ecological sustainability of industrial activities	Environmental impact	State Government (61)
	i	Limit the impacts of works able to be undertaken in fish habitats (seagrasses, mangroves and saltmarshes)	Environmental impact	State Government (58)
	j	Reduce potential negative environmental impacts from development where possible	Environmental impact	State Government (88)
	k	Increase protection of areas of high ecological significance against development.	Development planning	State Government (61)
	l	Improve development impact decision-making process by examining potential impacts fully and addressing those impacts based on sound environmental protection and management criteria with consideration of compensationary or offset options explored.	Development planning	State Government (88)
	m	Improve the planning process to adequately recommend infrastructure and facilities needs together with other design and operational measures required to minimise or compensate for adverse impacts and enhance benefits of development.	Development planning	State Government (88)
	n	Improve land-use planning process for the establishment of industrial development of regional, State and national significance	Development planning	State Government (61)
	o	Restrict incompatible land uses from establishing near industrial areas	Development planning	State Government (61)

Objective tree

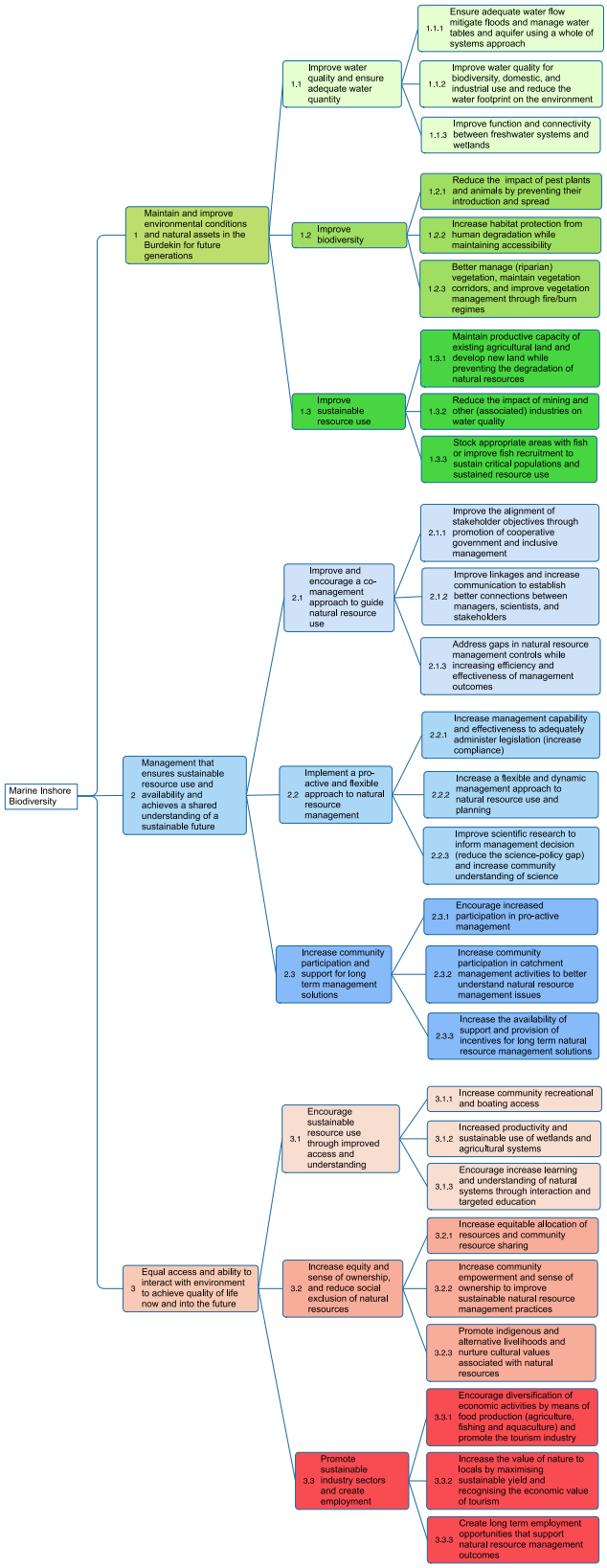


Figure 16: Final objectives tree for Bowen-Burdekin.

7.4 Discussion - comparison of approaches and advice

In this study, the objectives for the inshore areas of two separate regions (Mackay and the Bowen-Burdekin) were assessed. The development of objectives for the two respective regions was carried out using two different community engagement methods, despite attempting to start the engagement process in a similar manner. In Mackay, a series of workshops with stakeholder representatives were used to create a set of mutually agreed objectives. In the Bowen-Burdekin, due to local circumstances at the time and failing to generate support using a workshop approach, a list of objectives was developed by conducting one-to-one interviews with individual stakeholders or small stakeholder groups. The final list of objectives was agreed upon by individuals post interviews – but at no stage did all respondents in the Bowen-Burdekin consider the objectives as a group in a workshop.

Creation of a set of objectives is by no means an easy exercise. For instance, objectives need to be meaningful and re-examined over time and when circumstances change. The development of objectives therefore needs to be carefully thought through. In addition, after a set of objectives has been developed, decision-making organisations have to be willing to incorporate the objectives into their management planning processes.

Even though it was beyond the scope of this project to implement management actions on the basis of the developed set of objectives – it is acknowledged that this last step is by far the most important to enable change. Ideally, a management system evaluation would include i) setting objectives, ii) prioritising objectives, iii) developing management actions on the basis of the prioritised objectives, and iv) implementing these management actions, and (v) reviewing the effectiveness of actions on objectives should all be undertaken consecutively, with at least some participants being part of all five components for the sake of continuity. All these steps were undertaken in Mackay, and were planned, but unsuccessful in the Bowen-Burdekin for reasons external to the project.

Despite these different approaches and regional characteristics, overall there were only minor differences in the number of objectives for both regions. As mentioned above, two different methodological approaches were used to create the manageable set of objectives. The most prominent difference between the two methods was the far greater sense of ownership when the objectives were developed by a group in a workshop situation. It is evident that the level of ownership has considerable consequences for the level of uptake and the likelihood that future management actions will be developed on the basis of the objectives developed. Ownership of the objectives means that the community feels more empowered to lobby for them and to request that management organisations use these objectives to guide their decisions. This also facilitates communication and collaboration and the flow and exchange of information and knowledge between participants (local/indigenous groups, government, industry, and science providers). This can help local community leaders to be more effective in lobbying for funds and other resources to achieve objectives (Dutra et al. in press).

The fact that the objectives were created in a group context in Mackay is not the only variable that explains greater ownership, some aspects of the research approach (and research investment) and some characteristics of the region also explain ownership levels. Overall researchers spent more time in the Mackay area and there was a greater 'lead time' before objectives were set. In terms of local Mackay characteristics, the effectiveness and presence of a dedicated local person (the Mackay-based GBRMPA Liaison Manager) to link locals and researchers cannot be underestimated. Also, the lack of 'hot' political issues that divided stakeholders at the time of study, and the lack of historical adversity between individuals on the LMAC and within the sub-committee helped the process. From communications received after completion of the project it is evident that in the Bowen-Burdekin there is essentially no ownership of the objectives set, even at the LMAC level, and it is unlikely they will be incorporated in any management process in that region.

Even though the project in the Bowen-Burdekin may not come to the same desirable conclusion as in Mackay, some interesting observations can be made with respect to the objectives themselves. In both regions, the discussion was mainly about the environmental and the governance objectives. The fact that governance objectives were prominent in both regions seems to be a reflection of local stakeholder perceptions that current coastal zone management is not achieving the outcomes that they rate as important. In addition, there was some discussion of 'precedence' in the sense that the environmental objectives need to be achieved *before* the socio-economic outcomes can be, or *vice versa*, but this did not distract from the overall listing.

With environmental issues mostly centred around waterways, wetlands, and water quality (and to some degree water quantity or supply), it is not surprising that improving water quality was the central objective as it is has been the focus of considerable research effort in the GBR. The water quality issue has also led to some division in the community as farmers were perceived to some degree as being held solely responsible for influencing water quality (e.g. through reducing nutrient input) in the GBR. Associated with water quality was the concern about the management of riparian vegetation and vegetation more generally, and connectivity. This was the topic of some discussion as the Queensland State Government had recently changed land clearing legislation by reducing land clearing restrictions. The main environmental objectives (water quality and vegetation management) are arguably long standing and connected objectives relevant to the whole GBR.

It is interesting to note, although somewhat ironic, that in the Bowen-Burdekin region, where engagement with the local LMAC and stakeholders proved challenging, the governance objectives were primarily around increasing community engagement and co-management. Even in the environmental objectives this same issue came to the fore in the guise of increasing access and understanding which would not only lead to more sustainable management but also a greater 'care factor'. The lesson for the Bowen-Burdekin would therefore seem to be mainly around the question of how to make issues relevant to the local community and how to entice them into participating in the local management of public resources.

There are few surprises in the socio-economic objectives in either region. As in other studies, socio-economic objectives are based on growing industry profitability (tourism, agriculture, fishing, and other resource extraction such as mining and its related infrastructure), community income and employment. Aside from these general (possibly more predictable) objectives, indigenous livelihoods and equitable resource sharing featured highly. Indigenous ownership and participation in management are often stand alone objectives in natural resource management in Australia.

7.5 Conclusion

Some lessons can be learnt from the methodology applied in this current research which will be of use to future projects aimed at setting objectives for socio-ecological systems. In essence, the approach in the Bowen-Burdekin region was quick and cheap while the investment (in terms of overheads and time requirements) was far greater in Mackay. If research time and money are limited, an interview approach (as per the Bowen-Burdekin) is appropriate. With either of the two approaches, it is very important to consider if local (politically divisive) issues are present or may arise after commencing the research as these issues might take precedence and could influence the direction of the project. Careful timing of the research is essential as the presence of politically charged issues might derail the consultation process and the willingness to participate in group negotiations.

Researchers can save a lot of time by undertaking the 're-wording and rationalising' of a full set of objectives outside the group or workshop context. In general, the participants in the Bowen-Burdekin did not seem to object to researchers taking on this task as long as they were able to 'retrace' and identify the objectives they themselves had suggested in the interview.

To increase essential 'ownership' of the end result (i.e. the list of objectives and the associated trees), a dedicated project/research person in the locality for a period of time to directly interact with reference group members (rather than relying on a fly in-fly out approach) is beneficial. The level of ownership of the end product will no doubt increase through a workshop process at which the objectives are discussed in detail and agreed upon. Furthermore it is important to have support from local management groups (such as the LMAC) to drive the process and success largely depends on the pro-active nature of this group.

8 Qualitative modelling

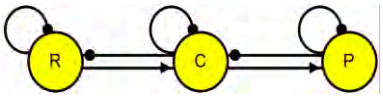
8.1 Introduction

A fundamental requirement for the development of management strategies is a shared understanding among stakeholders of the causal connections and dynamics associated with the assets being managed, and the pressures that threaten their desired status or state. This can be especially challenging where the assets and threats are themselves embedded within a complex ecological and socioeconomic system, which requires the bringing together of information and knowledge from a diverse array of researchers, managers and public representatives.

8.2 Methods

Based on input from this diverse array of stakeholders, the method of qualitative modelling was applied as a means to describe the general causal structure and dynamics of key assets of the inshore Great Barrier Reef (89, 90). Qualitative modelling proceeds from the construction of sign-directed graphs, or signed digraphs, which are depictions of the variables and interactions of a system. Here we are only concerned with the sign (+, -, 0) of the direct effects that link variables in a network of interactions.

As an example, the below signed digraph is a straight-chain system with a basal resource (R), consumer (C) and predator (P). There are two predator-prey relationships, where the predator receives a positive direct effect (i.e., nutrition, which is shown as link ending in an arrow (→)), and the prey receives a negative direct effect (i.e., mortality, which shown as link ending in a filled circle (•—)). Included also are self-effects, such as density dependent growth (i.e., such as intraspecific competition for limited habitat or resources).



8.3 Results

A total of 16 qualitative models were developed in seven separate workshops with stakeholders representing research and management agencies and public interest groups. The focus of these models ranged from the highly specific life history of key species (i.e., turtles, barramundi), to general landscape level dynamics (such as, for example, coastal development or water quality monitoring, regulation and governance), to a general depiction of social values associated with the harvesting of natural resources.

To compare understandings across different groups of stakeholders, we developed separate models for seagrass communities from three different stakeholder groups (i.e., Brisbane DPI, models 3-4; Townsville, model 6; and Mackay, model 10). These models had a large and general overlap in the ecological process and anthropogenic influences that were described as being important to seagrass dynamics. This was also the case for three separate models that described the life history of barramundi populations.

8.3.1 SIGNED DIGRAPHS

8.3.1.1 MACKAY LMAC REFERENCE GROUP

Attendees of 8 Aug: CSIRO, GBRMPA, LMAC RG.

Attendees 5 Sept.: CSIRO, GBRMPA, LMAC RG

Model 1. Creek Habitats & Cumulative Impacts

This model (see Figure and Table below) highlighted the importance of creek habitats in supporting fish populations (e.g., barramundi, fingermark, red bream or mangrove jack, and king salmon), their interdependence with near shore habitats, and the influence of multiple land use impacts. Creeks were divided into areas that provide food resources, breeding habitat for fish stocks, mudflats, and nursery habitats, with fish stocks also relying on near shore reefs and sea grass beds. Impacts from various agricultural practices have both direct and indirect effects on the habitats, with sediment and flow levels affecting multiple features of the system. The role of education, knowledge and learning was seen to have had a large and continuing role in improving land use practices, especially for that of cane farming.

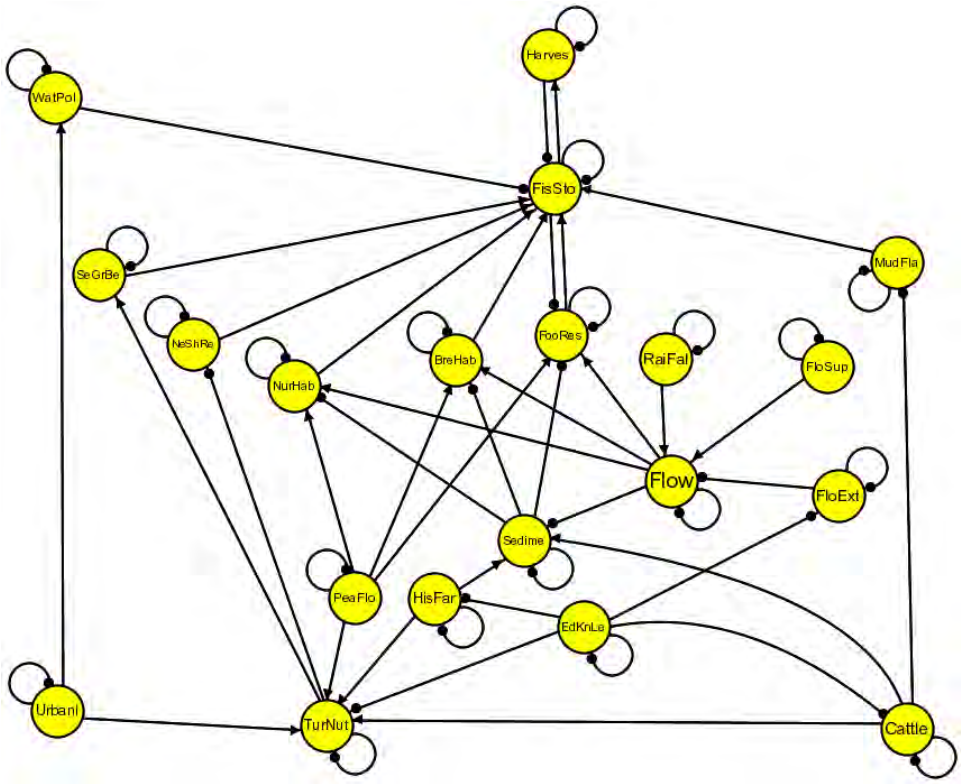


Figure 17: Creek Habitats & Cumulative Impacts model. BreHab: Breeding Habitats for fish stocks, Cattle: Cattle Farming, EdKnLe: Education Knowledge & Learning, FisSto: fish stocks, FloExt: Flow Extraction, FloSup: Flow Supplementation, Flow: river flow, FooRes: Food Resources, Harves: Harvest, HisFar: Historical Farming Practices, MudFla: Mud Flats, NeShRe: Near Shore Reefs, NurHab: Nursery Habitats, PeaFlo: peak river flow, RaiFal: Rain Fall, Sedime: Sediment, SeGrBe: Sea Grass Beds, TurNut: Turbidity & Nutrients, Urbani: Urbanisation, WatPol: Water Pollution.

Table 16: Description of links in signed digraph of above figure.

To	From	Comment
FisSto	Harves	Harvest mortality
FisSto	WatPol	Pollution impacts
FisSto	MudFla	Growth and recruitment
FisSto	SeGrBe	Growth and recruitment
FisSto	NeShRe	Growth and recruitment
FisSto	NurHab	Growth and recruitment
FisSto	BreHab	Recruitment
FisSto	FooRes	Growth
Harvest	FisSto	Fishing pressure increases with catch
FooRes	FisSto	Consumption of resources by fish stocks
WatPol	Urbani	Land use runoff (i.e., herbicide use for large-scale weed suppression)
TurNut	Urbani	Land use runoff (i.e., stormwater drainage)
SeGrBe	TurNut	Growth from low to intermediate levels of sediment and nutrients
NeShRe	TurNut	Habitat degradation (described as weak link)

To	From	Comment
TurNut	PeaFlo	High input from storm flows
TurNut	HisFar	High input from historic farming practices
TurNut	EdKnLe	Reduced loads from current practices
HisFar	EdKnLe	Revision of poor land use practices
Cattle	EdKnLe	Revision of poor land use practices
TurNut	Cattle	High input from land use practices
FloExt	EdKnLe	Revision of poor land use practices
Sedime	Cattle	High loads form land use practices
Sedime	HisFar	High input from land use practices
Flow	FloExt	Reduction in river flows
NurHab	Sedime	Habitat degradation
BreHab	Sedime	Habitat degradation
FooRes	Sedime	Diminished productivity
BreHab	PeaFlo	Critical feature of habitat
FooRes	PeaFlo	Critical feature of habitat
NurHab	PeaFlo	Critical feature of habitat
NurHab	Flow	Critical feature of habitat
BreHab	Flow	Critical feature of habitat
FooRes	Flow	Critical feature of productivity
Flow	RaiFal	Flow depends on rainfall
Flow	FloSup	Flow augmentation
Mudfla	Cattle	Habitat destruction-reclamation

Model 2. Sea Grass & Coastal Development

A model (see Figure and Table below) was developed to address impacts of coastal development on seagrass communities. This model combined a number of elements associated with land use runoff with dredging impacts. A limited role of management was included via State and Federal regulations guided by the Environmental and Environment Protection and Biodiversity Conservation Act 1999 and Australian Maritime Safety Authority regulations.

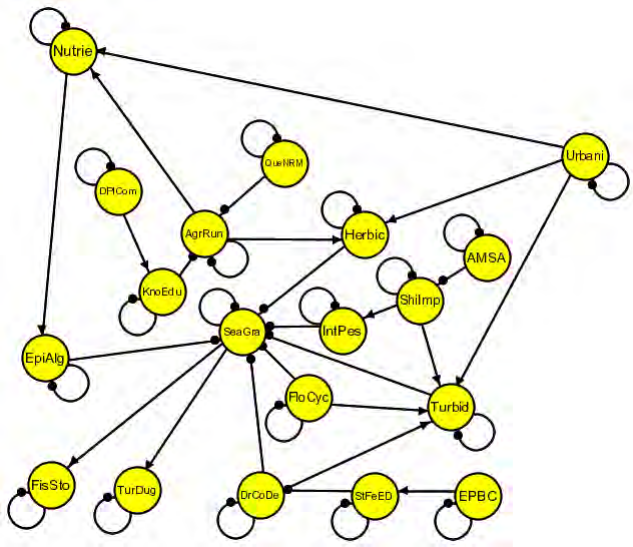


Figure 18: Sea Grass & Coastal Development model. AgrRun: Agricultural Runoff, AMSA: Australian Maritime Safety Authority, DPICom: Dept. Primary Industries Community Outreach, DrCoDe: Dredging from Coastal Development, EPBC: Environment Protection and Biodiversity Conservation, EpiAlg: Epiphytic Algae, FisSto: Fish Stocks, FloCyc: Flow Cycle, Herbic: Herbicides, IntPes: Introduced Pests, KnoEdu: Knowledge & Education, Nutrie: Nutrients, QueNRM: Queensland NRM, SeaGra: Sea Grass, Shilmp: Shipping Impacts, StFeED: state & federal environment departments, Turbid: Turbidity (above background levels), TurDug: Turtles & Dugong, Urbani: Urbanisation.

Table 17: Description of links in signed digraph of above figure.

To	From	Comment
SeaGra	EpiAlg	Reduced growth from shading
SeaGra	DrCoDe	Dredging impacts to seagrass beds
SeaGra	FloCyc	Seasonal flow cycle with storm flow impacts to seagrass beds
SeaGra	IntPes	Degradation of seagrass beds from introduced pests
SeaGra	Herbic	Degradation of seagrass beds from herbicides
SeaGra	Turbid	Increases in turbidity above background levels suppresses seagrass growth
FisSto	SeaGr	Resources and habitat benefit to fish stocks
TurDug	SeaGr	Resource benefit to turtles and dugongs
EpiAlg	Nutrie	Increase growth from enrichment
Turbid	FloCyc	Storm flow increase to turbidity
Turbid	DrCoDe	Dredging input to turbidity
StFeED	DrCoDe	Regulatory guidelines for environmental protection
DrCoED	EPBC	Effective regulation of dredging activities (described as weak link)
AgrRun	KnoEdu	Revision of poor land use practices
KnoEd	DPICom	Acceptance of improved land use practices (described as weak link)
Nutrie	AgrRun	Source of nutrient load
AgrRun	QueNRM	Regulation of nutrient loads in runoff

To	From	Comment
Nutrie	Urbani	Source of nutrient load
Herbic	Urbani	Source of herbicide load
Herbic	AgrRun	Source of herbicide load
Turbid	Urbani	Source of sediment load
Shilmp	AMSA	Effective regulation of shipping practices
IntPes	Shilmp	Increase in introduction of pests
Turbid	Shilmp	Increase in projected shipping traffic, turning up and re-suspending material above background levels

Model 3. Coastal Development (i)

A generalized model of coastal development was created that described the relationship between the major economic sectors (i.e., agriculture, urbanization, and ports), and the role of local, state and federal governments in regulating land use runoff (see Figure and Table below).

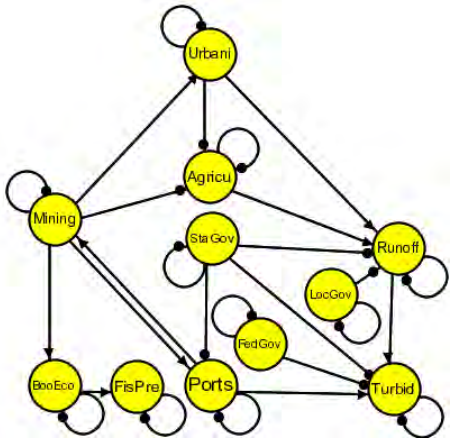


Figure 19: Coastal Development (i) model. Agricu: Agriculture, BooEco: boom economy, FedGov: Federal Government, FisPre: fishing pressure, LocGov: Local Government, Mining: mining industry, Ports: port developments & activities, Runoff: land use runoff, StaGov: State Government, Turbid: Turbidity, Urbani: Urbanisation.

Table 18: Description of links in signed digraph of above figure.

To	From	Comment
Runoff	Urbani	Source of runoff
Runoff	LocGov	Suppression of land use runoff from urban areas
Runoff	Agricu	Source of runoff
Runoff	StaGov	Suppression of land use runoff from agricultural lands
Urbani	Mining	Increase in urban growth associated with mining communities
Agricu	Mining	Suppression of agriculture by mining industry
Turbid	Runoff	Source of turbidity to coastal waters
Turbid	StaGov	Suppression of runoff loads
Turbid	Ports	Source of turbidity to coastal waters

To	From	Comment
Turbid	FedGov	Suppression of turbidity from ports
Ports	StaGov	Regulation of port development
Mining	Ports	Mining activity depends on availability of ports
Ports	Mining	Port development depends on level of mining activity
BooEco	Mining	Boom economy a function of mining activity
FisPre	BooEco	Fishing pressure increased by boom economy
Agricu	Urbani	Agriculture suppressed by urbanization.

Model 4. Coastal Development (ii)

Following the second Mackay workshop, project members developed a model of coastal development that described the interaction of the principle economic sectors with general features of habitat and water quality for coastal waters (see Figure and Table below). The main regulator of the mining sector was port development (and vice versa) and the boom economy was described as having a major effect on the relative levels of commercial and recreational fishing pressure.

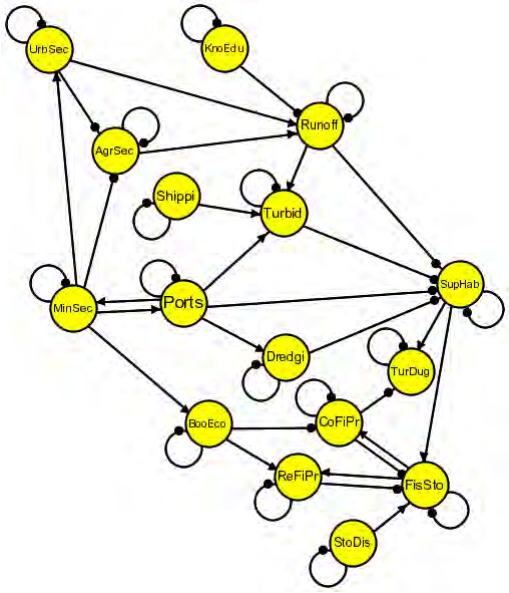


Figure 20: Coastal Development (ii) model. AgrSec: agricultural sector, BooEco: boom economy, CoFiPr: commercial fishing pressure, Dredgi: dredging, FisSto: fish stocks, KnoEdu: knowledge & education, MinSec: mining sector, Ports: port developments & activities, ReFiPr: recreational fishing pressure, Runoff: land use runoff, Shippi: shipping, StoDis: storm disturbances, SupHab: supporting habitats for fish stocks, Turbid: turbidity, TurDug: turtles and dugongs, UrbSec: urban sector.